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APA Handbook of

Behavior Analysis

Gregory J. Madden, *Editor-in-Chief*

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Translating Principles Into Practice

Gregory J. Madden, *Editor-in-Chief*

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TRANSLATIONAL RESEARCH IN BEHAVIOR ANALYSIS

CHAPTER 1

FROM BEHAVIORAL RESEARCH TO CLINICAL THERAPY

Paul M. Guinther and Michael J. Dougher

In this chapter, we provide an overview of the historical and conceptual development of clinical behavior analysis (CBA), characterize the translational research most relevant to CBA, and describe the specific CBA therapies informing and informed by translational research. Although the term *translational research* is sometimes used in different ways (e.g., see Hake, 1982; Lerman, 2003; Mace, 1994; McIlvane, 2009), for our purposes we describe it as the investigation of the role of known behavioral principles in understanding more complex social and clinically relevant behavior as well as the identification of behavioral principles that are necessary to account for complex human behavior. From this view, translational research is informed by both basic and applied research, thereby bridging the gap between basic findings and clinical applications at a faster pace than can be attained when relying on basic or applied research alone.

When it comes to CBA, the preponderance of current translational research involves the experimental analysis of verbal behavior and the behavioral processes that underlie it. In particular, CBA informs and is informed by translational research on rule governance, the indirect acquisition and transformation of stimulus functions via derived stimulus relations, and relational responding. Before delving more deeply into the relevant translational research and the therapies that constitute CBA, we begin with a historical and conceptual overview of CBA.

HISTORICAL OVERVIEW OF CBA

CBA is a branch of applied behavior analysis (ABA) distinguished by the types of clients and clinical problems addressed, the mode of therapeutic intervention, and the settings in which therapy is typically conducted (Dougher & Hayes, 2000). We should note that we are speaking here of the clinical applications of ABA. ABA is also used extensively in a variety of other contexts including educational settings, organizations and industry, and athletic performance enhancement. Within clinical contexts, ABA typically involves using direct contingency management to address the problems faced by, for example, children and other individuals with brain injury, autism, or other developmental disabilities. Such ABA populations tend to be treated in environments in which a great deal of control exists over reinforcement contingencies, such as residential treatment settings, schools, and hospitals. These features of ABA can be traced back to its emergence in the early 1960s, when psychologists with developmental and experimental backgrounds began applying B. F. Skinner's operant psychology to the problems faced by institutionalized patients and children in educational or therapeutic settings (see Volume 1, Chapter 4, this handbook). The success of direct contingency management procedures in such settings helped behavior analysts carve out a niche that has carried through to the present day, especially with respect to the ABA treatment of children with autism and other developmental disabilities.

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However, for all of its successes with these populations, ABA remains limited in its applicability to the more traditional problems in clinical psychology and psychiatry, such as adult depression, anxiety disorders, and adjustment disorders (Dougher & Hayes, 2000; Kohlenberg, Tsai, & Dougher, 1993). The clinical problems faced by verbally competent adults often involve complex verbal processes that are not readily or adequately addressed by ABA's direct contingency management procedures. In addition, therapists in typical outpatient settings have very limited access to or control over reinforcement contingencies outside the therapeutic context. Although Skinnerian psychology readily lent itself to application in the form of ABA, the extension of ABA to the treatment of traditional clinical problems was conceptually and practically limited (Kohlenberg et al., 1993).

Given the limitations of ABA, behaviorally oriented clinicians in the 1950s and 1960s who were interested in working with verbally competent adults in outpatient settings turned to or were part of the growing behavior therapy movement. Although behavior therapy shared with ABA an adherence to "empirically defined learning theory and conformity to well established experimental paradigms" (Franks & Wilson, 1974, p. 7), it was based on the methodological behaviorism of stimulus–response psychology (Mahoney, Kazdin, & Lesswing, 1974). In the late 1970s, behavior therapy went through a major change as stimulus–response theory merged with cognitive psychology. The change was not so much in terms of underlying philosophy, because both were essentially mechanistic and structuralistic (Dougher & Hayes, 2000), but rather in terms of a new mechanical metaphor, the computer, that guided theory and research. Mentalistic and mediational accounts of behavior change (e.g., Bandura, 1969) began to emerge and quickly grew into the cognitive–behavioral therapy (CBT) movement (Mahoney, 1974; Meichenbaum, 1977). Rather than grounding causality in operant and respondent contingencies, CBT views thoughts, feelings, and other mental or cognitive events as causal. Specifically, mental events are said to mediate the relation between the environment and behavior. Thus, the targets of intervention in CBT are the mental structures and processes (e.g., schemata, beliefs, expectancies, cognitive distortions) considered responsible for maladaptive behaviors and psychological suffering.

The adoption of this mentalistic–meditational orientation appeared to overcome the limitations of ABA (Kohlenberg et al., 1993). First, it made the locus of behavioral causality portable. That is, the problem of limited access to extratherapy contingencies became mute; the target of intervention was now the client's mind, which was present in the therapy session. Clients could carry mental changes made within session out into their daily lives. In addition, the inherent mentalism of CBT accorded well with the mentalistic view of behavior widely held by members of Western cultures. Specifically, many clients enter therapy with the belief that if they can change their ostensibly problematic thoughts and feelings, then they can lead happier lives (Dougher & Hayes, 2000; Kohlenberg et al., 1993). Moreover, empirical studies of CBT were reporting good outcomes, especially with depression and anxiety disorders, which enhanced the appeal of CBT's mentalistic approach. As CBT gained in prominence, ABA was further relegated to circumscribed settings and populations, and its application in outpatient settings diminished.

While CBT gained prominence over ABA, CBA was slowly taking form and beginning to grow. Unlike ABA, CBA is directly concerned with the same kinds of clinical problems and treatment settings as CBT. CBA takes as its focus an accounting of the behavioral processes governing publicly observable behavior and the covert behavior that makes up cognition. CBA is different from CBT in its epistemological foundation—radical behaviorism, which is philosophically incompatible with the methodological behaviorism of CBT. Thus, CBA rejects the mentalistic and mediational causal models of CBT.

One problem facing clinical behavior analysts was that the experimental analysis of behavior tended to focus on relatively simple operants rather than the kinds of complex behavior, especially verbal behavior, common in clinical contexts. As an example of the latter, clients frequently report strong fear reactions to stimuli or events they have never actually encountered. Likewise, individuals diagnosed with depression tend to selectively attend to and remember depressing events and often interpret seemingly neutral or even positive events negatively. Clients' behavior often seems to be controlled by rules, instructions, or inferences, even when they are in conflict with experience or with existing reinforcement contingencies. Laboratory studies of simple operant behavior provided little help for the clinician attempting to understand these complex sources of control.

Fortunately, in the 1980s and 1990s a resurgence of behavior-analytic research on verbal behavior and cognition began to provide a nonmediational and functional account of the kind of complex behavior that is commonly seen in clinical contexts. Thus, although the conceptual foundations of CBA can be found in Skinner (1957), Ferster (1972a, 1972b, 1973), and Goldiamond (1974/2002), its empirical roots are equally planted in more recent areas of research. This is not to say that CBA eschews direct contingency management procedures, but given its focus on verbally competent clients in outpatient settings, its development was dependent on a more developed behavior-analytic understanding of verbal processes.

Perhaps the first fully articulated behavior-analytic outpatient therapy was Israel Goldiamond's constructional approach to therapeutic change (Goldiamond, 1974/2002; Schwartz & Goldiamond, 1975). The more modern CBA therapies include functional analytic psychotherapy for enhancing the impact of therapeutic relationships (Kohlenberg & Tsai, 1991); integrative behavioral couples therapy for increasing the quality of romantic relationships (Christensen, Jacobson, & Babcock, 1995; Jacobson & Christensen, 1996); dialectical behavior therapy for the treatment of borderline personality disorder and other severe problems (Linehan, 1993); behavioral activation therapy for the treatment of depression (Kanter, Busch, & Rusch, 2009; Lejuez, Hopko, & Hopko, 2001; Martell, Addis, & Jacobson, 2001); and acceptance and commitment therapy (ACT) for the treatment of depression, anxiety, anger, and a variety of other quality-of-life concerns (Hayes, Strosahl, & Wilson, 1999; see Chapter 18, this volume). Although we describe each of these therapies in greater detail later in this chapter, we turn first to a conceptual overview of CBA and then to a discussion of relevant translational research.

CONCEPTUAL UNDERPINNINGS OF CBA

As previously noted, CBA is based on the philosophy of radical behaviorism. A more complete description of CBA's defining characteristics can be found in Dougher and Hayes (2000). Our focus here is on the radical behavioral treatment of private events (i.e., perceiving, thinking, feeling, remembering) and their role in a science and technology of behavior. A central problem presented by private events is that, by definition, they are not publicly or intersubjectively observable, which makes them difficult to study scientifically. The methodological behaviorist's approach to this dilemma is to treat private and public events differently. Specifically, private events are considered mental or cognitive as opposed to overt observable behavior, which is considered to be physical. Mental events are defined operationally and studied indirectly by inferring their existence from publicly observed responses to environmental manipulations. Methodological behaviorism has been adopted by most of mainstream psychology (Hayes & Brownstein, 1986) and is particularly characteristic of cognitive psychology, which infers the properties of causal mental structures (e.g., schemata) and their associated processes (e.g., memory retrieval) from their products (e.g., reported thoughts, feelings, and overt behaviors; see Hollon & Kriss, 1984, for a discussion of cognitive structures, processes, and products).

Insofar as it is based on the assumptions and principles of cognitive psychology, CBT is directed toward changing those cognitive structures and processes thought to be responsible for feelings and behavior. For example, much of CBT is based on the ABC paradigm (Ellis, 1962, 1970), in which it is conceived that antecedent environmental events (A) lead to thoughts (B) that then cause subsequent actions or emotions (C). Accordingly, replacing a maladaptive thought with an appropriate new thought leads to a new and more preferable emotion or action. For example, a person at a party (A) may have the distorted thought, "No one here wants to talk to me" (B) and subsequently feel rejected (C). In therapy, that person may learn to replace his or her original distorted thought with a more appropriate alternative thought such as, "Or maybe these people are just shy" and subsequently feel curious rather than rejected. Presumably, repeated rational corrections of maladaptive thinking eventually lead to changes in the core structures presumed to be responsible for maladaptive thoughts (Beck, 1976; Beck, Rush, Shaw, & Emery, 1979). At this point, the core structures cease to produce distorted cognitive products, emotional stabilization is thereby promoted, and treatment is deemed successful.

Contrary to a pervasive misconception, radical behaviorists do not deny the existence of thoughts (Skinner, 1974). Instead, thoughts are seen simply as instances of private behavior that, despite their lack of intersubjective observability, are not fundamentally different from public behavior. As such, behavior analysts consider thoughts to be dependent variables rather than independent variables or causes. Thus, an analysis of thoughts focuses on their environmental determinants and their relation to other behavior or, as Hayes and Brownstein (1986) put it, behavior–behavior relations. This does not mean that thoughts are considered unimportant or epiphenomenal. What it does mean is that there is no need in CBA to alter the occurrence or content of thought for a successful therapeutic outcome.

With respect to their influence on other behavior (i.e., behavior–behavior relations), a behavior-analytic view of thoughts (memories, inferences, conclusions, etc.) is that they are instances of verbal behavior in which the speaker and listener are in the same skin (e.g., Skinner, 1957). As with private events, radical behaviorism and methodological behaviorism have fundamental and substantial differences in their perspectives on verbal behavior. In line with its inherent mechanism and structuralism, methodological behaviorism focuses on language, or the structure or form of verbal behavior. In line with its functionalism, radical behaviorism defines verbal behavior functionally (Skinner, 1957; but see Hayes, Barnes-Holmes, & Roche, 2001) and is not particularly concerned with its form. Defined functionally, *verbal behavior* is behavior that is maintained by audience-mediated consequences. That is, rather than working directly on the environment, verbal behavior are stimuli that act on listeners (including the self as listener), whose reactions serve as controlling consequences. From this view, thoughts are verbal behavior that may influence other behavior through their stimulus functions, although this stimulus control is caused by environmental contingencies.

This radical behavioral view of private events and verbal behavior has important clinical implications, both in terms of specific CBA interventions and in terms of therapeutic objectives and outcomes. As already mentioned, private events are not seen as causes and, therefore, are not the specific targets of therapy. However, although CBA does not specifically target private events, they are not ignored. Instead, the focus is on altering the conditions that give rise to these private events and their functions; attempts are made to alter the function of thoughts and feelings so that they are no longer discriminative for maladaptive behavior. This fundamental difference between CBA and CBT runs parallel to their differing research bases. Grounded in the experimental analysis of behavior rather than in mainstream methodological behaviorism, the various CBA therapies are all informed by empirically derived behavioral principles and recent laboratory-based research findings. We turn now to a discussion of some of these findings.

TRANSLATIONAL RESEARCH RELEVANT TO CBA

Although the entire body of research that constitutes the experimental analysis of behavior informs CBA therapies, research on verbal behavior is particularly relevant because it provides a behavior-analytic account of language and cognition. Relevant to this account is research on rule governance, the indirect acquisition and transformation of stimulus functions via derived stimulus relations, and relational responding.

Rule Governance

A long-standing tradition within the experimental analysis of behavior is the use of nonhuman animal studies to illuminate the basic principles of behavior and conditioning. On the basis of the assumption of continuity of species, it was reasonably and widely assumed throughout the 1950s that any principles found to be applicable to nonhuman animals would be equally as applicable to humans. However, starting in the early 1960s, evidence slowly began to accumulate showing that human participants were not behaving in ways that would be predicted by animal models. An investigation by Kaufman, Baron, and Kopp (1966) illustrated some of these unique effects. In their study, three groups of participants were told that they would earn money according to a variable-interval, a variable-ratio, or a fixed-interval schedule of reinforcement. Participants in all three groups were then actually exposed to the same variable-interval schedule of reinforcement. The investigators found that participants' response rates were substantially influenced by what they had been told, which outweighed the influences of the actual reinforcement contingencies. Such behavior in humans was perplexing. Unlike nonhuman animals, humans in laboratory studies were shown to be more sensitive to instructions than to changes in programmed contingencies of reinforcement.

Humans were also found to be quite susceptible to instructions in other investigations. For example, humans were found to be relatively insensitive to changes in programmed contingencies (e.g., Ader & Tatum, 1961; Barrett, Deitz, Gaydos, & Quinn, 1987; Buskist, Bennett, & Miller, 1981; Catania, Matthews, & Shimoff, 1982; Harzem, Lowe, & Bagshaw, 1978; Matthews, Shimoff, Catania, & Sagvolden, 1977; Shimoff, Catania, & Matthews, 1981). Conversely, humans were often found to behave efficiently when provided with instructions about the operative schedule contingencies; this efficiency tended to develop more rapidly than when no instructions were provided (e.g., Baron, Kaufman, & Stauber, 1969; Turner & Solomon, 1962; Weiner, 1962). Humans were furthermore found to exhibit patterns of schedule performance that were systematically different from those of nonhuman animals (e.g., Leander, Lippman, & Meyer, 1968; Lowe, Harzem, & Hughes, 1978; Weiner, 1964, 1969), and humans were found to exhibit greater intersubject behavioral variability than nonhuman animals when exposed to the same programmed contingencies (e.g., Lippman & Meyer, 1967; Lowe, 1979). Investigations into the sources of these differences converged on verbal processes, particularly those involved in instructional control (see Baron & Galizio, 1983, for a review), also known as *rule-governed behavior* (Skinner, 1966, 1974).

Instructions and rules are verbal stimuli that specify antecedent, behavioral, and consequent components of operant contingencies (Skinner, 1966, 1974). They can be presented by others or be self-generated. As examples, a participant in a human operant conditioning experiment may follow the written instructions "Every two minutes, you can press the button in order to earn points," or a person may follow the self-spoken rule "After each meal, I should brush my teeth to avoid cavities." That is, accurate rules tell people how to go about behaving in ways that are likely to produce desirable results (i.e., acquiring reinforcers or avoiding punishers). However, following rules that specify a relation among an antecedent, behavior, and consequence is sometimes incompatible with effectively responding to operative contingencies (e.g., Catania et al., 1982; Galizio, 1979). For example, a person who sweeps his or her bedroom floor on an hourly basis because of the rule that "cleanliness is next to godliness" (i.e., sweep on the hour so as to maintain piety and avoid sin) may not connect with the fact that it would take considerably longer than an hour for the floor to become dirty or that cleanliness is, in fact, not a path to godliness. Likewise, if a person generates and follows the rule "If I leave the house, something terrible will happen to me," staying in the house will be negatively reinforced by the absence of terrible events. The avoidance of these verbally described terrible events may also increase the probability of generating and following other potentially maladaptive rules. Instructions and rules are clearly tied to both adaptive and maladaptive behaviors and are, therefore, of special interest to clinical behavior analysts.

Initially, how behavior analysts were to account for findings that human laboratory behavior appeared to be more susceptible to instructions and self-generated rules than to programmed contingencies was unclear. Such perplexing findings appeared to lend credence to the mentalistic underpinnings of folk psychology and CBT (e.g., Ellis's [1962, 1970] ABC paradigm; Beck's [1976] schema theory). In particular, the findings appeared to support the view that thoughts or cognition control adult human behavior to a greater extent than the environment. Indeed, some theorists (e.g., Brewer, 1974) interpreted such findings to mean that neither classical nor operant conditioning had ever been conclusively demonstrated in adult humans. Others (e.g., Bandura, 1971, 1974) took such findings to mean that beliefs and expectancies were at least as important as reinforcement contingencies in controlling human behavior.

Clearly, if behavior analysis was to continue to be a viable paradigm, it was going to have to deal with the fact that rules and instructions seemed to exert as much control over adult human behavior as programmed contingencies. This fact led to some very interesting conceptual issues and empirical research. In particular, behavior analysts had to develop a conceptually coherent account of verbal stimuli, including self-generated and covert verbal stimuli (e.g., beliefs, expectancies, reasons, cognitions), and how these stimuli come to exert control over behavior. ACT and aspects of other CBA therapies emerged, interestingly, in the investigation of these issues, in large part through the research efforts of clinicians who regularly observed the complex verbal behavior of adult outpatients.

Rule following is operant behavior. An important experiment conducted by Galizio (1979) demonstrated that rule following is an operant. Recall that an operant response is a class of behavior affected by its consequences. In Galizio's experiment, human participants tended to follow experimenter-provided rules as long as there were no negative consequences for doing so. For example, in one condition, participants followed instructions to respond quickly to avoid monetary losses. This was not the most efficient way to respond (slower responding would have avoided just as many losses), but it did work; nearly all losses were avoided. Rule following decreased in a different condition, however, when responding at the instructed pace was insufficient to avoid all losses. Galizio argued that experimenter-provided rules would be followed only as long as rule following did not result in punishing consequences.

A second characteristic of an operant is that its emission can be controlled by antecedent stimuli signaling the likelihood of response-contingent reinforcement or punishment. In Galizio's (1979) experiment, human rule following came under antecedent stimulus control. When an orange light was on, the experimenter-provided rules were accurate, and following them resulted in the efficient avoidance of monetary losses. However, when a purple light was on, the instructions were inaccurate and following them resulted in periodic losses. Participants were not instructed about the meaning of these lights, but they quickly followed the rules only when the orange light was on, thereby demonstrating stimulus control of rule following as an operant.

Finally, Galizio (1979) hypothesized that rule following was a generalized operant. That is, rule following is an operant that generalizes to different contexts that in some way resemble those in which rule following has been reinforced in the past. For example, if rule following has been reinforced in the presence of one's parents while at home, this behavior is likely to generalize to rules given by the same parents at the grocery store. When following other people's rules (e.g., aunts and uncles, teachers, police officers) is also reinforced, the operant is likely to generalize to still other adults. By the time human participants enter an experiment such as the one arranged by Galizio, they have an extensive history of reinforcement for following rules that have been provided by authority figures such as experimenters. Given this history, it should not be surprising that participants conform to experimenter-provided instructions (see Milgram, 1963, for an extreme and troubling example of control by experimenter instructions).

Classes of rule following. Not long after Galizio (1979) demonstrated that rule following was an operant, Zettle and Hayes (1982) suggested that rule following could be usefully classified on the basis of the type of consequences that maintain it. One category of rule following is tracking (Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986; Zettle & Hayes, 1982). *Tracking* is rule following that is maintained by the consequences specified by the rule. For example, supposing one is instructed to meet one's sales quota to earn a bonus, then following the rule (meeting the quota) is an example of tracking if the reinforcer (the bonus) is responsible for future rule following. The participants in Galizio's experiment could be said to be tracking if they continued to follow the instruction to respond quickly to avoid losses because doing so was followed by a loss-free period.

A second class of rule following is called *pliance* (Hayes Brownstein, Zettle, et al., 1986; Zettle & Hayes, 1982). Pliance occurs when one follows a rule because of one's history of socially mediated consequences of being compliant or noncompliant. For example, when a parent instructs a child to do his or her homework, no natural consequence of the act is specified (e.g., boredom). Instead, if rule following occurs, it probably does so because of a history of socially mediated reinforcement for compliance (e.g., the child may be allowed a snack or access to a favored television program) and a history of socially mediated punishment for noncompliance (e.g., a time out or loss of privileges). Participants in Galizio's study (1979) were likely predisposed to follow instructions because of such histories.

Given that rule following can be maintained by social contingencies, one would expect that rule-governed insensitivity to otherwise trackable contingencies of reinforcement would vary across individuals as a function of the relative strength or potentiation of the social consequences for rule following, differential histories of reinforcement for rule compliance, or both. In particular, individuals for whom pliance has been strongly reinforced (or for whom noncompliance has been punished) may be especially likely to follow rules even when rule following leads to decreased rates of reinforcement (Wulfert, Greenway, Farkas, Hayes, & Dougher, 1994). Such histories have been posited to underlie the rigid cognitive expectations (i.e., rules) of individuals who compulsively attempt perfectionism and to avoid mistakes (Beck & Freeman, 1990).

To see whether individual differences in trait rigidity would predict insensitivity to programmed contingencies, Wulfert et al. (1994) first assessed participants' trait rigidity using a questionnaire that measured constriction, inhibition, conservatism, intolerance of ambiguity, and perseverative tendencies (Rehfisch, 1958a, 1958b); the questionnaire was known to correlate with measures of social anxiety. Next, participants were given a task with either accurate instructions (i.e., depending on the status of the signal light, press the button at different rates to earn points) or minimal instructions (i.e., press the button to earn points). At the beginning of the task, points were delivered contingent on button presses, but then an extinction schedule was imposed in which responses were no longer followed by points. Although accurate instructions generally resulted in perseveration after the switch to extinction, this effect was especially pronounced among participants whose answers to the questionnaire suggested high trait rigidity. Even in the minimal instructions condition, trait-rigid participants were more likely to continue pressing the button during extinction. Thus, highly rigid individuals appeared to be especially prone to pliance, even in the face of discrepant feedback.

In sum, insensitivity to programmed contingencies of reinforcement arranged in human operant experiments appears to be a product of two types of rule-following behavior. First, insensitivity may occur because of a history of reinforcement for tracking: Following rules has generally led to a host of naturally occurring reinforcers. Because of this history, track-based rule following generalizes to the human operant laboratory and precludes behavior that would be more efficient than the behavior specified by inaccurate experimenter-provided rules (e.g., Baron & Galizio, 1983; Galizio, 1979; Hayes, Brownstein, Zettle, et al., 1986; Joyce & Chase, 1990). Second, contingency insensitivity may result from pliance or the differential sensitivity to the social consequences for following rules and instructions (e.g., Barrett et al., 1987; Hayes, Brownstein, Haas, & Greenway, 1986; Hayes, Brownstein, Zettle, et al., 1986; for a review, see Hayes, Zettle, & Rosenfarb, 1989). Although investigated in the context of human operant experiments, tracking and pliance presumably account for the rule-following behavior exhibited by clients.

More important, a history of reinforcement for rule following would naturally lead individuals to generate and follow their own rules. To the extent that these self-rules lead to effective behavior, then rule generation and self-rule following would be reinforced. In addition to such track-based reinforcement for generating and following self-rules, there are inherent consequences for complying with one's own rules (self-pliance) just as there are for complying with rules provided by others (Hayes et al., 1999). Doing what one says one is going to do or what one thinks one should do has a long history of social reinforcement in most cultures and is considered a desirable and admirable personal characteristic indicative of high intelligence (Wegner, 2002). Taken together, these two sets of reinforcement contingencies can establish a sense-making repertoire that is pervasive and leads individuals to generate rules and stick with them, even when they are not particularly effective.

Persistent ineffective behavior is at least partly definitional of clinical disorders. Virtually all forms of cognitive therapy hold that adhering to ineffective rules underlies clinical disorders. CBT encourages clients to adopt or generate new rules that, if properly constructed, could place clients in contact with actual contingencies (e.g., through the correction of cognitive distortions). How is CBA different? To answer this, we must first articulate how verbal stimuli influence behavior. That is, although studies such as Galizio's (1979) have demonstrated that rules can be discriminative for the operant behavior of rule following, such studies have not fully illuminated how rules alter the functions of the elements of the contingencies they specify (see Dulany, 1968; Parrot, 1987; Schlinger, 1990, 1993; Zettle & Hayes, 1982). An articulation of function alteration via verbal processes will go beyond the prevalent assumption in mainstream psychology and the general culture that thoughts are causal. Behavior-analytic research examining how verbal stimuli influence behavior is sometimes not intuitive. However, this research has widened researchers' understanding of the causal conditions under which cognitions come to exert stimulus control, thereby revealing therapeutic alternatives to the CBT approach to rules and other cognitions. Research on the environmental determinants of function alteration via rules and cognitions, described in the following sections, provides much of the empirical foundation for the alternative therapeutic approaches used by CBA therapists.

Equivalence Relations and the Transfer of Stimulus Functions

Stimulus equivalence is a behavioral phenomenon that emerges from certain natural conditions and laboratory arrangements (Sidman, 1994; Sidman & Tailby, 1982). Roughly speaking, equivalent stimuli are those that, despite their physical dissimilarity, mean the same thing. That is, they are functionally interchangeable or do the same things. Otherwise distinct stimuli can acquire common functions in many different ways, including through direct Pavlovian conditioning, through direct operant conditioning, and through stimulus generalization (see Catania, 1998; Donahoe & Palmer, 2004). What is particularly interesting about equivalent stimuli is that they can acquire functions indirectly, in the absence of direct conditioning or generalization. For example, for most English speakers, the word *araña* is not emotionally arousing. However, when told that *araña* is Spanish for *spider, araña* may acquire an eliciting function. That is, by establishing an equivalence relation between the words *spider* and *araña, araña* may indirectly acquire the functions of the word *spider*. More generally, words stand in an equivalence relation with the events in the world they reference or stand for, and by that we mean they take on many of the functions of their referents and vice versa. This is how rules can alter the functions of the elements of the contingencies they specify and how words can make people laugh, cry, cringe, or fall in love.

Although stimulus equivalence is of interest in its own right (a discussion of stimulus equivalence and the methods used to study it can be found in Volume 1, Chapter 16, this handbook), its clinical relevance is most apparent in demonstrations of the transfer of functions among stimuli that are members of the same stimulus equivalence class (see Dougher, 1998). Laboratory studies of equivalence-based transfer of function typically start by using matching-to-sample procedures to train and test some number of stimulus equivalence classes. A subset of one of the classes is then given a new function, and investigators test to see if that function is indirectly acquired by other members of the same class but not by members of the other classes.

For example, Dougher, Augustson, Markham, Greenway, and Wulfurt (1994) used a matching-to-sample training procedure to establish two four-member classes consisting of unfamiliar figures (i.e., A1, B1, C1, D1 and A2, B2, C2, D2), in which the A stimuli were conditional for the selection of the B, C, and D stimuli (i.e., A–B, A–C, and A–D matching was directly reinforced for the Class 1 and Class 2 stimuli). After participants reached the matching-to-sample training criterion, they were given tests without feedback to determine whether the training had in fact established equivalence relations. Participants passed tests of symmetry (i.e., emergent B–A, C–A, and D–A matching was demonstrated with the Class 1 and Class 2 stimuli) and transitivity (i.e., emergent B–C, C–B, B–D, D–B, C–D, and D–C matching was demonstrated with the Class 1 and Class 2 stimuli), thereby demonstrating the formation of two equivalence classes (see Sidman, 1994; Sidman & Tailby, 1982). Next, a classical conditioning paradigm was used to directly alter the function of the B1 and B2 stimuli. B1 acquired a positive conditioned stimulus function because its presentation was followed with a mild electric shock. B2 acquired a negative conditioned stimulus function because it preceded a shock-free period. Skin conductance level served as the measure of conditioning. After this direct acquisition of stimulus functions by the B stimuli, skin conductance was measured when C1, D1, C2, and D2 stimuli were presented in the absence of shock (A1 and A2 stimuli were not presented because they had been directly related to the B1 and B2 stimuli, respectively, during the initial matching-to-sample training). For most participants, C1 and D1 elicited higher skin conductance levels than either C2 or D2, despite the fact that C1 and D1 had never been paired with electric shock. That is, C1 and D1 indirectly acquired the fear-eliciting function of B1 because of their common class membership, as produced by arbitrary matching-to-sample training. In a similar study, Roche and Barnes (1997) demonstrated the transfer of sexual arousal through stimulus classes. These studies begin to offer an explanation for how events can acquire and lose emotion-eliciting functions in the absence of direct training. They also suggest that explanations for this kind of phenomena go beyond the basic Pavlovian or operant contingency.

In a second experiment, Dougher et al. (1994) demonstrated that the effects of extinction can also indirectly transfer among members of stimulus equivalence classes. As in their first experiment, two four-member stimulus equivalence classes were established and tested. Next, all of the Class 1 stimuli except A1 (i.e., B1, C1, and D1) directly acquired positive conditioned stimulus (CS+) function by preceding mild electric shock. In Class 2, B2, C2, and D2 directly acquired negative conditioned stimulus (CS−) function by preceding shock-free periods. As expected, this procedure resulted in greater skin conductance responses to all of the Class 1 stimuli than to any of the Class 2 stimuli. The function of B1 was then directly altered by presenting B1 in extinction (without shock) for six trials. To determine whether the new CS− function of B1 would indirectly transfer to C1 and D1, all of the Class 1 and Class 2 stimuli (again, except the A stimuli) were presented individually. Consistent with an indirect transfer of B1's CS− function to same-class stimuli, no difference in skin conductance elicitation between the two stimulus classes was found after extinction of B1. In a final condition, B1 was reconditioned as a CS+ by preceding shock, and all of the stimuli were again presented to see whether this reconditioning would transfer to C1 and D1. The results confirmed that it did.

Continuing this line of research, Augustson and Dougher (1997) found that operant avoidance behavior can be occasioned by members of a stimulus equivalence class even when only one member of the class has directly acquired response-evoking stimulus function. In their experiment, two four-member stimulus equivalence classes were trained and tested (as described earlier), and B1 was established as a CS+ using mild shock. Next, participants learned that they could avoid the shock that followed B1 if they pressed the space bar on a computer keyboard a set number of times within a set time period. No shock followed presentations of B2 (CS−), so no avoidance responses were required. After avoidance was reliably occasioned by B1, participants were presented with the B, C, and D stimuli from both classes in extinction (i.e., no shock was delivered even if participants failed to emit the avoidance response). Despite never having been paired with shock and not being included in avoidance training, both C1 and D1 evoked avoidance responding in all participants. As was the case with B2, neither C2 nor D2 evoked avoidance responding.

In addition to the transfer of emotion-eliciting and avoidance-evoking functions among members of stimulus equivalence classes, investigators have demonstrated the transfer of a substantial number of other stimulus functions, including contextual stimulus control (Gatch & Osborne, 1989; Kohlenberg, Hayes, & Hayes, 1991), conditional control (Roche & Barnes, 1996; Wulfert & Hayes, 1988), discriminative control (Barnes & Keenan, 1993; de Rose, McIlvane, Dube, Galpin, & Stoddard, 1988; Roche, Barnes-Holmes, Smeets, Barnes-Holmes, & McGeady, 2000), conditioned reinforcement and punishment (Greenway, Dougher, & Wulfurt, 1996; Hayes, Kohlenberg, & Hayes, 1991), ordinal control (i.e., first, second; Green, Sigurdardottir, & Saunders, 1991; Lazar 1977; Lazar & Kotlarchyk, 1986; Wulfert & Hayes, 1988), and instructional control (McGuigan & Keenan, 2002). Taken together, these studies have provided convincing evidence that a wide range of Pavlovian or operant functions can transfer between equivalent stimuli via derived stimulus relations.

To return to our earlier question of how verbal stimuli affect behavior, a plausible explanation develops if one assumes that words and other verbal stimuli (whether spoken, written, drawn, thought, pictured, imagined, etc.) are in equivalence relations with corresponding events or objects (i.e., referents). The research just cited has suggested that verbal stimuli can elicit emotions and evoke operant behavior when the stimuli directly or indirectly acquire the stimulus functions of their emotion-eliciting or operant-evoking referents. Words such as *death, vomit, murder, torture, love, peace,* and *calm* are all likely to have directly and indirectly acquired stimulus functions; they can elicit many of the same kinds of emotional reactions and evoke many of the same kinds of actions as their equivalent referents. This is why a novel, poem, or slogan can move people to tears, make them laugh, or spur them to action. This is why repeating the word *calm* can induce a state of relaxation and why thinking about death can induce fear in some and relief in others, even in the absence of any direct experience with death. The equivalence relations between words and their referents may also explain why clients frequently cry when relating painful past experiences or feel better after having talked about them (see Pennebaker, 1997, for a review). Talking about emotionally painful events (CS+) in a neutral environment (CS−) may promote extinction of the eliciting functions of those events. Equivalence relations may also explain how rules and instructions can alter the operant functions of relevant stimuli. For example, the rule "Turn right at the corner to reach your destination" alters the function of the actual corner such that it becomes discriminative for the behavior of turning right. In sum, these findings begin to provide a behavior-analytic account of cognitively mediated stimulus functions and how individuals come to respond both appropriately and inappropriately in novel contexts.

Other Stimulus Relations and the Transformation of Functions

Although equivalence relations are particularly relevant for discussions of how verbal stimuli affect human behavior, several stimulus relations other than equivalence can also alter stimulus functions and influence behavior. These include *opposition* and *difference* (Roche & Barnes, 1996, 1997; Steele & Hayes, 1991; Whelan & Barnes-Holmes, 2004), *more than* and *less than* (Berens & Hayes, 2007; Dymond & Barnes, 1995; O'Hora, Roche, Barnes-Holmes, & Smeets, 2002; Reilly, Whelan, & Barnes-Holmes, 2005; Whelan, Barnes-Holmes, & Dymond, 2006), *before* and *after* (O'Hora, Barnes-Holmes, Roche, & Smeets, 2004), and many others. Relational frame theory (RFT; Hayes et al., 2001) was developed on the assumption that a more comprehensive theory of verbal behavior would result from a more general account of stimulus relations and what is called *arbitrarily applicable relational responding* (details follow). A complete account of RFT is beyond the scope of this chapter, but it is important to provide an overview here to illustrate its translational and clinical relevance.

To respond to a relation or to respond relationally is to respond to one stimulus in terms of another. Most organisms can learn to respond to physical relations among stimuli, as when a rat learns to enter the brighter or darker of two runways or a pigeon learns to peck the brighter or darker of two keys, regardless of their absolute brightness (see Reese, 1968; Skinner, 1953). Relational responding, however, can also be established with arbitrary relations among stimuli, for example, when humans learn that a name is equivalent to an object (e.g., the word *cup* and a cup), that the numeral 10 is greater than the numeral 5, or that the word *white* is the opposite of the word *black*. These relations are arbitrary in that they are defined by social convention rather than by the physical features of the stimuli. A critically important feature of RFT is that arbitrary relational responding as typically seen in humans is itself hypothesized to be a contextually controlled generalized operant class that emerges as a result of extensive formal and informal multiple-exemplar training over several years and in many contexts (Luciano, Becerra, & Valverde, 2007). That is, responding relationally is differentially reinforced in certain contexts or in the presence of certain cues, and over time, those contextual cues come to occasion relational responding.

As a naturalistic example of the learning history thought to be responsible for arbitrary relational responding, a child presented with a relatively small cat and a large dog is asked, "Which of these is bigger?" and is reinforced for picking the physically larger dog. The child is then asked, "Which of these is smaller?" and is reinforced for picking the physically smaller cat. Later, the child may be presented with a relatively small toy car and a larger ball, asked again to identify which is bigger and which is smaller, and reinforced for the appropriate selection. After many such instances of reinforced responding in the context of the words *bigger* and *smaller,* the child comes to occasion the correct selection between any two stimuli. The words *bigger* and *smaller* can then be used to condition arbitrary relationships, as when a child is reinforced for picking a dime over a nickel when asked, "Which is bigger?" In addition, the child also learns that if one of two stimuli is called *bigger,* then it can be derived that the other is called *smaller*. Similarly, if trained that a nickel represents a certain value (e.g., $0.05 worth) and told that a nickel is smaller than a dime, one can derive that a dime has a larger value (i.e., more than $0.05 worth) despite its smaller physical size.

When an arbitrary stimulus relation has been established with two or more stimuli, RFT proposes that those stimuli participate in a relational frame. Relational frames are defined by three characteristics (Hayes et al., 2001). The first is mutual entailment. That is, given any relation, *x,* between stimuli A and B, there is an entailed relation, *y,* between B and A. Symmetry in equivalence relations is an example of mutual entailment. Given A = B, then the symmetric relation B = A is entailed. In relations other than equivalence, mutual entailment involves asymmetrical relationships. Given A < B, then the asymmetrical relation B > A is entailed.

The second defining characteristic of relational frames is combinatorial mutual entailment. Given a relation, *r,* between stimuli A and B, and another relation, *x,* between B and C, then there is an entailed relation, *y,* between A and C and an entailed relation, *z,* between C and A. Transitivity in equivalence relations exemplifies combinatorial mutual entailment. Given A = B and B = C, then A = C and C = A are entailed. Similarly, given A < B and B < C, then A < C and C > A are entailed.

The final defining characteristic of relational frames is transfer or transformation of functions. The term *transfer* characterizes relational frames of equivalence, and the term *transformation* characterizes relational frames other than equivalence. For example, if A is a reinforcer and it is arbitrarily established that A is the same as B, then the reinforcing function of A will be indirectly acquired by B without alteration. That is, the function will transfer as reinforcement in accordance with the relational frame of equivalence. However, the functions that are indirectly acquired via relations other than equivalence vary depending on the specific type of relation that has been applied. For example, if A is a reinforcer and it is arbitrarily established that A is the opposite of B, then the reinforcing function of A will be indirectly acquired by B with alteration. That is, the function will transform into punishment in accordance with the relational frame of opposition.

To reiterate, by definition the transfer or transformation of stimulus functions results from engaging in the behavior of arbitrarily applicable relational responding. However, exactly which arbitrary stimulus relations will influence behavior, and exactly which functions will transfer or be transformed, can be brought under contextual control (Dougher, Perkins, Greenway, Koons, & Chiasson, 2002; Wulfert & Hayes, 1988), permitting a high degree of behavioral flexibility with regards to relational responding.

Roche and Barnes (1997) conducted an early laboratory investigation of function transformation in accordance with stimulus relations other than equivalence. They began by replicating the Dougher et al. (1994) finding that members of a stimulus equivalence class could indirectly acquire eliciting functions, in this case showing a transfer of the arousing functions of filmed sexual stimuli. Skin resistance, measured by polygraph, served as the dependent measure. With respect to nonequivalence relations and the transformation of stimulus functions, Roche and Barnes implemented a training procedure resembling Steele and Hayes's (1991) procedure for establishing a network of same and opposite relations among various experimental stimuli (see Figure 1.1). During pretraining, participants learned to respond to the nonarbitrary relations same and opposite in the presence of arbitrary same (S) and opposite (O) contextual stimuli, respectively (the actual contextual stimuli were repeated characters: !!!!!! and %%%%%). For example, given S as a contextual stimulus, a short line as a sample, and short, medium, and long lines as comparisons, participants were reinforced for selecting the short line. In contrast, given this same problem but with O as a contextual stimulus, participants were reinforced for selecting the long line. The S and O contextual stimuli then were used to train a set of arbitrary relations between five other stimuli (i.e., A1 same B1, A1 same C1, A1 opposite B2, and A1 opposite C2). After successful direct training, several derivable relations were tested and shown to be derived (i.e., B1 same C1, B2 same C2, B1 opposite C2, and B2 opposite C1; see Figure 1.1). Next, a counterbalanced

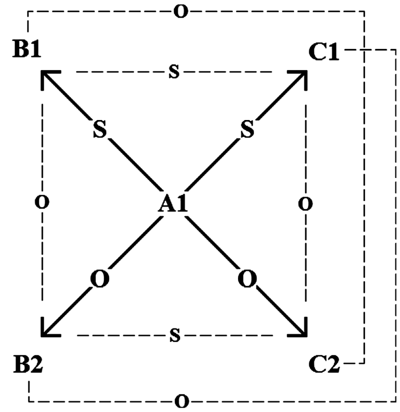

FIGURE 1.1. Based on a popular training preparation (e.g., Dymond et al., 2007, 2008; Roche & Barnes, 1997; Roche et al., 2008; Steele & Hayes, 1991; Whelan & Barnes-Homes, 2004), the figure shows a relational network consisting of directly trained (solid lines) and derived (dashed lines) relationships, where S and O represent same and opposite relations, respectively.

classical conditioning procedure paired B1 and B2 with sexual and nonsexual film clips. When B1 preceded a sexual film clip, its sexually arousing function was indirectly acquired by C1, which was the same as B1 through two same relations (i.e., B1 same A1 same C1). In addition, when B2 was paired with a sexual clip, its arousing function was indirectly acquired by C2, which was the same as B2 through two opposite relations (B2 opposite A1 opposite C2). This combinatorially entailed transformation of function occurred despite the fact that the tests for transformation (i.e., elicitation of a sexual response) were conducted in the absence of the S and O contextual stimuli. Thus, the eliciting functions were transformed in accord with a network of derived and arbitrarily applied relations.

Using similar training procedures (see Figure 1.1), Whelan and Barnes-Holmes (2004) established B2 as a punisher, after which C2 functioned as a punisher and C1 functioned as a reinforcer. The reinforcing function of the C1 stimulus emerged even though no member of the relational network had been directly established as a reinforcer. Thus, C1's reinforcing function emerged through the transformation of the B2 punishing function in accord with the relation of opposite.

More recent studies using comparable procedures (Dymond, Roche, Forsyth, Whelan, & Rhoden, 2007, 2008) have shown the transformation of avoidance and nonavoidance functions in line with the relations same and opposite. As in earlier studies, a relational network was first established in which A1 was the same as B1 and C1 but was the opposite of B2 and C2 (see Figure 1.1). In the signaled avoidance task that followed, participants learned to press a button in the presence of B1 to prevent the presentation of aversive images and sounds; presentations of B2 were followed by the presentation of nonaversive images and did not lead to avoidant responding. Thereafter, participants engaged in avoidance responding in the presence of C1 but not in the presence of C2, demonstrating the transformation of avoidance and nonavoidance functions.

In a follow-up investigation, Roche, Kanter, Brown, Dymond, and Fogarty (2008) first replicated their demonstration of a network transformation of avoidance (B1 to C1, not C2) and nonavoidance (B2 to C2, not C1) functions. They then disabled the avoidance response button and presented the experimental stimuli in extinction. In a direct extinction group ($n = 9$), the response button was disabled and presentations of B1 and B2 ceased to be followed by images or sounds. In a derived extinction group ($n = 9$), the response button was disabled and presentations of C1 and C2 were not followed by images or sounds. After the extinction phase, all participants were exposed to all four stimuli, and avoidance responses were recorded in extinction. In the direct extinction group, only one participant did not avoid B1, whereas two participants did not avoid C1. Within the indirect extinction group, five participants did not avoid B1, whereas eight participants did not avoid C1. If these surprising results are replicable, they raise a question for further translational research on extinguishing avoidance behavior: Are there circumstances in which derived exposure (e.g., talking about a feared event) could produce therapeutic gains that are comparable or even superior to direct exposure (e.g., being in the presence of a feared event)?

In another study of the transformation of stimulus functions via relations other than equivalence, Dougher, Hamilton, Fink, and Harrington (2007) demonstrated the transformation of discriminative and eliciting functions in accord with the relations less than and greater than. First, relational functions were established for three visual forms labeled A, B, and C by reinforcing across multiple training trials selections of the physically smallest, medium, or largest of three comparisons in the presence of samples A, B, and C stimuli, respectively. On each trial, one of the samples would appear at the top of the computer screen along with three visual comparisons across the bottom that varied in size but were otherwise identical. New comparison arrays were presented across trials, but regardless of the array, selections of the smallest comparison were reinforced when A was the sample, selections of the medium comparison were reinforced when B was the sample, and selections of the largest comparison were reinforced when C was the sample. This training was intended to establish the comparative relations $A < B < C$ among the samples.

After successful training, the B stimulus was presented for 30 seconds, and participants were instructed to press the space bar on the computer keyboard at a steady rate. They were also told that the stimulus presented on the computer screen would sometimes change and to "press the bar at a rate that you think is appropriate for each symbol you see." After a steady state of button pressing in the presence of the B stimulus was attained, participants were then presented with the A and C stimuli while their response rates were recorded. Without further instruction and for all eight participants, presentations of the A and C stimuli occasioned slower and faster responding, respectively, than the B stimulus. Thus, the discriminative functions of the A and C stimuli were transformed in line with their respective relations to the B stimulus.

In the next phase of the experiment, the B stimulus acquired a CS+ function by following it with a mild electric shock; skin conductance served as the dependent measure. After this direct conditioning, the A and C stimuli were presented without instructions, and skin conductance levels were recorded. Six of eight participants showed lower skin conductance response to the A stimulus and higher skin conductance responses to the C stimulus than they did to the directly conditioned B stimulus. All participants reported that they expected to receive a larger shock to C than to B, despite the fact that C had never been paired with shock. One participant became so alarmed at the presentation of the C stimulus that she tried to remove the shock electrodes from her arm, fearing that the shock would be too severe. These results demonstrated that, along with their discriminative functions, the fear-eliciting functions of A and C stimuli had been transformed in line with their respective relation to the B stimulus. Roche and Dymond (2008) reported similar results with sexually arousing stimuli.

VERBAL BEHAVIOR AND THE CLINICAL RELEVANCE OF RFT

According to Hayes et al. (2001), "The primary pragmatic purpose of the analysis of derived relations . . . is an analysis of the development of verbal rules (e.g., through thinking, reasoning, and problem-solving), and the use of verbal formulae to guide behavior" (pp. 104–105). As mentioned, rules often allow for greater prediction and control of events, and the generation, derivation, and following of rules may therefore be reinforced as operant behavior (Hayes et al., 2001). At the same time, people's social environments often require and reinforce the formulation of complete and coherent narratives about their actions and the events in their lives. Skinner (1953, 1974) suggested that this verbal behavior is the basis of the development of self-awareness. Social demands for coherent narratives about one's own behavior require discrimination of oneself from the rest of the environment and that the narratives one generates fit with culturally acceptable explanations. To respond to such questions as "Where are you going?" or "How do you feel?" or "What do you intend to do tomorrow?" the responder must first be able to discriminate him- or herself from other objects and events in the environment. A fundamental assumption of both ACT and RFT is that networks of derived stimulus relations play a critical role in this process and give rise to an abstracted, reified, and transcendent sense of self. A detailed description of these processes is beyond the scope of this chapter (see Hayes, 1984, and Barnes-Holmes, Stewart, Dymond, & Roche, 2000, for a more thorough accounting), but the important implication here is that most typically developing individuals are encouraged by their verbal community (culture) to act as if the self is a real entity. Furthermore, people are taught that the self roughly corresponds to their thoughts and feelings, which are treated as causes of behavior. Taken together, the sense of self as a real entity and the tendency to explain behavior by appeal to private experience can be problematic and contribute to clinical problems.

As mentioned in our earlier discussion of rule governance, rule following can be maladaptive, especially if one has a strong history of reinforcement for pliance and when rule following precludes contact with discrepant actual contingencies and consequences. Hayes et al. (1999, 2001) argued that one particularly troublesome domain of maladaptive rules includes those that promote the avoidance of private experience or emotional avoidance. The rules promoting this experiential avoidance can take many forms but are largely rooted in cultural prescriptions that certain thoughts and feelings are good and others are bad. Very few individuals would argue with the classification of depression, sadness, anxiety, insecurity, fear, regret, and remorse as bad, and many sources of information, including parents, friends, popular media, and mental health professionals, articulate and support that view. Most mental health professionals clearly see these emotions as undesirable, and most therapies are aimed at getting rid of them. In contrast, from a CBA and especially an ACT perspective, experiential avoidance is the source of many clinical problems.

The human tendency to constantly verbalize (think) and problem solve as people interact with the environment around them extends to the world of private events, and people's verbal behavior with respect to these private events can itself become problematic. The trouble starts with a simple fact of life: Negative thoughts and feelings are inevitable. Living in a complex world without encountering frustration, failure, loss, sadness, fear, worry, insecurity, incompetence, and so forth is unimaginable. As people encounter such inevitabilities, however, resulting statements such as "I feel depressed" do not occur in isolation. Once said, "I," which is assumed to be a real entity, is placed in an equivalence relation with "depressed," which, by virtue of living in a culture in which depression is considered bad, is in an equivalence relation with "bad." Through combinatorial entailment, "I" is then equivalent to "bad," which, via function transformation, has the potential to elicit other negative private events and perhaps alter the functions of otherwise reinforcing events or activities (Dougher & Hackbert, 1994).

Many clients attempt to solve such problem in the ways they have successfully solved other problems in their lives. In particular, one often reinforced problem-solving strategy is to remove or alter the determinants of the problem. Coupled with a history of reinforcement for attributing causation to the self and private events, "I am depressed" naturally leads to the conclusion that "I have to get rid of this depression" and other related rules such as "I can't do anything else until I don't feel depressed" (Hayes et al., 1999, 2001). At an extreme, a rule requiring the elimination of depressive feeling can entail an elimination of the self as a viable solution (i.e., suicide). Attempts to eliminate feelings of sadness or depression can take many forms, but these attempts are often not very helpful or healthy, precisely because the actions that are likely to alleviate the depression, such as engaging in productive, valued activities, are contradicted by self-generated rules or are depotentiated as reinforcers by the events that cause the depression in the first place (Dougher & Hackbert, 1994). In other words, depressed individuals just do not feel like engaging in previously reinforcing activities. Instead, they may attempt experiential avoidance (e.g., through social withdrawal, excessive sleeping, self-medicating with alcohol or drugs) or spend time trying to think (ruminate) their way out of the problem. Paradoxically, because of the equivalence relations between words and their referents and the attendant transfer of functions, attempting to verbally control private events only makes them more likely to occur (see also Wegner, 1994), and one may be better off accepting private experiences rather than struggling to alter their occurrence (Hayes et al., 1999; see Chapter 18, this volume).

CBA THERAPIES

The existing CBA therapies, although differing in domain of application and degree of emphasis on the role of verbal processes in the development and treatment of clinical disorders, share core philosophical assumptions about the origins of human suffering, the means by which quality of life can be improved, and the goals or objectives of therapy. One commonality among the CBA therapies is a focus on constructing effective repertoires rather than eliminating unwanted private events. The overarching objective is to help clients lead rich and valued lives. A formal explication of this position can be found in Israel Goldiamond's constructional approach to therapy (Goldiamond, 1974/2002; Schwartz & Goldiamond, 1975; see also Delprato, 1981; Fleming, 1984; Layng, 2009), which was perhaps the first outpatient therapy based primarily on behavior-analytic principles and assumptions.

Israel Goldiamond (1919–1995) first developed his constructional approach with an eye toward protecting the constitutional and human rights of individuals living under institutional control (Goldiamond, 1974/2002; Schwartz & Goldiamond, 1975). Within institutions such as prisons and mental hospitals, the prevailing ideology of the time was that the purpose of the institution was to establish total control over the lives and behaviors of those who were institutionalized, an approach that Goldiamond (1974/2002) believed precluded the freedom to assent or dissent to treatment. Therapeutic objectives in these institutions tend to focus on eliminating socially undesirable behavior, where power differentials allow the institution, as opposed to patients, to determine which behaviors are desirable and undesirable. Goldiamond argued that this total control approach to mental health treatment is not only ethically problematic but is also antithetical to the social purpose of ostensibly therapeutic agencies. Alternatively, the needs of society and the rights of clients are usually better met through a sort of constitutional allegiance between therapists and clients, in which those behaviors constituting therapeutic outcomes are agreed on by both therapist and client rather than dictated by the therapist. This emphasis on respecting client autonomy is especially relevant in outpatient settings, in which a total control approach is neither pragmatic nor ethical. Instead, a constructional therapist attempts to influence client behavior only insofar as it helps clients bring their behavior under their own control and helps them achieve their own goals.

More important, the objectives of a constructional treatment agreement are to be framed in positive rather than negative terms (Goldiamond, 1974/2002; Schwartz & Goldiamond, 1975; see also Delprato, 1981; Fleming, 1984). Using the U.S. Constitution as an analogy, Goldiamond (1974/2002) noted that the framers sought to ensure domestic tranquility, not prevent unnecessary violent revolts. More literally, CBA therapists seek to ensure valued activity, not prevent undesirable thoughts and behavior. Framing outcomes in negative terms is what Goldiamond referred to as an *eliminative* approach. Under an eliminative approach, patients were often diagnosed according to their socially undesirable patterns of behavior, with successful treatment defined in terms of the elimination of those behavioral patterns. The general problem with an eliminative approach is that there are typically many ways to eliminate an unwanted behavior, but there is no guarantee that it will be replaced by desirable or more effective behavior. For example, under an eliminative approach, the successful treatment of stuttering would be defined as its elimination (or reduction). Sedation, punishment, and even surgical removal of the tongue and larynx would all eliminate stuttering, but none would be expected to result in more fluent speech. Indeed, one far too frequently used therapy of the 1960s for the treatment of disturbing behaviors was frontal lobotomy, a surgical procedure that was highly successful at eliminating behaviors but far less effective at constructing effective repertoires.

In contrast, a constructional approach to stuttering entails promoting fluid speech. In the case of depression, it amounts to switching from the goal of eliminating depressive thoughts and feelings to the goal of promoting valued, personally meaningful activity. The latter is important; a therapist could unilaterally impose a positively framed constructional program, but there would be no guarantee that this program would reflect the client's values. Thus, the construction of therapeutic outcomes should be informed by the client's values, not the therapist's. By focusing on valued, personally meaningful activity as a therapeutic outcome, the constructional approach fulfills the ethical responsibility of social institutions and professionals to provide therapeutic services while respecting and promoting clients' autonomy (Goldiamond, 1974/2002).

Although Goldiamond (1974/2002; Schwartz & Goldiamond, 1975) reported case examples of the successful use of a constructional approach, the approach represents a philosophical assertion of what it means for an outcome to be therapeutic and is therefore not subject to empirical verification. Rather, a constructional approach has been used successfully whenever treatment helps a client engage in behaviors that are consistent with the client's values, thereby improving the client's quality of life by definition.

In addition to being rooted in a constructional approach and client values, CBA therapies are either based on or are consistent with the philosophy of radical behaviorism and its modern elaboration, functional contextualism (see Gifford & Hayes, 1999; Hayes, 1993; Pepper, 1942; Skinner, 1953, 1974; Vilardaga, Hayes, Levin, & Muto, 2009). That is, when CBA therapists conduct a behavioral analysis, public and private behaviors are understood to be a function of their current and historical contexts, and a behavioral analysis is said to be true or valid to the extent that it leads to effective action with respect to the achievement of specified goals. The inherent monism and nonmentalism of radical behaviorism (see Dougher & Hayes, 2000) leads behavior analysts to eschew explanations of behavior that rely on organismic states, traits, predispositions, thoughts, beliefs, expectancies, or attitudes as sources of causation (see Hayes & Brownstein, 1986). The inherent pragmatism of radical behaviorism requires behavioral theories and explanations to be cast in terms of identifiable and manipulable environmental determinants. As we tried to make clear earlier, however, this does not mean that behavior analysts ignore private or verbal events or their roles as links in complex chains of behavior. Instead, an adequate explanation of behavior cannot stop with private events and must explain both the occurrence of private events and their influence on other behavior.

The third commonality among CBA therapies is that they tend to emphasize experience and experiential learning over rules and rule governance. Clients are encouraged to set aside their verbal defenses and justifications for their actions in favor of direct evaluation of whether their actions are leading to valued outcomes. An important aspect of this process is clients' discrimination of the actual results of their own rule following. As such, CBA therapists do not seek to specifically develop better rules (thoughts, beliefs) for the client to live by. Instead, therapy focuses on helping clients experientially evaluate their customary ways of behaving, including their ways of thinking, in terms of whether they facilitate or detract from valued outcomes.

The fourth commonality is that CBA therapies encourage clients to accept experiences and situations that cannot be changed, that is, for which there can be no effective action. Especially within ACT (Hayes et al., 1999; cf. Martell et al., 2001), this acceptance includes the painful or negative thoughts, emotions, or memories that inevitably arise as humans interact in the world. It should not be interpreted as reflecting a cynicism or pessimism about the human condition or a kind of Nietzschean no-pain, no-gain philosophy. Rather, it is more in line with Zen Buddhist teachings; although pain is inevitable, suffering is the result of verbal distortions of the world and people's beliefs that the world should be different than it is. Human suffering is exacerbated by struggling against what is and attempting to control what cannot be controlled. Among the CBA therapies, ACT (see Chapter 18, this volume) has the most developed perspective on acceptance. On the basis of basic laboratory research on rule governance, transformation of function, and RFT, ACT makes a convincing case that negative private experiences acquire a disproportionate amount of control over behavior and that because of the nature of verbal processes (relational frames), the very act of trying to avoid these experiences necessarily exacerbates them and detracts from valued living. For this reason, learning to accept private events and see them for what they really are (i.e., verbal events) instead of what they appear to be (i.e., the real condition of the world) is a key element of therapy.

Functional Analytic Psychotherapy

One of the first verbally based outpatient therapies based on behavior-analytic principles and assumptions is functional analytic psychotherapy (FAP). Developed by Robert Kohlenberg and Mavis Tsai (1991), FAP is based on the assumption that the problems faced by verbally competent outpatient adults are mostly interpersonal, and the context of the therapy relationship is an ideal place to observe, understand, and shape clients' interpersonal behavior. Clients miss sessions, have insights, pick fights, express appreciation, fear disclosure, avoid certain topics, lie, cry, relate, dissociate, and otherwise engage in myriad behaviors that therapists can directly observe, functionally analyze, and consequate. Thus, the basic premises of FAP are that the therapeutic relationship involves contingencies that can be used to decrease the frequency of problematic behavior and increase the frequency of desirable behavior in vivo and that these changes may then generalize to other interpersonal relationships (Kohlenberg & Tsai, 1991).

Although usable as a stand-alone treatment, FAP is more commonly used as a therapeutic adjunct to other primary treatments (Kohlenberg & Tsai, 1991). However, FAP assumes that an exclusive focus on the primary treatment may result in therapists missing opportunities to better understand the functional effects of their clients' behavior as it occurs in session and to shape client behavior directly. In this sense, FAP resembles the direct contingency management procedures of ABA but is specifically tailored to the context of outpatient therapy.

Much of the research to support the efficacy of FAP consists of case studies (see Ferro García, 2008). FAP-enhanced therapy has been conducted with clients with anxiety disorders (Carrascoso López, 2003; Kohlenberg & Tsai, 1998), personality disorders (Callaghan, Summers, & Weidman, 2003; Holmes, Dykstra, Williams, Diwan, & River, 2003), and chronic pain (Queiroz & Vandenberghe, 2006). Vandenberghe (2007) argued that FAP is also well suited to facilitate exposure-based treatments for posttraumatic stress disorder and obsessive–compulsive disorder (see also Kohlenberg & Tsai, 1998; Kohlenberg & Vandenberghe, 2007). Further investigations have examined the use of FAP in treating depression after a breakup (Ferro García, Valero Aguayo, & Vives Montero, 2006), exhibitionism (Paul, Marx, & Orsillo, 1999), and chronic pain and fibromyalgia (Vandenberghe & Ferro, 2005; Vandenberghe, Ferro, & Furtado da Cruz, 2003; see also Queiroz & Vandenberghe, 2006). FAP-enhanced cognitive therapy (see Kohlenberg & Tsai, 1994) has been shown to be effective for the treatment of depression (Gaynor & Lawrence, 2002; Kohlenberg, Kanter, Bolling, Parker, & Tsai, 2002), as has FAP-enhanced ACT (Dougher & Hackbert, 1994); FAP-enhanced behavioral activation also shows promise in the treatment of relationship distress (Manos et al., 2009). Other investigations are beginning to reveal the active components of FAP (Busch et al., 2009; Kanter, Schildcrout, & Kohlenberg, 2005; Kohlenberg et al., 2002), indicating that in vivo work leads to improved interpersonal functioning. Thus, across differing treatments and clinical issues, FAP shows promise as a widely applicable and effective interpersonal approach to therapy.

Integrative Behavioral Couple Therapy

The use of behavioral principles in treating couples was originally developed in the form of behavioral marital therapy (Jacobson & Margolin, 1979), or what is now called *traditional behavioral couple therapy* (TBCT; see Christensen et al., 1995). With more than 20 randomized clinical trials of TBCT's efficacy, it is the most widely studied treatment for marital distress (see Baucom, Shoham, Mueser, Daiuto, & Stickle, 1998; Christensen & Heavey, 1999; Jacobson & Addis, 1993; Shadish & Baldwin, 2005). Despite this impressive level of empirical scrutiny, one of the pioneers of TBCT, Neil Jacobson, was not fully satisfied with its reported clinical significance (see Christensen et al., 1995). Impressed with increasing reports of success for acceptance-based therapies, Jacobson and his colleague, Andrew Christensen, explored whether TBCT could be made more effective by including techniques for fostering acceptance. This gave rise to what is now called *integrative behavioral couple therapy* (IBCT; Christensen et al., 1995; Jacobson & Christensen, 1996, 1998).

Jacobson and Christensen (1996) reasoned that people engage in romantic relationships because of the reinforcement inherent in them. Relationship difficulties, then, can arise when relationships lose their reinforcing functions or develop aversive functions. One way this occurs is through reinforcement erosion, which is essentially habituation to the rewarding aspects of a relationship. Relationship difficulties can also arise from changes in the life circumstances of one or both partners, such as having children, loss or change of a job, increasing work stress, or financial difficulties. Incompatibilities that arise from such changes can lead a couple to vilify each other's differences and to withhold gratification from each other in a polarization process (Jacobson & Christensen, 1996), further reducing the reinforcing qualities of a relationship. A functional analysis of a given couple's polarization process allows the clinician to sort topographically distinct problem behaviors into functional response classes, which helps to identify the underlying theme of the couple's primary conflict (Jacobson & Christensen, 1996). After the problem theme is identified, the partners are in a better position to collaborate on finding solutions that reduce polarization, promote each other's needs, and improve the quality of their relationship (Berns, Jacobson, & Christensen, 2000).

As opposed to targeting particular behavioral topographies (as advocated by TBCT), IBCT change strategies are directed toward placing clients in contact with contingencies that will reduce the frequency of the functional class of problematic behaviors identified by the theme. For example (see Berns et al., 2000), initiating sex may serve the function of promoting intimacy for one couple, but that same topography could be a means of domination for another couple. For the first couple, initiations of sex could alter the frequency of behaviors from a functional response class associated with attempts to achieve intimacy, whereas modifications of this topography would not benefit the latter couple in their attempts to achieve greater intimacy. Given its more functional orientation, IBCT is more clearly aligned with modern CBA than is TBCT.

Change strategies are common to both TBCT and IBCT (Christensen et al., 1995; Jacobson & Christensen, 1996; Jacobson & Margolin, 1979). First, behavioral exchange procedures are used to encourage couples to increase the number of reinforcing behaviors in their relationships, which can help counteract reinforcement erosion. For example, each partner may make a list of the other partner's wants, discuss their lists with each other and the therapist to plan behaviors around these wants, and then try some of the behaviors to see whether they increase happiness or satisfaction in the other partner. Second, clients are given communication skills training, including speaking and listening skills, which can help counteract the polarization process. The therapist may instruct and model extensively during the initial shaping of communication and reduce his or her level of involvement over time. Finally, problem-solving training may be used to help couples define and communicate problems, generate potential solutions in the form of alternate behaviors, evaluate and negotiate the alternatives, and implement and evaluate planned change.

In addition to these change strategies, IBCT includes strategies for promoting emotional acceptance of aspects of the other person that cannot be changed (Christensen et al., 1995; Jacobson & Christensen, 1998), the idea being that closer relationships can be built on acceptance when change is not possible. Most couples will have problems that cannot be changed, and IBCT therefore stresses that emotional acceptance strategies are as important, or even more important, than behavioral change strategies (Christensen et al., 2004). Moreover, acceptance may change the context of a relationship such that behavioral change is more likely, paradoxically being more effective than direct attempts at inducing behavioral change (Jacobson & Christensen, 1996).

As mentioned, TBCT's efficacy has been well established (see Baucom et al., 1998; Christensen & Heavey, 1999; Jacobson & Addis, 1993; Shadish & Baldwin, 2005), but research into IBCT's efficacy has been relatively limited. An early investigation by Wimberly (1998) found that eight couples randomly assigned to IBCT were more satisfied after treatment than were nine couples randomly assigned to a wait-list control. Christensen and Heavey (1999) reported an unpublished study by Trapp, Pace, and Stoltenberg (1997) showing that IBCT was as effective as cognitive therapy in reducing the depression of 29 maritally distressed women. Jacobson, Christensen, Prince, Cordova, and Eldridge (2000) compared TBCT and IBCT in a randomized controlled trial (RCT) of 21 couples experiencing clinically significant marital distress. Although statistical analyses were not reported, descriptive analyses showed that 64% of TBCT couples had improved or recovered by the end of therapy, whereas 80% of IBCT couples had improved or recovered. Christensen et al. (2004) conducted a large RCT with 134 moderately to severely distressed couples, concluding that TBCT and IBCT were equally as efficacious by the end of treatment; 60% of TBCT and 69% of IBCT couples were still reporting significant improvements at 2-year follow-up (Christensen, Atkins, Yi, Baucom, & George, 2006). Doss, Meng Thum, Sevier, Atkins, and Christensen (2005) examined the 2004 RCT data and concluded that both therapies worked according to their differing theoretical mechanisms of change (see also Cordova, Jacobson, & Christensen, 1998). That is, TBCT decreased targeted damaging behaviors and increased targeted helpful behaviors to produce relatively quick therapeutic gains, whereas IBCT gradually increased the amount of acceptance for behaviors that could not be changed easily. Thus, although IBCT tends to outperform TBCT, the available research would suggest that IBCT and TBCT are equally efficacious but qualitatively distinct therapies.

Dialectical Behavioral Therapy

Marsha Linehan developed dialectical behavioral therapy (DBT) during the 1980s while investigating the use of CBT for the treatment of parasuicidal clients (Linehan, 1993). More recently, however, DBT has come to be most closely associated with the treatment of borderline personality disorder. During Linehan's early CBT investigations, a treatment team examined her and her clients' interactions during therapy sessions. Although they found that certain CBT components, particularly behavioral components, were beneficial (Linehan, 1993), it was also clear that aspects of Linehan's therapeutic style were playing an important role in the efficacy of treatment. Specifically, her therapy involved features of Zen Buddhism, in that Linehan encouraged clients to accept that they can and do have simultaneously different and even conflicting thoughts and feelings. Also, as a means of eliciting behavioral change, Linehan tended to modulate her verbal style between being warm and empathic and being blunt and confrontational. Thus, not unlike IBCT, her seemingly paradoxical but effective therapeutic style involved a dual focus on acceptance and change, leading Linehan to explore the tradition of dialectics and to create DBT (Linehan, 1993).

Specific DBT treatment targets include emotional regulation, behavioral regulation, interpersonal regulation, regulation of a sense of self, and cognitive regulation (Linehan, 1993). Early stages of DBT therapy focus on reducing suicidal behavior or other life-interfering behaviors (e.g., substance abuse) through the introduction of new behavioral skills such as mindfulness, interpersonal effectiveness, emotional regulation, distress tolerance, and self-management. After the introduction of stabilizing behavioral skills, clients are exposed to feared or unwanted thoughts. This exposure will often be in relation to traumatic experiences, which are common with individuals with borderline personality disorder. Clients may then begin working on more general life-related skills in domains such as employment and interpersonal relationships, with efforts directed toward the achievement of individual goals and self-respect. The end stages of treatment are directed toward enhancing quality of life while accepting that struggles are an inevitable part of life.

The first RCT investigation of the efficacy of DBT for the treatment of chronically suicidal female outpatients with borderline personality disorder showed some positive effects of the treatment (Linehan, Armstrong, Suarez, Allmon, & Heard, 1991; Linehan, Heard, & Armstrong, 1993; Linehan, Tutek, Heard, & Armstrong, 1994). Compared with treatment as usual, DBT clients showed higher retention rates, fewer parasuicidal acts, fewer inpatient psychiatric hospitalizations, and greater self- and other-reported improvements in anger and social adjustment (see also van den Bosch, Verhuel, Schippers, & van den Brink, 2002). Benefits of DBT relative to treatment as usual have also been demonstrated in a veteran population (Koons et al., 2001), including significant reductions in suicidal ideation, depression, and hopelessness.

To address some of the shortcomings of earlier RCT investigations (e.g., see Hoffman, 1993), more recent efforts have revisited the DBT treatment of borderline personality disorder, showing that DBT reduces suicide attempts, leads to fewer psychiatric hospitalizations, lowers dropout rates, decreases suicidal ideation, improves depression, and improves reasons to live (Linehan et al., 2006). In addition, RCTs have demonstrated the effectiveness of DBT in reducing substance use in outpatients with borderline personality disorder (Linehan et al., 1999), including long-standing reductions in opiate use (Linehan et al., 2002). DBT has been shown to be effective in reducing binge eating among clients with binge eating disorder relative to wait-list controls (Telch, Agras, & Linehan, 2001), accompanied by reductions in concerns about weight, shape, and eating. Similarly, DBT has also been shown to reduce binging and purging in individuals diagnosed with bulimia nervosa (Safer, Telch, & Agras, 2001a, 2001b). Thus, a substantial body of evidence has accumulated to mark DBT as a relatively effective treatment for borderline personality disorder, with or without comorbid substance abuse, and indications are good that DBT may be effective in the treatment of eating disorders.

Behavioral Activation Therapy

With respect to the CBA treatment of depression, Kanter et al. (2009) have identified four distinct therapies that fall under the general heading of behavioral activation therapy (BAT), with the two major modern CBA BAT therapies being behavioral activation (BA; Martell et al., 2001) and behavioral activation for the treatment of depression (BATD; Lejuez, Hopko, LePage, Hopko, & McNeil, 2001). Early behavior-analytic writings on depression (e.g., Ferster, 1973; Skinner, 1953) laid the foundation for Lewinsohn (1974) to develop the first version of BAT, which consisted of activity scheduling and was based on the observation that depression arises from extinction or the loss of stable sources of positive reinforcement. With the rise in popularity of Ellis's (1962) rational emotive therapy and other cognitive therapies, BAT was added or incorporated into cognitive therapies, as exemplified by Beck's cognitive therapy (CT) for depression (Beck et al., 1979). In this second BAT approach, the theoretical purpose of activity scheduling changed from increasing the density of reinforcement to providing experiences that could facilitate cognitive restructuring. Although CT has been the preeminent empirically supported treatment for depression for the past three decades, the clinical contributions of the cognitive components of CT were called into question by the results of a well-designed component analysis (Jacobson et al., 1996), which showed that behavioral activation, in and of itself, accounted for positive therapeutic outcomes. The cognitive components added relatively little to the treatment.

In light of these findings, Martell et al. (2001) developed BA. Because of its realignment with a behavior-analytic theoretical foundation, Martell et al.'s modern BA resembles Lewinsohn's (1974) original BAT, but with the addition of techniques for the identification and treatment of avoidance. The role of avoidance in depression was originally elaborated by Ferster (1973), who, like Lewinsohn, was strongly influenced by Skinner. Ferster recognized that low levels of positive reinforcement can result from low levels of activity resulting from avoidance of aversive situations. In line with this thinking, BA includes functional analyses of avoidance behaviors, with the intention of helping clients overcome avoidance and create small, achievable goals. Core treatment components include activity monitoring, activity scheduling, stimulus control, skills training, self-reinforcement, identifying avoidance, understanding rumination, and practicing mindfulness. When BA was compared with CT, paroxetine, and placebo (Dimidjian et al., 2006), it was comparably effective to CT and paroxetine for the treatment of clients with mild depression. For the treatment of clients with moderate to severe depression, BA outperformed CT and was as effective as paroxetine. In another study, clients treated with BA had lower dropout and relapse rates than clients taking paroxetine (Dobson et al., 2004). The BA approach appears to be effective in group formats (Porter, Spates, & Smitham, 2004), and evidence has shown that adaptations may be successfully used in the treatment of individuals with posttraumatic stress disorder (Jakupcak et al., 2006; Mulick & Naugle, 2004).

BATD (Lejuez, Hopko, LePage, et al., 2001) draws its primary theoretical rationale from Herrnstein's (1961, 1970) matching law (see also McDowell, 1982), which suggests that the proportion of depressive behavior (B_D) to nondepressive behavior (B_{ND}) exhibited is equal to the proportion of reinforcers received by engaging in depressive behavior (R_D) versus nondepressive behavior (R_{ND}):

$$\frac{B_D}{B_D + B_{ND}} = \frac{R_D}{R_D + R_{ND}}.$$

Accordingly, two strategies should decrease the proportion of depressive activities: (a) Increase the rate or amount of reinforcement for functionally nondepressive (i.e., healthy) behavior (R_{ND}) and (b) decrease reinforcement provided contingent on depressive behavior (R_D).

Relative to BA, in BATD activity scheduling is given primary attention, and avoidance is given less attention (see Hopko, Lejuez, Ruggiero, & Eifert, 2003). Core treatment components cover activity monitoring, values assessment, activity hierarchy, activity scheduling, stimulus control, contingency contracting, and self-reinforcement. Because of its streamlined nature, BATD may be practical when conducting therapy in time-limited treatment settings, as occurs with hospitalized inpatients. In support of this view, an RCT comparing BATD and general supportive therapy found that BATD was superior in reducing self-reported depressive symptoms among hospitalized inpatients (Hopko, Lejuez, LePage, Hopko, & McNeil, 2003). Although intended to be applicable in inpatient settings, BATD has also been used successfully to reduce depression among outpatients (Lejuez, Hopko, LePage, et al., 2001). An RCT with moderately depressed university students compared BATD and a wait-list control. Results showed that a single session of BATD with 2 weeks of implementation significantly reduced depression and increased environmental reward. Preliminary evidence has shown that BATD can be effective in treating comorbid depression and anxiety (Hopko, Lejuez, & Hopko, 2004), that BATD can reduce suicidal ideation in individuals with borderline personality disorder (Hopko, Sanchez, Hopko, Dvir, & Lejuez, 2003), and that BATD can be a useful adjunct to pharmacotherapy (Hopko, Lejuez, McNeil, & Hopko, 1999). Overall, the research on BAT has suggested that a focus on BA can produce powerful therapeutic changes.

Acceptance and Commitment Therapy

Of the CBA therapies, ACT (Hayes et al., 1999; see Chapter 18, this volume) is most directly concerned with the interaction between clients' learning histories and their verbal processes. Within ACT, verbal processes are understood in terms of RFT (Hayes et al., 2001); rules, derived relationships, and the transformation of stimulus functions are thought to play important roles in the etiology and maintenance of psychological disorders. As described earlier, ACT therapists are concerned with the role that verbal rules can play in promoting experiential avoidance, a destructive behavioral pattern in which people attempt to avoid or escape their own private experiences (Hayes & Gifford, 1997; Hayes, Wilson, Gifford, Follette, & Strosahl, 1996; Zettle, 2005). In ACT therapy, mindfulness techniques are taught to help clients disengage from rule following when it is not working to their benefit, accept their private experiences, and thereby neutralize the negative effects of experiential avoidance.

Conversely, ACT also takes advantage of rule-governed behavior by bringing clients under the stimulus control of their values, which are "verbally construed global desired life consequences" (Hayes et al., 1999, p. 206). Specifically, clients are encouraged to commit to the pursuit of valued goals even in the face of unwanted private experiences. For example, even though the thought of visiting a dying relative may cause anxiety, a person may be willing to experience the anxiety and entertain visiting because of the verbally construed, positive consequences of the behavior of visiting (e.g., "I value caring for my family, and visiting my dying grandmother is consistent with this value, so I'll willingly go even though it scares me"). Thus, as with IBCT, DBT, and BAT, ACT targets both acceptance and change, but with a particular emphasis on verbal processes (for a comparison of ACT and BAT in their treatment of verbal processes, acceptance, and change, see Kanter, Baruch, & Gaynor, 2006).

As reviewed in Chapter 18 (this volume), a growing body of research has supported ACT's efficacy in treating a variety of life concerns (for additional reviews, see Gaudiano, 2009; Hayes, Luoma, Bond, Masuda, & Lillis, 2006; Hayes, Masuda, Bissett, Luoma, & Guerrero, 2004; Öst, 2008; Powers, Zum Vörde Sive Vörding, & Emmelkamp, 2009).

CONCLUDING REMARKS

Behavior analysis is one of the few schools of psychology that maintains a strong alliance between its basic and applied wings. Basic laboratory research is the foundation of CBA, and clinical behavior analysts feel quite comfortable conducting basic research on behavioral phenomena evident in and relevant to clinical work. Of particular relevance to CBA is the recent research in verbal behavior. Over the past three decades, this research has led to novel and useful explanations of the development of clinical disorders, alternative approaches to clinical assessment and classification, new and innovative therapeutic interventions, and new treatment goals and objectives. Much work still needs to be done, but it is clear that continued progress in CBA will depend on progress in the translational research on which it is based.

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Chapter 2

TRANSLATIONAL APPLIED BEHAVIOR ANALYSIS AND NEUROSCIENCE

Travis Thompson

As the field of behavior analysis has matured, B. F. Skinner's (1989) vision that "human behavior will eventually be explained (as it can only be explained) by the cooperative action of ethology, brain science, and behavior analysis" (p. 18) is increasingly becoming a reality. In this chapter, I examine the pathway from the laboratory to application at the interface of behavior analysis and neuroscience, with an emphasis on application. I begin by discussing early neuroscience behavior-analytic research on subcortical electrical self-stimulation and conclude by exploring applications in physical rehabilitation, substance abuse treatment, treatments for conditions associated with autism and developmental disabilities, and brain imaging.

BEHAVIOR ANALYSIS IN PHYSIOLOGICAL PSYCHOLOGY

Joseph V. Brady established one of the first interdisciplinary physiological psychology (now called *neuroscience*) research programs at Walter Reed Army Research Institute in the 1950s. He concurrently established one of the first major behavioral pharmacology laboratories 8 miles across town at the University of Maryland in College Park. Among the earliest important work at Walter Reed was Sidman, Brady, Boren, Conrad, and Schulman's (1955) research on the influence of reinforcement schedules on behavior maintained by intracranial self-stimulation, which was published in the interdisciplinary journal *Science*. At about the same time, Olds and Milner (1954) published an article demonstrating similar behavioral control by means of self-administered subcortical electrical stimulation. Porter, Conrad, and Brady's (1959) article in the *Journal of the Experimental Analysis of Behavior* examined implications of integrating operant principles and brain science. This early behavior analysis neuroscience work made two important contributions. It disseminated the power of behavior analysis principles broadly outside the world of operant learning researchers. In addition, it made Skinner's operant chamber and the associated apparatus controlling stimulus conditions and reinforcement contingencies standard equipment for studying a wide array of brain and pharmacological variables. To this day, behavioral neuroscientists continue to use operant learning procedures to study brain processes.

EARLY BEHAVIORAL PHARMACOLOGY

Early in Skinner's career, he studied effects of caffeine and dl-amphetamine on operant lever pressing by rats (Skinner & Heron, 1937), and two decades later in *Schedules of Reinforcement,* Ferster and Skinner (1957) described drug effects on key pecking under simple as well as complex reinforcement schedules. The field of behavioral pharmacology received a tremendous boost when Joseph Brady persuaded Karl Beyer, vice president for research at Merck Sharp and Dohme, and K. K. Chen, director

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of research at the Eli Lilly Company, to hire John Boren and Thom Verhave, behavior analyst researchers, to set up their behavioral pharmacology laboratories (J. V. Brady, personal communication, February 4, 2010). All told, more than 20 psychologists trained in operant theory and methodology were hired by pharmaceutical companies between 1955 and 1963, most from Columbia and Harvard Universities, which launched the field of behavioral pharmacology (Laties, 2003, p. 245). Their goal was to develop animal laboratory behavioral screening procedures to predict which putative psychotherapeutic drugs would likely be useful in treating people with mental health problems. This work legitimized operant learning procedures in pharmacology and, more broadly, in nascent neuroscience.

The seminal research laying the foundation for much of behavioral pharmacology was done by Peter Dews (1955a, 1955b) at Harvard University and Joseph Brady, Murray Sidman, and their colleagues at Walter Reed Army Research Institute (Brady, 1959; Sidman, 1955). Peter Dews (1955a, 1955b) demonstrated that the behavioral effects of drugs depended on the reinforcement contingencies maintaining operant responding. The central nervous system stimulant d-amphetamine produced increases in responding maintained under fixed-interval (FI) schedules of food reinforcement but decreases in response rate under fixed-ratio (FR) schedules (Dews, 1955b). Similarly, the central nervous system depressant pentobarbital increased responding under FR schedules but decreased responding under FI schedules (Dews, 1955a). The implication of Dew's findings was that the stimulant or depressant properties of drugs did not reside solely within the drug molecules and receptors to which they bound but also depended on the environmental contingencies maintaining behavior (Kelleher & Morse, 1968).

HUMAN BEHAVIORAL PHARMACOLOGY APPLICATIONS

One of the earliest human behavioral pharmacology studies was by Dews and Morse (1958), who examined the effect of d-amphetamine on operant responding by typical adult volunteers. Several years later, Ferster and DeMyer (1961) published an article titled "Increased Performances of an Autistic Child With Prochlorperazine Administration," which had until recently received little attention (Morris & Fouquette, 2009). They used a three-panel matching-to-sample procedure under FR reinforcement schedules to examine effects of an antipsychotic drug. McConahey, Thompson, and Zimmerman (1977) studied the effects of chlorpromazine alone and in combination with a behavior analysis–based token system on the behavior of women with intellectual disability in a public residential setting. They found that the reinforcement contingencies had much more behavioral effect than the medication in regulating both adaptive and maladaptive behavior. Sprague and Sleator (1977), in a widely cited study, investigated effects of the stimulant methylphenidate on the learning and behavior of children diagnosed with attention deficit disorder. They found a peak enhancement of operant learning in children after being given a dose of 0.3 milligram per kilogram of body weight and a decrement in learning at larger doses; social behavior showed the most improvement in children at the larger doses (e.g., 1.0 milligrams per kilogram) that impaired operant learning. Mace et al. (2009) evaluated the evocative effects of four conditions (high- and low-preference activities, low and divided attention) and stimulant medication on the behavior of a 16-year-old boy with attention-deficit/hyperactivity disorder and moderate intellectual disability. Activity engagement, activity changes, inappropriate touching, rude behaviors, and physical aggression all improved with stimulant medication in most conditions, but undesirable behavior was not reduced to acceptable levels in all conditions, suggesting that stimulant medication may be a valuable adjunct to function-based (i.e., behavior-analytic) interventions (see Chapter 15, this volume).

Schaal and Hackenberg (1994) promoted an understanding of drug effects in humans in terms of the functional consequences of behavior in a behavior-analytic framework. Crosland et al. (2003) analyzed differential effects of risperidone on the behavioral functions of challenging behavior in an adult and in a child diagnosed with autism. The subjects were exposed to multielement functional analysis conditions each day, with risperidone and placebo alternated in a double-blind fashion. The adult participant's self-injury appeared more responsive to the medication than did his aggression. In a related study, Zarcone et al. (2004) conducted a functional behavioral analysis of circumstances associated with challenging behavior among 13 individuals with intellectual and developmental disabilities, using an analogue measurement procedure. The functional analysis results yielded information about the degree to which challenging behavior was maintained by attention, avoidance or escape from demands, or internal stimulatory consequences (also called *automatic reinforcement*). With that information in hand, they then evaluated the effects of risperidone. Ten subjects were responsive to the medication. Seven of these individuals exhibited behavior that was not socially motivated, as identified through pretreatment functional analysis. The problem behavior of the remaining three individuals who responded to risperidone was reduced specific to the function originally identified in the pretreatment analysis (i.e., escape or avoidance), which suggests that for approximately one quarter of people receiving risperidone, the medication effects depend on the social consequences maintaining their challenging behavior.

EXPERIMENTAL SUBSTANCE ABUSE RESEARCH

Joseph Brady's University of Maryland behavioral pharmacology laboratory was the *sine qua non* of interdisciplinary research environments, and Brady was the master of integrative strategic thinking. Brady surrounded himself with some of the brightest up-and-coming psychologists as well as established psychologists, such as Charles B. Ferster, Louis R. Gollub, Stanley Pliskoff, Charles R. Schuster, Jack D. Findley, and me. In this heady research environment, Bob (Charles R.) Schuster and I conducted one of the first studies of an animal model of opiate addiction using rhesus monkeys as subjects (Thompson & Schuster, 1964). Reinforcement schedules, stimulus control procedures, and other typical contingency manipulations affected drug-maintained behavior in ways that were largely indistinguishable from behavior maintained by other consequences (Pickens & Thompson, 1968; Schuster & Thompson, 1969). In a recent review article, Balster, Walsh, and Bigelow (2009) wrote, “Thompson and Schuster's textbook [*Behavioral Pharmacology* (1968)] offered the first comprehensive explanation of the application of behavioral pharmacology to the study of drug abuse” (p. 135).

These and subsequent studies suggested that understanding addiction required explication of the relationships among a drug's biochemical and physiological effects and their interaction with reinforcement contingencies. Numerous studies have demonstrated that when most drugs are self-administered by laboratory animals, those agents bind to specific brain receptors that mediate the reinforcing effect of the drug. If those neurochemical receptors are blocked by an antagonist medication, the drug no longer serves as a reinforcer, and previously drug-maintained operant behavior extinguishes (Yokel, 1987; see also Volume 1, Chapter 23, this handbook).

Addiction, however, does not reside solely in drug receptor binding, a concept that had been a precept in most of pharmacology. Whether drug administration serves as a maintaining event also depends on the nature of the contingency relationship between responses and their consequences. Spealman (1979) trained squirrel monkeys to self-administer cocaine under a variable-interval 3-minute reinforcement schedule. Concurrently, the monkeys could extinguish (for 1 minute) a red light signaling the availability of the self-administered cocaine by pressing a second lever under a FI 3-minute schedule of reinforcement. That is, termination of the stimulus indicating that cocaine could be self-administered was available under a separate schedule. The monkeys reliably terminated the opportunity to self-administer cocaine under the fixed-interval schedule and continued to self-administer cocaine under a variable-interval schedule at other times, a counterintuitive finding. Although self-administered cocaine maintained operant responding, whether stimulus conditions associated with cocaine self-administration maintain responding depends on the specific contingencies.

Performance in these animal models is highly predictive of which newly developed drugs are mostly likely to have addictive properties in people (Ator & Griffiths, 2003; Higgins, Heil, & Lussier, 2004; Meisch, 2001; Vanderschuren & Everitt, 2005). As a consequence, operant drug self-administration procedures are now required as part of the approval process by the U.S. Food and Drug Administration and are used worldwide to screen for the abuse liability of newly developed drugs.

SUBSTANCE ABUSE TREATMENT

Applied behavior analysis and behavioral pharmacology have merged in the development of substance abuse treatments. Contingency management of substance abuse capitalizes on clinically relevant reinforcers by arranging a contingency between drug abstinence and reinforcers such as small increases in methadone dose and take-home doses of methadone (Stitzer & Vandrey, 2008). Larger magnitude reinforcers such as money or vouchers exchangeable for goods and services were shown to further improve abstinence outcomes (see review in Chapter 19, this volume). Voucher procedures have been applied across substance use disorders and treatment environments, which has led to their adoption in clinical practice settings (Balster et al., 2009).

Behavioral economics has provided a theoretical framework for reevaluating substance abuse treatment. In behavioral economics, reinforcers are treated as commodities, and the amount of behavior required to obtain those commodities is the price. *Unit price* refers to the behavior necessary to obtain one unit of the reinforcer, and this price may vary with changing circumstances (e.g., the availability of drugs). Outcome measures such as response rate, which had yielded previously unpredictable results, become understandable when constraint on drug consumption is quantified as unit price (e.g., DeGrandpre, Bickel, Hughes, Layng, & Badger, 1993). Other useful economic concepts include quantifying the effects of constraint on demand for drugs as price elasticity (the degree to which demand falls off as unit price increases) and understanding interactions between drugs in terms of economic substitutes and complements: As the unit price of a reinforcer increases and consumption decreases, consumption of a substitute reinforcer increases, and consumption of a complement reinforcer decreases (Bickel, Marsch, & Carroll, 2000; see Chapter 8, this volume).

Delay discounting explains how reinforcers lose value as the time to their anticipated delivery is increased (Bickel & Marsch, 2001). Delay-discounting procedures have been used in several studies to provide a better understanding of how changes in reinforcer magnitude and delay of reinforcement affect the choice to use drugs and the efficacy of nondrug reinforcers designed to reduce drug taking (e.g., Roll, Reilly, & Johanson, 2000). Individual differences among subjects in delay-discounting behavior have been used as experimental measures of impulsivity, providing a quantitative context for choice behavior (Balster et al., 2009).

NEURORECEPTOR-MEDIATED INTERNAL STIMULI

Evidence that internal stimuli could serve discriminative stimulus functions, much as lights or tones in a traditional operant paradigm, emerged in the 1970s. Schuster and Brady (1971) brought a lever-pressing operant of rhesus monkeys under the stimulus control of the intravenous infusion of epinephrine. Responses produced food reinforcement under a fixed-ratio schedule after epinephrine infusion but produced no programmed consequences after a saline infusion. The monkeys lever pressed reliably only after epinephrine infusion and rarely after the saline infusion. The interoceptive stimulus events after epinephrine binding to alpha and beta adrenergic receptors (increased heart rate, blood pressure) set the occasion for lever pressing reinforced by food.

In later studies, other researchers demonstrated that a wide variety of drugs produced internal states that could reliably serve discriminative stimulus functions (Thompson & Pickens, 1971). Many drugs used to treat mental health problems (including some drugs that are addictive) bind to the same chemical receptors in the brain as do naturally occurring neurotransmitters and have discriminative stimulus properties (Society for Stimulus Properties of Drugs, 2009). Laboratory studies have indicated that animals can reliably respond discriminatively to the effects of drugs that mimic normal brain chemical transmitter function. Not only do animals respond discriminatively to the consequences of a drug's binding to one brain chemical receptor type versus another (e.g., dopamine vs. GABA), they can also distinguish between effects of dosages of the same drug and corresponding internal stimulus states. Animal laboratory drug discrimination procedures were applied to human research as well (Preston, Bigelow, Bickel, & Liebson, 1987), making it possible to examine the relation of subjective to discriminative effects of drugs (Balster et al., 2009; Preston & Bigelow, 1991).

ESTABLISHING OPERATIONS: FOOD MOTIVATION

Neuropeptide Y (NPY) is an endogenous peptide that strongly induces food intake. In an effort to measure food motivation produced by NPY, Jewett, Cleary, Levine, Schaal, and Thompson (1995) measured break points under a progressive ratio 1 (PR 1) reinforcement schedule using rats as subjects. Under this schedule, the number of responses required to obtain a 45-milligram food pellet increased by one lever press after each successive reinforcer (i.e., 1, 2, 3, . . .). The break point is the number of responses emitted to obtain the last reinforcer before the rat pauses for more than a specified interval. One might think of it as the highest price the rat is willing to pay to obtain food. As such, break point is considered a measure of reinforcing efficacy or motivational strength of the food reinforcer. NPY (0.3–10 micrograms) significantly increased break point to levels comparable to those produced by 36 to 48 hours of food deprivation. Although insulin (3–8 units per kilogram) and 2-deoxyglucose (150–250 milligrams per kilogram) also increased food intake, neither increased break points to levels produced by NPY or food deprivation. These data suggest that NPY may change the value of food in ways that cannot be accounted for by changes in insulin, glucose levels, or intracellular glucoprivation.

The effect of NPY on the behavior and food intake of food-satiated rats was examined under three different food availability conditions (Jewett, Cleary, Levine, Schall & Thompson, 1992). Food was available during times when rats normally do not eat under either an FR or an FI reinforcement schedule or it was freely available in the bottom of the cage. Forty responses were required for each 45-milligram food pellet under the ratio schedule (FR 40) and for the first response to occur 15 seconds after the previous reinforcement under the interval schedule (FI 15 seconds). NPY (5 micrograms) significantly increased food intake under all conditions and increased food-reinforced responses under the FR and FI schedules. NPY's effect on food intake was greatest when food was freely available, and its effect was least for rats working under the schedule requiring the most effort (FR 40). NPY substantially increased food-maintained behavior and is a potent inducer of food intake even under conditions in which considerable effort is required to obtain food. The conditions under which food is made available can dramatically alter NPY's effect on the temporal pattern of food-maintained responding, feeding, and latency to eat.

In a third study, we wondered whether the interoceptive feeling state associated with NPY was similar to being food deprived (hungry; Jewett, Schaal, Cleary, Thompson, & Levine, 1991). Rats rapidly learned to press the appropriate lever during training sessions in which they learned to discriminate NPY from saline. NPY discrimination was dose dependent. NPY's discriminative stimulus properties were compared with those of two doses of peptide YY and 24 and 48 hours of food deprivation, conditions that also increase feeding. Both doses of peptide YY generalized to NPY, supporting previous findings that peptide YY has effects similar to NPY. Although food deprivation increased feeding in a manner similar to NPY, food deprivation did not result in NPY-appropriate responding in the discrimination task, which suggests that the mechanism underlying increased food-maintained responding by NPY is not the same as that associated with food deprivation (hunger).

Holsen et al. (2005) examined functional magnetic resonance imaging (fMRI) of neurotypical normal-weight children and youths before and after eating a meal. Visual food stimuli increased activation in the amygdala, medial frontal and orbitofrontal cortex, and insula in the premeal condition; no regions of interest responded in the postmeal condition. These results closely parallel previous findings in adults (Führer, Zysset, & Stumvoli, 2008). In addition, Holsen et al. found evidence for habituation to food stimuli in the amygdala in the premeal session. These findings provide evidence that normal patterns of neural activity related to food motivation begin in childhood. In a subsequent study, Holsen et al. (2006) studied brain activation patterns among individuals with Prader-Willi syndrome (PWS), a chromosome 15 disability associated with extreme appetite and obesity. Food is one of the most salient motivators for people with PWS. Subjects with PWS and control subjects were presented with food and non–food-related stimuli in the fMRI scanner both before and after eating a standardized meal. Pictures of food, animals, and blurred control images were presented in a block design format during acquisition of fMRI data. In the control (non-PWS) group, viewing food pictures before a meal increased activity (relative to postmeal data) in the amygdala, orbitofrontal cortex, medial prefrontal cortex, and frontal operculum. In comparison, the group with PWS exhibited greater activation to food pictures in the postmeal condition compared with the premeal condition in the orbitofrontal cortex, medial prefrontal cortex, insula, hippocampus, and parahippocampal gyrus. These results point to distinct neural mechanisms associated with hyperphagia in PWS. After eating a meal, the PWS group showed hyperfunction in limbic and paralimbic regions that drive eating behavior (e.g., the amygdala) and in regions that suppress food intake (e.g., the medial prefrontal cortex).

TREATMENT OF SELF-INJURIOUS BEHAVIOR

Operant principles and methods have been applied for improving skills and reducing behavioral challenges of people with intellectual and developmental disabilities, first in institutional settings (e.g., Thompson & Grabowski, 1972) and later in schools and in families' homes (e.g., Thompson, 2007a). Among the conditions most successfully treated with applied behavior-analytic strategies has been self-injurious behavior (Iwata, Dorsey, Slifer, Bauman, & Richman, 1994; Iwata, Pace, Kalsher, Cowdery, & Cataldo, 1990). Particularly difficult-to-treat cases of self-injurious behavior, in which attention or escape from task demands is not a primary motivator, have posed a challenge to practitioners of these behavior-analytic techniques. In the course of developing practical solutions to this problem, the drug self-administration work that Schuster and I did (Schuster & Thompson, 1969; Thompson & Schuster, 1964) laid the foundation for research designed to develop a new treatment for self-injury by individuals with autism and related developmental disabilities. Cataldo and Harris (1982) proposed the possibility that some forms of self-injury were maintained by endogenous opioids that were released during self-injury. We suspected they were right and hypothesized that self-injurious behavior, such as head hitting or hand biting, released beta endorphin that bound to the mu opiate receptor, thereby serving as a reinforcer, much as endogenous morphine had reinforced lever pressing leading to morphine infusion to laboratory monkeys (Schuster & Thompson, 1969; Thompson & Schuster, 1964). A substantial basic neuroscience literature suggests this analysis is plausible (Stein & Zöllner, 2009). We reasoned that if people engaging in self-injury were treated with a medication that blocked the opiate receptors, then the self-injurious behavior should undergo extinction. In an initial study, Bernstein, Hughes, Mitchell, and Thompson (1987) evaluated the effects of an opiate antagonist on severe self-injurious head banging by a young man with severe intellectual disability and autism symptoms. Self-injury ceased during opioid antagonist treatment. In a subsequent study with oral naltrexone, a potent opioid antagonist, Thompson, Hackenberg, Cerutti, Baker, and Axtell (1994) found that self-injury directed at some body sites (frontal and temporal head regions, radial region of the wrist, and proximal and medial phalanges of the index finger) were selectively reduced by naltrexone among eight adults with chronic self-injury. Sandman, Hetrick, Taylor, and Chicz-DeMet (1997) demonstrated the degree to which self-injury reduced by naltrexone was correlated with the amount of increase in plasma beta-endorphin after self-injury, consistent with our hypothesis. Thus, it appears that self-injury is multiply maintained, often by attention and escape from task demands but also at times by the release and binding of endogenous opioids to the brain's opiate receptors (Thompson, Symons, Delaney, & England, 1995).

EARLY INTENSIVE BEHAVIORAL INTERVENTION IN AUTISM AND SYNAPTOGENESIS

In 1987, Ivar Lovaas published a landmark article demonstrating that approximately half of a group of children diagnosed with autism functioned intellectually within a typical range and were integrated in regular education after 3 years of intensive behavior therapy for 40 hours per week (Lovaas, 1987). Numerous subsequent studies have had approximately the same outcomes (e.g., Remington et al., 2007; Sallows & Graupner, 2005). As important as these remarkable improvements in the lives of children with autism truly are, the findings have raised the question of why half of the children show these striking changes and the other half show modest improvements. For the past 7 years, I have directed community home-based behavior therapy services for young children with autism spectrum disorders, and I have been struck by the marked differences between responders and nonresponders to intensive early behavior therapy. Thompson (2005) suggested that this difference is due to the possibility of experience-dependent synaptogenesis compensating for the deficits among rapid-learning children and a different mechanism underlying the autism symptoms among slow-learning children or nonresponders.

This is more than theoretical speculation. Substantial research has indicated that synapse formation can be activity dependent (Cohen-Cory, 2002; Grossman et al., 2003; Jontes & Smith, 2000). Errors in brain development in some human disabilities are associated with insufficient activity-dependent retraction of dendritic spines (Boulanger & Shatz, 2004). Dendritic spines are the locus on brain neurons where synapses are formed. Nonfunctional dendritic spines are excessively long and fail to convey synaptic currents from the head of the spine to the dendrite (and cell body) to which the extralong spine neck is attached. In normal brain tissue, dendritic spines change continuously through typical use and disuse. The spines contract with mechanisms similar to muscle: actin and myosin. Early disuse could reduce expression of the molecules needed for spine contraction, which is required to make the spine functional. By identifying the genes that produce the proper amount of substrate required for dendritic spine contractions that are only turned on by performing specific tasks, one has a more complete account of how synapse formation does or does not occur.

To the degree that functional behavior analysis procedures promote discriminative responding that can only be accomplished by causing release of neurotransmitters in cells within structures that are synaptically deficient, one system, the four-component behavioral operant (establishing operations, discriminative stimuli, conjoint mediating events, and maintaining consequences), interacts with another functional system (synaptogenesis). The promotive effect of operant experience on synaptogenesis does not imply that the four-component operant is reduced to synaptogenesis. Rather, it suggests that a conjoint mediating event (synapse formation and consolidation) becomes a component of the four-component operant. The point of contact between the two systems is the activity-dependent release of neurotransmitters that promotes synapse formation.

Although one need not refer to correlated brain changes (synaptic-reinforced mediating events) to conduct early intensive behavioral intervention with young children with autism, failing to do so leaves unanswered the question, "Why do some children greatly benefit from early intensive behavioral intervention and others do not?" Those who do not benefit equally from early intensive behavioral intervention may have damage to some of the same brain structures, but the damage may have been produced by a different mechanism, one that is not amenable to amelioration by forming and consolidating new synapses. Axons could have been misrouted to the wrong structures or receptors necessary for forming synapses could be damaged, as happens as a result of toxin exposure or some genetic defects (e.g., in fetal alcohol syndrome or in GABA receptor gene deletion in PWS; Thompson, 2009). This possibility does not imply that children who are minimally responsive to early intensive behavioral intervention should receive no intervention. However, it suggests that researchers must better understand the mechanisms underlying their disability and determine which intervention strategies are most likely to ameliorate those limitations.

This possibility would be consistent with evidence that reinforced responding in laboratory animals leads to increased synapse formation per cell in rats and monkeys, and when reinforcement is discontinued, the number of synapses declines (Kleim et al., 2002). Morrow et al. (2008) presented evidence of several genetic mutations associated with activity-dependent synaptogenesis defects among individuals with autism, which suggests that a genetic endophenotype may be associated with a synaptic dysfunction, whereas other autism phenotypes may be the result of different mechanisms.

CONSTRAINT-INDUCED REHABILITATION

Studies with squirrel monkeys have revealed that severing a sensory nerve from the hand to the cerebral cortex leads to massive reorganization of the motor areas of the brain corresponding to the hand (Merzenich et al., 1983). If the functional hand was physically constrained and successive approximations of using the other hand were differentially reinforced, recovery of function was much more rapid and the motor cortex showed corresponding changes (i.e., neurogenesis; Taub, 1980). On the basis of this basic animal laboratory research, Edward Taub, Uswatte, and Pidikiti (1999) developed constraint-induced therapy for rehabilitation of people with stroke and individuals with other neurodevelopmental disabilities (see also Volume 1, Chapter 15, this handbook). The technique involves shaping by successive approximations and differential reinforcement for successively larger movements of the impaired hand and arm. A mitten is placed on the functional hand to discourage use of that hand during 6-hour daily therapy sessions. Outcome studies performed from 3 months to 1 year after therapy have yielded statistically and clinically significant improvements in function (Taub, Ramey, DeLuca, & Echols, 2004; Wolf et al., 2008). Liepert et al. (2000) conducted MRI analysis of the amount of gray matter in the outer layers of the brain in patients with stroke who received constraint-induced therapy compared with that of typical stroke rehabilitation controls. Gray matter was increased in the motor regions of the brain for the constraint-induced therapy group, whereas those patients receiving conventional therapy showed no apparent change. This increase in gray matter corresponded to a similar increase in the patients' ability to use an affected arm in daily living.

BRAIN IMAGING AND BEHAVIOR ANALYSIS

Although MRI had been conducted in humans as early as 1967, not until the late 1980s did the first studies emerge showing structural abnormalities among individuals with autism (Courchesne et al., 1989). fMRI revolutionized study of brain function in real time. A research participant is presented with a neutral stimulus while inside the MRI scanner (e.g., a random array of squares of varying darkness) and is then shown a probe stimulus (e.g., the image of a person's face). Brain areas that become more active (are more extensively oxygenated) during and immediately after the probe stimulus presentation than during baseline are assumed to be involved in whatever psychological processes occur when viewing the probe stimuli. To conduct brain imaging with children or people with developmental disabilities who often find it difficult to lie still inside the scanning device, Slifer, Cataldo, Cataldo, Llorente, and Gerson (1993) devised a semiautomated shaping procedure and device to train subjects to lie still within the scanner, which was later refined (Slifer, Koontz, & Cataldo, 2002). The promise of neuroimaging techniques for studying behavior-analytic processes has only recently begun to emerge (Timberlake, Schaal, & Steinmetz, 2005).

Schlund and Cataldo (2005) used functional neuroimaging to study brain activation correlated with presentation of discriminative stimuli. Before neuroimaging, adult human subjects were exposed to three sets of experimental stimuli (Greek letters). Two of the sets were used for operant discrimination training. In the presence of stimuli from the first set, money was delivered after button pressing on a variable-ratio 3 schedule; these stimuli were thus discriminative for a positive reinforcement contingency. In the presence of stimuli from a second set, no money was available, and this state of affairs continued until subjects refrained from button pressing for 10 seconds, at which time the stimulus was terminated. Thus, members of the second set of stimuli were discriminative for a negative reinforcement contingency (removal of a stimulus signaling that money was not available). After the discriminations were acquired, subjects were instructed to view and memorize a third set of control stimuli that were not associated with any operant contingencies; these stimuli were introduced in this way so that they would be familiar during the imaging that was to follow and not produce activation merely because of novelty. Several hours after training, fMRI was performed while subjects viewed discriminative and control stimuli, with stimulus presentations occurring every 6 seconds on average. Significantly more activation was found in frontal and striatal brain regions to both sets of discriminative stimuli relative to control stimuli. Activation increased significantly in the caudate, several frontal regions, and the putamen to discriminative stimuli previously correlated with operant contingencies than with control stimuli not correlated with operant contingencies. Recognition of stimuli previously associated with either instructions or operant contingencies (i.e., discriminative stimuli) generally recruited similar inferior frontal and occipitoparietal regions and right posterior parietal cortex, with the right occipitoparietal region showing the largest effect. These findings suggest that declarative memory processes are involved in human operant behavior (Schlund & Cataldo, 2007).

Using electrophysiological brain recording techniques, Haimson, Wilkinson, Rosenquist, Ouimet, and McIlvane (2009) studied neural processes relating to stimulus equivalence class formation (Sidman, 1994; see Chapter 1, this volume). In an initial study, two types of word pairs were presented successively to typically capable adults. In one type, the words had related usage in English (e.g., *uncle, aunt*). In the other, the two words were not typically related in their usage (e.g., *wrist, corn*). For pairs of both types, event-related cortical potentials were recorded during and immediately after the presentation of the second word. The obtained waveforms differentiated these two types of pairs. For the unrelated pairs, the waveforms were significantly more negative about 400 milliseconds after the second word was presented, thus replicating the N400 phenomenon of the cognitive neuroscience literature. In addition, a strong positive-tending waveform difference poststimulus presentation (which peaked at about 500 milliseconds) also differentiated the unrelated stimulus pairs from the related stimulus pairs. A second experiment examined arbitrary stimulus–stimulus relations established via matching-to-sample training in a stimulus equivalence paradigm. Subjects were experimentally naive adults. Sample stimuli (Set A) were trigrams, and comparison stimuli (Sets B, C, D, E, and F) were nonrepresentative forms. Behavioral tests evaluated potentially emergent equivalence relations (i.e., BD, DF, CE), and the results for all subjects were consistent equivalence classes established by arbitrary matching training. They were also exposed to an event-related potential procedure like that used in Experiment 1, with the nonrepresentative forms that had been comparison stimuli. Some received the event-related potential procedure before equivalence tests, and some received it after. Only those subjects who received event-related potential procedures after equivalence tests exhibited robust N400 differentiation initially. These results suggested that equivalence tests may provide contextual support for forming equivalence classes, including those that emerge gradually during testing. In related work, Barnes-Holmes et al. (2005) have used event-related potentials to examine electrophysiological correlates of semantic categories within stimulus equivalence classes.

CONCLUDING CONSIDERATIONS

I have argued elsewhere that behavioral and brain systems are interacting functional systems (Thompson, 2007b) and that it is a mistake to treat them as alternative competing explanations of important aspects of the human condition. Behavior analysts have profitably studied the role of microstructural, physiological, and biochemical variables as components of three-term operant contingencies, as establishing operations (e.g., hunger) and antecedent stimuli (e.g., subjective feeling states and discriminative stimuli), and as maintaining consequences (e.g., endogenous opioid binding to the mu receptors). A fourth term, *conjoint mediating events,* has now been added between antecedents and consequences, operating in parallel with operant responses. Operant responding that leads to a reinforcing event is called an *effector event* (i.e., an activity of the muscle, gland, or organ or the nerve impulse activating those structures). Neurochemical and microstructural brain changes associated with reinforced responding cannot properly be called effector events because they are not muscular or glandular activities. Instead, they are conjoint mediating events that occur in conjunction with reinforced effector events. For example, rats trained to perform a reaching task followed by positive reinforcement not only displayed an increased percentage of correct responding in motor performance but also developed significantly more synapses per neuron than controls within layer V of the caudal forelimb area. In the absence of reinforcement after execution of the reaching response (i.e., extinction), the number of synapses per cell declines (Kleim et al., 2002). The rats' reaching responses are effector events, and the synaptic changes constitute conjointly strengthened mediating events. Having increased the number of synapses in structures involved in emitting a given response, the probability of recurrence of that response is increased, thereby laying the foundation for later learning and fluency. Future research concerning bidirectionality of gene expression and operant behavioral processes has great promise for providing a more complete account. This evolution of operant theory shows potential for studying important scientific questions at the interface of applied behavior analysis, neuroscience, and genetics.

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CHAPTER 3

ARRANGING REINFORCEMENT CONTINGENCIES IN APPLIED SETTINGS: FUNDAMENTALS AND IMPLICATIONS OF RECENT BASIC AND APPLIED RESEARCH

Iser G. DeLeon, Christopher E. Bullock, and A. Charles Catania

Arranged reinforcement contingencies are by definition contrived, but reinforcement contingencies are ubiquitous. If researchers do not design them, environments will provide them nevertheless.

In this chapter, we focus on how basic and translational research can inform the arrangement of reinforcement contingencies in applied settings. We have restricted our discussion to findings that have found their way into applied arenas in the sense that they have been used to some benefit in arranging practical contingencies or have been replicated with clinical populations. Many other chapters in this handbook are directly concerned with basic and translational research related to arranging reinforcement contingencies (see, e.g., Chapters 5, 7, and 8, this volume). We have tried not to tread too far into areas discussed in greater detail elsewhere in this handbook. Programmed reinforcement contingencies are probably nowhere more common than in arranging instructional contexts for children and for individuals with developmental disabilities, so much of our discussion focuses on these sorts of instructional arrangements.

The chapter is organized into four interrelated sections. Our emphasis is on best practices for applying reinforcement contingencies given what we know from basic research. Consider an educator thinking about how to arrange a reinforcement system in a given context. That individual has numerous decisions to make, including what reinforcer to use and what behavior or aspect of behavior to reinforce, according to what arrangement. Each question corresponds to a term of the three-term contingency or to relations among those terms, and each forms a section of this chapter.

The three-term contingency consists of antecedents, behavior, and consequences. Each term is worthy of consideration. Those antecedents called *discriminative stimuli* are treated in other chapters, so we consider them here only in passing. More crucial to our concerns are (a) the contingencies themselves, often characterized as schedules of reinforcement; (b) the responses targeted by the contingencies; (c) the reinforcers or other consequences arranged for them; and (d) the antecedents, sometimes called *motivational* or *establishing,* that change the effectiveness of consequences as reinforcers or punishers.

Our hypothetical educator may harbor concerns about possible harm stemming from the planned contingency and distress over the possibility that the planned contingency will fail to produce its anticipated outcome. For example, a consequence expected to serve as a reinforcer may instead function as a punisher, or it may not be effective because its application deviated in some way from the planned contingency. Some instances may best be

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understood in terms of deviations from well-established procedures (as in so-called detrimental effects of reward, discussed later in some detail; see also Cameron, Banko, & Pierce, 2001). We examine these and other ways in which reinforcement contingencies can seem to have effects opposite to those intended.

THE CONTINGENCIES: WHICH SCHEDULE SHOULD ONE USE?

A stimulus serves as a reinforcer if, when access to this stimulus is contingent on a response within some class (usually called an *operant class*), responses within that class become more probable because of the contingent production of the stimulus (Skinner, 1938, 1981). The term *reinforcer* identifies a member of such a stimulus class; the term *reinforcement* identifies either the contingency (e.g., "reinforcement was arranged for the child's correct responses") or the changes in behavior produced by the contingency ("reinforcement was demonstrated by the increase in the child's correct responses"). In specifying the reinforcement contingencies for an organism's behavior, researchers must include the context in which the behavior occurred, the operant class involved in the contingency, and the changes in responding that depend on the contingent production of the reinforcer (Ferster & Skinner, 1957). The temporal and behavioral conditions under which reinforcers are delivered have been called *schedules of reinforcement.*

Some Basic Schedules

The simplest arrangement is to reinforce every response; paradoxically, arranging a discrete consequence for each discrete response is sometimes called *continuous reinforcement.* However, both within and outside the laboratory, it is unusual for every response to be reinforced. Environments vary along many dimensions that often make reinforcers only intermittently available. These dimensions determine schedules of reinforcement and include but are not limited to the number of responses, the time when responses are emitted, and the passage of time without responses. We can review only a few basic schedule arrangements in this chapter. The interested reader will find more exhaustive treatments in Ferster and Skinner (1957) and Lattal (1991).

Classifications of schedules often break them down in terms of whether they are based on number of responses (ratio schedules) or on when responses occur (interval schedules), but these are only two of several categories we discuss. For example, reinforcers can be delivered without reference to behavior (e.g., time schedules) or on the basis of temporal spacing of responses (e.g., differential reinforcement of low rates or of high rates). Schedules can also combine different contingencies (as in alternative schedules, in which a reinforcer is delivered if responding satisfies either of two conditions). Table 3.1 summarizes the properties of some basic schedules.

Ratio Schedules

Fixed-ratio schedules. When every response produces a reinforcer in continuous reinforcement, the ratio of responses to reinforcers is fixed and equal to 1; this is a fixed-ratio (FR) 1 schedule. FR schedules deliver a reinforcer after the last of a fixed number of responses. In studies with nonhumans, FR schedules produce responding characterized by a pause at the start of each ratio (i.e., after the prior reinforcer) followed by rapid and fairly constant responding (Capehart, Eckerman, Guilkey, & Shull, 1980; Crossman, Bonem, & Phelps, 1987). The pause typically becomes longer with increases in ratio size (Crossman, 1968) and with increases in alternative sources of reinforcement (Derenne & Baron, 2002).

Overall response rate typically decreases as the FR becomes larger and as responding decreases reinforcers are delivered less often (but see Chapter 8, this volume, for a discussion of a different relation when responding within the current environment is the only source of the reinforcer). These relations are useful in assessing the effectiveness of reinforcers and in developing appropriate treatments. For example, one way to deal with problem behavior once the reinforcers that maintain it have been identified is to increase the amount of behavior required per reinforcer, thereby decreasing response rate and making more socially appropriate responses reinforced on denser schedules more likely. Another way would be to change response allocation by

TABLE 3.1

Basic Schedules

Name and abbreviation	Contingency	Comment
Variable interval (VI); random interval (RI)	*t* seconds, then 1 response	*t* varies; with random intervals, response rate is roughly constant.
Fixed interval (FI)	*t* seconds, then 1 response	*t* constant; generates increasing rates within intervals (scallops).
Variable ratio (VR); random ratio (RR)	*n* responses	*n* varies; high constant rates; large *n* may produce response breaks (strain).
Fixed ratio (FR)	*n* responses	*n* constant; generates postreinforcer pauses and high-rate runs.
Variable time (VT)	*t* seconds	*t* varies; response-independent reinforcers
Fixed time (FT)	*t* seconds	*t* constant; response-independent reinforcers
Continuous reinforcement (FR 1)	1 response	all responses reinforced; sometimes abbreviated *CRF*
Extinction (EXT)	—	Useful term for nonreinforcement even if the response has never been reinforced.
Limited hold (LH)	Reinforcer cancelled if no reinforced response within *t* seconds.	*t* constant if not otherwise specified; LH added to other schedules, cannot stand alone.
Differential reinforcement		
Of low rate (DRL)	*t* seconds without response, then one response	Maintains responding well because slower responding increases reinforcement.
Of high rate (DRH)	1 response within *t* seconds or less of last response	Alternatively, at least *n* responses within *t* s; hard to maintain because reinforcers stop when responding slows.
Of paced responding (DRP)	1 response between *t* and *t*′ seconds of last response	Sets both upper and lower limits on response rates that can be reinforced.
Of other or alternative behavior (DRO or DRA)	*t* seconds without a response	Usually decreases rate of designated response (a negative punishment procedure).

Note. *t* = time. From *Learning* (4th interim ed., Table 10-1), by A. C. Catania, 2007, Cornwall-on-Hudson, NY: Sloan. Copyright 2007 by Sloan Publishing. Adapted with permission.

reducing the required ratio for more socially appropriate alternatives.

Variable-ratio schedules. Variable-ratio (VR) schedules arrange reinforcers for the last of a number of responses that vary from one reinforcer to the next. These schedules characteristically produce high response rates without the postreinforcement pauses seen with FR schedules. A VR schedule is often described in terms of the average ratio, but the particular ratios can make a difference. For example, a VR schedule that involves many short ratios balanced by a few very long ones may support more behavior than one with only a few short ratios balanced by many moderately long ones, even though both have the same mean ratio value.

In laboratory settings, such details can readily be automated, but arranging them in applied settings is often impractical. In general, the advantage of VR over FR schedules is that VR schedules are less likely to produce postreinforcement pauses (Andrzejewski, Field, & Hineline, 2001; Crossman et al., 1987; Mazur, 1983; Schlinger, Blakely, & Kaczor, 1990). Specifying the distribution of the ratios that make up a particular mean VR is important, but the effects of different distributions are likely to be seen only with extended exposure to the schedule. A simple arrangement is to generate a list of integers in an arithmetic progression (e.g., 2, 4, 6, 8, 10, . . .) in which the difference between the values is constant and to then shuffle items in the list. A VR 2 schedule consisting of just three ratios, 1, 2, and 3, qualifies as such a schedule and for some applications may be perfectly adequate (e.g., Foster, Hackenberg, & Vaidya, 2001). With VR schedules based on arithmetic distributions, reinforcement probability increases over successive responses within a ratio, eventually reaching 1.0 for the largest value. To compensate for this, VR progressions can be generated so as to approximate a constant probability distribution (see Catania & Reynolds, 1968; Fleshler & Hoffman, 1962), but contemporary technology often makes random scheduling of ratios more practical. Random-ratio (RR) schedules are a subcategory of VR schedules in which the probability with which a response will be reinforced remains constant over successive responses. Although its mean value can be specified, the maximum ratio value is indeterminate (Sidley & Schoenfeld, 1964). These schedules eschew preset ratios in favor of letting a random generator determine whether the current response should be reinforced; the mean ratio is given by the reciprocal of the probability (e.g., reinforcing responses with a probability of .05 generate an RR 20 schedule). Arranging an RR schedule outside the laboratory is as simple as rolling a die. For example, a six-sided die arranges RR 6 if a response is reinforced whenever the die roll results in a 6. Game stores sell many different-sided dice, ranging from four sides to 100.

Interval Schedules

Fixed-interval schedules. A fixed-interval (FI) schedule delivers a reinforcer contingent on the first response after some constant time period has elapsed. An FI schedule generates positively accelerated response patterns (i.e., the response rate increases as time passes within the interval, producing a visual pattern generated by cumulative records that is sometimes called *scalloping*; Ferster & Skinner, 1957). Pauses after reinforcement and the pattern of responding over time in the interval depend on the duration of the FI (e.g., Capehart et al., 1980). Prolonged exposure to an FI schedule sometimes produces pauses followed by high rates. Because responding is sensitive to time within the interval, FI schedules have often served as baselines for studying temporal discrimination (e.g., Machado, Malheiro, & Erlhagen, 2009).

Variable-interval schedules. Variable-interval (VI) schedules similarly arrange reinforcers contingent on the first response after a specified time, but the time varies from one reinforcer to the next, and these schedules generally produce moderate and relatively stable rates of responding with few pauses. The function relating response rate to VI reinforcement rate is negatively accelerated, that is, the higher the reinforcement rate is, the smaller the increment in response rate produced by a given added increment in reinforcement rate will be. Similar to VR schedules, VI schedules are identified by mean interval. They have been widely used in behavioral research because variables that affect response rate (e.g., drug administration) produce relatively small changes in the rate at which reinforcers are delivered.

As with VR schedules, the distribution of intervals can be generated in different ways. This distribution can affect VI responding, so it should be selected with care (Catania & Reynolds, 1968). For example, increasing shorter intervals relative to moderate ones will make response rates soon after the last reinforcer higher than at those occurring at later times. With a finite distribution of intervals, the probability that a response will be reinforced increases as time passes in the interval. The Fleshler and Hoffman (1962) formula for approximating a constant probability distribution is one way to address this concern, but the variant known as random interval (RI) avoids the problem because no longest interval can be specified (Millenson, 1963). In RI schedules, reinforcers are arranged (or set up) by repeatedly sampling probabilities (e.g., every 10th of a second). Even with low probabilities, the probability that a reinforcer has been set up grows as time passes without a response. The mean time between reinforcers is determined by the ratio t/p, where t is the cycle duration and p is the probability; for example, a sampling probability of .005 with cycles of 0.1 seconds will yield VI 20 seconds.

Arranging Schedules for Human Behavior: Some Caveats

Basic research on reinforcement schedules has typically been conducted with readily repeated responses of brief duration, such as pigeons' key pecks or rats' lever presses. These responses are free operant in the sense that they are unconstrained except by the contingencies that maintain them. The organism is not removed from the situation between responses, nor is the opportunity to respond constrained by removing relevant stimuli, as in procedures based on discrete trials. Only some applied settings allow comparable contingencies. Laboratory procedures may maintain schedule contingencies over extended durations and many thousands of responses, whereas applied interventions are typically more limited in scope. Getting dressed, grooming oneself, toileting, or completing an arithmetic problem all take time, and these and many other tasks intrinsically involve trials or quasitrials. Expecting contingencies arranged for such complex response classes to produce effects similar to those seen in the research laboratory is therefore often unrealistic. Furthermore, the feasible range of schedule parameters in applied settings is typically much narrower than that explored with nonhuman organisms.

Another problem with extrapolating from basic schedule research with nonhumans to human behavior is that humans engage in verbal behavior. The contingencies involved in maintaining verbal behavior, especially verbal behavior that involves descriptions of one's own behavior, interact with nonverbal behavior in complex ways, especially because verbal behavior itself is also subject to contingencies. Thus, human performances maintained by schedules often look very different from nonhuman performances maintained by equivalent schedules (e.g., Catania, Lowe, & Horne, 1990; Catania, Matthews, & Shimoff, 1982; Shimoff & Catania, 1998). A detailed account is beyond the scope of this chapter, but it is reasonable to say that in verbally competent humans (children perhaps as young as 5 years as well as adults), it is often easier to shape verbal behavior related to performance than to directly shape the performance itself.

Other Schedules With Applied Relevance

Along with the fundamental ratio and interval cases, basic researchers have examined performances under an enormous variety of alternative and combined schedule arrangements. Many complex schedules have yet to be used in applied work, but descriptions of these schedules can be found in Table 3.2. We consider a few cases with established utility in applied settings, either as direct arrangements of applied reinforcement contingencies or as tools for the analysis of applications, with others introduced elsewhere when relevant.

Differential reinforcement schedules. Differential reinforcement simply means that some responses are reinforced and others are not. Differential reinforcement can target various properties of response classes, including topography, temporal parameters (e.g., response duration), magnitude, and so forth. In applied settings, differential reinforcement is perhaps most common in shaping (see Shaping and Percentile Schedules section) and in treating problem behavior. Some varieties of differential reinforcement are used to reduce problem behavior. Differential reinforcement of zero or other behavior (DRO) targets the absence of responding or unspecified alternative responding by delivering reinforcers after some time without a response. Differential reinforcement of low rate (DRL) and differential reinforcement of high rate (DRH) target responses based on temporal parameters (Staddon, 1965). In DRL schedules, a response is reinforced only if a minimum time has passed since the last response (the interresponse time). These schedules maintain responding at a low rate, which is useful, for example, when responding occurs under appropriate conditions but needs to be slowed down (e.g., as in overly rapid eating; Wright & Vollmer, 2002). In DRH schedules, a response is reinforced if a minimum number of responses is emitted within a given time (e.g., within the past *t* seconds), thus ensuring that responding persists at a pace not otherwise sustained in the absence of the contingency. This is useful, for example, when responding occurs under appropriate conditions but too slowly (e.g., as in excessively slow eating; Girolami, Kahng, Hilker, & Girolami, 2009).

Differential reinforcement of alternative behavior reinforces members of one response class while extinguishing responses outside that class. In contrast to DRO, DRA reinforces a specific alternative response rather than just any other response,

TABLE 3.2

Schedule Combinations

Schedule	Definition	Example
Multiple	A during S^A alternates with B during S^B.	mult VI EXT: VI (A) during red (S^A) alternates with EXT (B) during green (S^B).
Mixed	A and B alternate but without correlated stimuli.	mix DRL FI: DRL (A) alternates with FI (B), both during blue.
Chained	During S^A, completing A produces S^B; during S^B, completing B produces reinforcer.	chain VR FR: completing VR (A) during blue (S^A) produces yellow; completing FR (B) during yellow (S^B) produces food.
Tandem	Without correlated stimuli, completing A produces B and completing B produces reinforcer.	tand VR DRH: Completing VR (A) produces DRH (B), and completing DRH produces food, both during yellow.
Concurrent	A operates for one response; B operates for another response.	conc VI VI: One VI (A) operates for presses on left button; another VI (B) operates for presses on right button.
Conjoint	A and B operate at the same time but independently for a single response (as with concurrent schedules but without different responses).	conjt VI avoidance: VI (A) and avoidance (B) operate simultaneously for presses on a single key.
Second order	Completing A is reinforced according to B (reinforcing the second-order schedule according to C creates third-order schedule, etc.).	FI (FR): Successive FRs (A) are treated as response units reinforced according to an FI schedule (B).
Alternative	Reinforcer depends on completing either A or B.	altern VR VI: Responding is reinforced on satisfying either VR (A) or VI (B) contingency, whichever occurs first.
Conjunctive	Reinforcer depends on completing both A and B.	conjunc FR FI: Responding is reinforced on satisfying both FR (A) and FI (B) contingencies.
Interlocking	Reinforcer depends on completing some combined function of A and B.	interl FR FT: Responding is reinforced when the sum of responses (A) plus elapsed seconds (B) reaches some constant value.
Progressive	Some schedule parameter changes systematically over successive reinforcers or blocks of reinforcers.	progressive FI: After every *n*th reinforcer, time in seconds is added to the value of an FI.

Note. For convenience, we define each case in terms of just two arbitrary component schedules, A and B, but combinations can include any number of components. S = stimuli; superscripts identify the schedule, A or B, each one accompanies. DRH = differential reinforcement of high rate; DRL = differential reinforcement of low rate; EXT = extinction; FI = fixed interval; FR = fixed ratio; VI = variable interval; VR = variable ratio. From *Learning* (4th interim ed., Table 11-1), by A. C. Catania, 2007, Cornwall-on-Hudson, NY: Sloan. Copyright 2007 by Sloan Publishing. Adapted with permission.

thereby increasing the rate of some responses while reducing that of others. For example, if problem behavior is maintained by a certain class of reinforcers, therapists can establish and strengthen a more appropriate response that produces that same reinforcer. Differential reinforcement in the treatment of problem behavior is discussed in Chapter 14 (this volume), so we consider such schedules only when relevant. A special case of differential reinforcement called *shaping* (of successive approximations to some target response) is described in more detail later.

Response-independent (time-based) schedules. Fixed-time (FT) and variable-time (VT) schedules deliver stimuli known in other contexts to be reinforcers solely on the basis of time, independent of responding. Technically speaking, FT and VT are not reinforcement schedules at all, in that they do not arrange reinforcers contingent on responding. For a stimulus to be considered a reinforcer, it must increase the responding on which it is contingent. The stimuli typically chosen in FT and VT schedules, however, are those previously shown to be effective reinforcers (Lattal, 1972; Zeiler, 1968).

FT and VT schedules are useful for studying the variables that reduce response probability when a response contingency is weakened. For example, Madden and Perone (2003) superimposed FT schedules onto ongoing VI schedules, thus weakening the contingency between the target responses (moving a joystick) and delivery of the reinforcers (points later exchangeable for money). They observed that target responses declined relative to when the responses were maintained on the VI schedules alone or when the supplemental reinforcers were delivered only immediately after the target responses. These schedules are easy to implement and reduce response probability without removing access to reinforcers, so they have become commonplace in applied studies and clinical practice for treating problem behavior. Time-based schedules obviate difficulties associated with other forms of intervention. For example, when problem behavior is reduced by FT schedules, it is not accompanied by the extinction bursts that sometimes accompany extinction in isolation (Vollmer et al., 1998; although note that time-based schedules may enhance response persistence if they increase the overall rate of reinforcement under given conditions; see Nevin, Tota, Torquato, & Shull, 1990; Chapter 5, this volume). Time schedules have also provided baselines against which to assess effects of other contingencies. Because they involve reinforcer delivery but no response–reinforcer contingency, they are useful in separating effects of the contingency from effects of mere reinforcer presentations (Rescorla & Skucy, 1969; see also Thompson, Iwata, Hanley, Dozier, & Samaha, 2003, on the relative utility of time-based and other schedules as control procedures in applied settings).

Concurrent schedules. Schedules are called *concurrent* when two or more operate simultaneously and independently for different response classes (e.g., consider the different contingencies operating for presses on a doorbell button and those on a nearby elevator button). Concurrent schedules, essential to studies of choice and relative response allocation (Fantino & Romanowich, 2007; Fisher & Mazur, 1997; Herrnstein, 1961; Reynolds, 1963), have often been used in applied settings to gauge the relative effectiveness of reinforcers varying along dimensions such as rate, quality, and magnitude. We couch our discussions of preferences and the effectiveness of reinforcers in terms of response allocation under concurrent schedules.

Delay Contingencies

Reinforcement contingencies are most effective when reinforcers are delivered promptly after target responses, but within limits delayed reinforcers also sustain responding. In fact, earlier responses that preceded the reinforced response usually also participate in the effects of the reinforcer. Analyses in terms of delay contingencies can therefore reveal important properties of schedules. Much of the terminology of reinforcement schedules was developed ad hoc as different contingencies were invented and explored experimentally (Skinner, 1938, 1956), and other systems were developed to organize schedules more systematically (e.g., Schoenfeld & Cole, 1972). It may be most appropriate, however, to categorize schedules not on the basis of their formal properties but rather in terms of interactions between responses and contingencies as schedules take hold of behavior.

When a reinforcer follows a response, its effect depends on its relation not only to that response but also to other responses preceding it; all are followed by the reinforcer even though only the last response produced it and even though the delay between response and reinforcer is longer for earlier than for later ones (Catania, 1971; Dews, 1962; see Catania, 2005, for a theoretical treatment). Such relations are important in applied as well as basic settings, especially when inappropriate as well as appropriate responses can follow each other closely in time. For example, according to this analysis if an error is immediately followed by a reinforced correct response in an instructional procedure, that reinforcer will probably strengthen the error along with the correct response at least temporarily.

Consider how the delayed reinforcement of earlier responses within a reinforced sequence affects the interaction between responses and reinforcers. When reinforcers depend on number of responses, the responses per reinforcer remain constant, but increased response rate will mean that all responses are more closely followed by the reinforcer (shorter delays); these shorter delays will strengthen responding still further and so lead to higher and higher response rates. When reinforcers depend on a response at the end of a given interval, however, the time to the reinforcer remains constant, which means that if response rate increases, the responses per reinforcer will also increase. At the same time, some responses late in the interval will be closer to the reinforcer, but earlier ones will still be far from it (long delays). The strengthening effects of the reinforcer will be balanced by its increasing cost and will therefore lead to more moderate rather than higher response rates. These dynamics are described in more detail in Catania (2005).

Other aspects of delayed reinforcement merit attention. Mathematical models of self-control describe how delay influences reinforcer effectiveness (Grace, 1999; Mazur, 1987), which generally decreases monotonically as delay increases. Candidate delay functions include hyperbolic and exponential decay, for which best fits depend on both data and such details as how reinforcer effectiveness is measured (see Volume 1, Chapter 14, this handbook; Chapters 7 and 8, this volume). Within some range of delays, delayed reinforcers can maintain responding in both humans and nonhumans (e.g., 30 seconds in both Okouchi, 2009, and Lattal & Gleeson, 1990). Contingencies operating across delays may also explain why some interventions seem ineffective despite being well constructed. For example, a 5-second DRO contingency may strengthen responses other than the target response, but if the target response often occurs just 6 seconds before reinforcer delivery, it may be maintained by delayed reinforcement.

Schedule Contingencies and Resistance of Behavior to Change

Schedule contingencies not only determine the rate at which target responses are maintained, to the extent that they also produce different rates of reinforcement, they may also determine response fragility or resistance to change (Nevin & Grace, 2000; see also Chapter 5, this volume). These two measures, response rate and resistance of responding to change, are independent properties of behavior. Depending on schedules and other variables, some high response rates can be very fragile (as in rapid extinction after very large FRs), whereas some low rates can be extremely persistent (as in extended extinction responding after DRL reinforcement). Resistance to disruption by procedural changes is a property of behavior revealed not only during extinction but also during other interventions, such as introducing reinforcers for alternative responses.

Some properties of schedule contingencies themselves, along with such dimensions as reinforcer magnitude, length of exposure to a schedule, and motivational variables, may determine resistance to change. For example, if a ratio schedule maintains high response rates and rates decrease for any reason (e.g., a minor beak injury in a pigeon), reinforcers will be produced less often, thus reducing response rates still further and satisfying the contingency less often still, and so on. Nevertheless, ratio responding might recover because responses will eventually produce reinforcers in ratio schedules even if they are emitted slowly. With DRH, slow responding never produces reinforcers, so responding may not recover at all after a period of slow responding. With interval schedules, however, reinforcers become available at particular intervals, so changes in response rate over a large range may only slightly affect how often reinforcers are delivered. Thus, more stable responding tends to be maintained by interval schedules rather than by ratio schedules. With DRL, reinforcers depend on a response preceded by some minimum time without responding, so reinforcers are typically produced more often as response rate decreases, making DRL responding durable over time (Ferster & Skinner, 1957).

THE RESPONSE: WHAT RESPONSE SHOULD ONE REINFORCE?

Agents responsible for arranging reinforcement contingencies generally enter the instructional context with an idea of which response class they want to strengthen. Those response classes, however, may vary in terms of how well established they are, ranging from not at all established to fully established but unmotivated. How then does one determine whether the lack of responding is a skills deficit (the individual simply has not learned the skill) or a performance deficit (the skill is intact, but the person is unmotivated to respond under appropriate stimulus conditions)? Performance deficits can be accurately distinguished from skills deficits in an educational context on the basis of whether supplemental reinforcement for correct responding rapidly increases accuracy (Lerman, Vorndran, Addison, & Kuhn, 2004). If an appropriate reinforcement contingency very rapidly eliminates a performance deficit, the skill must already have been learned. Skills deficits, however, may require different interventions depending on the learner's abilities and whether some of the skill has already been learned.

Shaping and Percentile Schedules

In shaping, some property of responding is gradually changed by differentially reinforcing successive approximations to target behavior (Catania, 2007; Skinner, 1951). Shaping is used when target responses are sufficiently complex or of sufficiently low probability that they are unlikely to be emitted without this gradual intervention. Numerous instances in the applied behavior-analytic literature involve a great variety of response properties (e.g., voice volume, Fleece et al.,1981; drug abstinence, Dallery & Glenn, 2005; communication responses, Lerman, Kelley, Vorndran, Kuhn, & LaRue, 2002).

In practice, shaping is often (and properly) viewed as an art form (Lattal & Neef, 1996), mastered only by those who have had many opportunities to try it. Shaping is often contingency shaped, in the sense that the most effective shaping typically arises from the shaper's substantial experience with shaping rather than from learning some specific set of rules (Galbicka, 1994). One sometimes overlooked contribution of basic research to shaping is the percentile schedule, used as a systematic way to decide which approximations to reinforce and how often to do so. Percentile schedules deconstruct shaping into its components by specifying changes in reinforcement criteria (e.g., based on latency, effort, location, or duration) as behavior moves toward the shaping target (Galbicka, 1994). To begin, some sample of behavior is collected (e.g., the last 100 responses). The behavior analyst then specifies that to be reinforced, the next response must fall into some portion of the sampled distribution (e.g., above the 70th percentile). For example, in the shaping of more fluent reading of words on a computer screen, the next correct reading would be reinforced only if its speed (1 per latency) exceeded the speed at the 70th percentile of the last 100 speeds sampled. After this reading is reinforced (or not), its speed is added to the sample, and the oldest one in the distribution is dropped. Thus, the reinforcement criterion changes as progress is made toward the target. This elegant approach to shaping also allows the behavior analyst to specify reinforcement probability in advance throughout shaping. In this example, the probability that the next response will exceed the 70th percentile value and therefore be reinforced is roughly 30%.

Although easily managed with computer programs in a laboratory, percentile schedules demand moment-to-moment analysis of data and so are often impractical in applications. Nevertheless, their effects can be approximated by some rules of thumb, such as mainly reinforcing responses closer to the target than any others emitted so far. Such rules must be tempered. The skilled shaper, for example, relaxes that rule if many responses have been unreinforced, so as not to jeopardize the progress so far with de facto extinction.

Clinically and educationally relevant responses have been shaped with percentile schedules, such as increased durations of work on academic tasks, with percentile criteria based on the preceding 20 task engagements (Athens, Vollmer, & St. Peter Pipkin, 2007), and longer durations of eye contact for participants diagnosed with fragile X syndrome, with a percentile schedule based on just the three immediately preceding responses (S. S. Hall, Maynes, & Reiss, 2009).

Novel Responding and Response Diversity

Shaping often hones response topography by differentially reinforcing increasingly narrow forms of the response. Ultimately, response diversity decreases. Paradoxically, shaping appears to work because the extinction component of shaping increases response variability (see Neuringer, Kornell, & Olufs, 2001), thereby permitting novel response forms to contact reinforcement. Applied researchers have taken advantage of the variability induced by extinction to establish such new behavior as untrained topographies of toy play (e.g., Lalli, Zanolli, & Wohn, 1994).

Response diversity has become increasingly important in the study and practice of behavior analysis through the prominent and widespread use of behavior-analytic principles and procedures in early intervention for autism spectrum disorders (see Chapter 12, this volume). A core diagnostic symptom of autism spectrum disorders is restricted and repetitive behavior, characterized by "stereotyped patterns of behavior, interests and activities" (American Psychiatric Association, 2000, p. 71). As has long been understood, variability is a property of responding sensitive to reinforcement (Page & Neuringer, 1985; see Volume 1, Chapter 22, this handbook, for an extended treatment). A common arrangement to increase response variability is a type of percentile schedule called the *lag-reinforcement schedule.* The lag is the number of responses separating the current response from an earlier one like it. For example, repeatedly playing the same note on a piano is highly stereotyped because zero different notes are played between the most recent note and the prior one (lag 0). However, playing 10 different notes before getting back to the first one (lag 10) is much more variable. In a lag *x* reinforcement schedule, the current response is reinforced if it differs from the last *x* preceding responses along the specified dimension. The variability of pigeons' sequences of key pecks was maintained with variability requirements as stringent as lag 50 (Page & Neuringer, 1985).

As with percentile schedules in general, lag reinforcement schedules have increasingly been used in applied contexts to increase diversity in a variety of response classes, including toy play such as building block structures (Napolitano, Smith, Zarcone, Goodkin, & McAdam, 2010), verbal responses to social questions (Lee, McComas, & Jawor, 2002; Lee & Sturmey, 2006), and selection of classroom activities (Cammilleri & Hanley, 2005). Applied studies typically use lag requirements that are fairly easy to meet, including lag 1 schedules, in which reinforcement is contingent on a response that differs only from the immediately preceding one (Lee & Sturmey, 2006). Even with such minimal lag contingencies, novel responding and creativity can be enhanced through differential reinforcement.

Reinforcement Within Prompted Response Sequences

"Pure" shaping of entirely novel responses, or shaping without prompts, may be relatively uncommon in applied settings. When skills deficits are apparent, instructional or motivational strategies will often involve some verbal instruction and prompting with regard to the target. For example, in what is often termed *least-to-most prompting,* the instructor delivers verbal instruction on the correct response (e.g., "Turn the handle to the left") followed by modeling a correct response. If these fail to evoke correct behavior, they are often followed by physical guidance in completing of the response. Such sequences raise the question of where in the sequence the reinforcer should be delivered. If only unprompted correct responses are reinforced, the instructor risks delivering infrequent reinforcers, because unprompted correct responses are rare. At the other extreme, reinforcing responses that are correct only because they have been physically guided risk strengthening behavior that will not generalize beyond the learning setting because it consists only of passive compliance with prompts.

Applied researchers have approached this issue by varying the reinforcement delivered after prompted versus unprompted responses. For example, during nondifferential reinforcement within instructional trials, both praise and high-quality food reinforcers were contingent on either prompted or unprompted responses (Karsten & Carr, 2009). During differential reinforcement, when praise alone was contingent on prompted responses, whereas high-quality food reinforcers were contingent on unprompted responses, unprompted responding generally increased. When independent accurate responding is promoted by arranging higher reinforcement rates for independent than for prompted responses (e.g., Olenick & Pear, 1980; Touchette & Howard, 1984), independent responding is more rapidly acquired, and prompts can be minimized or made less intrusive (see a review by Vladescu & Kodak, 2010).

So-Called Hidden Costs of Reward

Perhaps the most vehemently debated aspect of reinforcement has its source in the social psychology literature on the so-called hidden costs of reward, also referred to as the *overjustification effect* or the *detrimental effect of extrinsic reward on intrinsic motivation* (Lepper, Greene, & Nisbett, 1973). Some of these critics have cautioned educators against using reinforcement, suggesting that it reduces creativity and intrinsic motivation (e.g., Kohn, 1993; Pink, 2009). For example, if someone who enjoys completing puzzles for their own sake receives extrinsic rewards for doing so, the claim is that the intrinsic interest in completing puzzles will decline once the extrinsic reward is withdrawn (Deci, 1971; Greene & Lepper, 1974). These accounts are based on research that has shown variable and inconsistent effects, typically of small magnitude (Cameron et al., 2001; Cameron & Pierce, 1994; Eisenberger & Cameron, 1996). That has not dissuaded its proponents from citing it in support of arguments against reinforcement and other behavior-analytic tools.

An intrinsic reward is naturally related to the responses that produce it, whereas an extrinsic one is arbitrarily related to them (e.g., music is an intrinsic outcome of playing an instrument; the music teacher's praise is extrinsic to the playing). Events presumed to be effective reinforcers because their function has been instructed have been called *extrinsic reinforcers* (as when a child is told it is important to earn good grades), but labeling them is no guarantee they will be effective. This matters because the literature on the detrimental effects of extrinsic reward rarely includes studies using reinforcement as defined in behavior analysis. Often, the rewards are not delivered contingent on the relevant behavior, and no evidence shows that their delivery increases responding (see Dickinson, 1989). Nonetheless, despite much contrary evidence, the argument that extrinsic outcomes undermine the effectiveness of intrinsic ones persists and still affects the use of operant contingencies in schools and other settings (Cameron et al., 2001; Cameron & Pierce, 1994; Eisenberger & Cameron, 1996). Here we merely point out why the issue is irrelevant to our applied concerns.

One fairly consistent finding is that overjustification effects are more pronounced when behavior already occurs at a high level without extrinsic reward (Cameron et al., 2001; Deci, Koestner, & Ryan, 1999). These findings are significant because applied behavior analysts do not ordinarily design interventions to deliver reinforcers contingent on behavior that already occurs frequently. In fact, arranging such contingencies may well reduce responding, even during reinforcement, let alone during a postreinforcement period. The initial conclusion might be that the stimulus is not a reinforcer, but this reduction in responding might happen for many reasons even though the stimulus may be effective as a reinforcer under other circumstances. For example, when intrinsic outcomes are powerful, separate and less preferred added reinforcers may interfere with the effectiveness of the original reinforcer (Roane, Fisher, & McDonough, 2003). Alternatively, the delivery of some reinforcers may require time and effort (handling costs; Madden, Bickel, & Jacobs, 2000) in preparing them for consumption or, through the discriminative property of reinforcers, may evoke other responses that interrupt or are incompatible with the behavior being measured (Frank-Crawford et al., 2012). Either process can decrease responding relative to responding in situations in which it is uninterrupted by reinforcer delivery.

Another issue is equating reinforcers with bribes in the literature on hidden costs of reward (Kohn, 1993), but the bribes invoked by critics of the practice of reinforcement seldom involve direct effects of reinforcers. There are good reasons to advise parents against specifying consequences when asking a child to do something (e.g., "Put away your toys and you can play a computer game"), but those reasons are different from those offered by the critics. When parents complain that their child only cooperates with requests when there is an immediate and explicit payoff, stimulus control is the problem: The child has learned to comply only when the parent makes an adequate offer.

A bribe specifies behavior and its consequences, so offers of bribes set the occasion for particular contingencies. The frequently bribed child soon discriminates between bribes being in effect and bribes not being in effect. The bribing parent will eventually discover that the child complies only when bribes are offered. If initiation rests with the briber, one should not expect the child to initiate appropriate behavior. In such cases, reinforcement merely strengthens compliance with bribes, which is hardly a desirable way to use reinforcers. The parent who has heard the language of bribes applied to the practice of reinforcement and is reluctant to reinforce a child's appropriate behavior must learn not to accompany the contingencies with statements of those contingencies (which is probably also good advice for teachers and clinicians).

The claimed deleterious effects of extrinsic reward are only inconsistently demonstrable and are small and transient when found (Cameron et al., 2001; Cameron & Pierce, 1994); problems are more likely when extrinsic rewards are not contingent on performance than when they are (Eisenberger & Cameron, 1996). The alternative, to forgo reinforcers in cases in which no intrinsic reinforcers maintain the behavior of concern, is unacceptable. To assume that students with limited skills will work effectively without positive outcomes is irresponsible (Heward, 2005). Extrinsic reinforcers can build behavior that will allow students to contact the natural contingencies generated by successful performance.

THE REINFORCER: WHICH REINFORCER SHOULD ONE CHOOSE?

In clinical interventions, the aspect of reinforcement contingencies perhaps least informed by basic research is that of which stimulus will be delivered contingent on the target behavior. Basic research has used varied stimuli shown to have reinforcing effects, including water, food, heat, access to females, escape from time out, electrical brain stimulation, and all manner of pharmacological agents (Crawford, Holloway, & Domjan, 1993; Jenkins & Moore, 1973; Katz, 1979; Wasserman, Hunter, Gutowski, & Bader, 1975). The sustained value of food and other primary reinforcers is ensured by such operations as maintaining an organism at 80% of its free-feeding weight; such motivating operations cannot be used with humans in most applied settings.

The effectiveness of a reinforcer depends on the behavior allowed or occasioned by that reinforcer. Food, for example, allows eating, and food deprivation affects the effectiveness of a food reinforcer by raising the probability of eating given food. In general, a particular consequence serves as a reinforcer if the behavior it occasions is restricted below its baseline rate (Timberlake & Allison, 1974). Furthermore, its effectiveness varies with the probability of the to-be-reinforced response relative to the response occasioned by the reinforcer. For example, whether a rat's eating will be reinforced by an opportunity to run on a wheel or wheel running will be reinforced by an opportunity to eat can be determined by varying the relative probabilities of wheel running or eating by depriving the organism of access to, respectively, a wheel or food.

Implementing the motivational antecedents that will make a stimulus reinforcing is often impracticable in applied settings. Much effort has therefore been expended to develop, refine, and validate methods for predicting which stimuli will function as reinforcers. These methods are reviewed extensively elsewhere (e.g., Cannella, O'Reilly, & Lancioni, 2005; Hagopian, Long, & Rush, 2004; Logan & Gast, 2001), so in what follows we provide only a brief overview of some procedures. Later, we describe a potential model for efficiently and effectively selecting reinforcers.

Preference and Reinforcer Assessment

Preference assessment. Procedures to identify items that may serve as effective reinforcers involve multiple steps, often starting with nominations from the people themselves or, when individuals may not be reliable self-informants, perhaps because of limited abilities, from parents, teachers, or other caregivers. With several instruments, surveys, and checklists developed for this purpose (e.g., Fisher, Piazza, Bowman, & Amari, 1996; Sarafino & Graham, 2006), the process could end here, but teachers, caregivers, and students (with or without disabilities) are not always accurate in suggesting which stimuli will function effectively as reinforcers (Cote, Thompson, Hanley, & McKerchar, 2007; Green et al., 1988; Northup, 2000). Thus, the next step is often to assess preferences among items systematically with a stimulus preference assessment. Such assessments may repeatedly present an entire array of items simultaneously (DeLeon & Iwata, 1996; Windsor, Piche, & Locke, 1994), or they may present the items one at a time (e.g., Pace, Ivancic, Edwards, Iwata, & Page, 1985) or in pairs (Fisher et al., 1992).

The most selected items are then taken as those most likely to be effective reinforcers. Assessment variants measure the duration of engagement with items when presented individually (DeLeon, Iwata, Conners, & Wallace, 1999) or simultaneously (Hanley, Iwata, Lindberg, & Conners, 2003; Roane, Vollmer, Ringdahl, & Marcus, 1998), on the assumption that behavior occasioned by the item will predict its effectiveness as a contingent reinforcer.

Presentations of single stimuli are perhaps simplest and permit evaluation of any number of items, but they may be more likely to produce false positives because such low-effort responses may inaccurately predict reinforcing effects under more stringent response requirements or with different response classes. Presenting items together, thereby allowing choices on each trial, may provide more sensitive indices of preference (Fisher et al., 1992), but counterbalancing presentations of multiple items makes assessments far more time consuming. For example, assessing all pairs of just 16 items (as in Fisher et al., 1992) requires 120 trials and so can take upward of 2 hours. When all stimuli are presented simultaneously, either on every trial (Windsor et al., 1994) or without replacement across trials (DeLeon & Iwata, 1996), more stimuli can be evaluated in less time. Thus, such procedures are useful for frequent assessment, but the number of items in a single array may be limited by how well learners can scan and select items within large arrays. Furthermore, assessments with all items available on each trial (Windsor et al., 1994) or continuously available during duration-based assessments (Roane et al., 1998) may yield engagement with just a single item, providing reasonable certainty that the selected item is the most highly preferred but little information about the potential utility of other items.

Reinforcer assessment. In research, but perhaps less so in practice, preference assessments are often followed by what has come to be known as *reinforcer assessment.* The rationale is that stimulus preference assessments may predict viable reinforcers, but the effort of simply engaging an item is so small that items thus chosen may not function as reinforcers for more effortful and perhaps more meaningful target behavior. Thus, the validity of stimulus preference assessment outcomes is often tested by delivering the selected items contingent on a unique response and determining whether contingent delivery increases responding above baseline levels.

When multiple items are assessed as reinforcers with either preference or response rate measures, stimuli from the top end of a preference hierarchy generally engender more responding than stimuli from the middle or bottom ends of the hierarchy (e.g., Carr, Nicolson, & Higbee, 2000). Similarly, with concurrent contingencies, arranging continuous access to high-preference stimuli for staying on one side of a room and continuous access to items selected less often for standing or sitting in another part, more time was typically spent in the areas associated with high-preference stimuli (Piazza, Fisher, Hagopian, Bowman, & Toole, 1996).

Concurrent choices, as in Piazza et al. (1996), are highly sensitive to differences in reinforcer effectiveness. The interactions that make such differences easy to see with concurrent responding, however, may not operate when reinforcers are contingent on single responses. For example, when differently preferred stimuli were concurrently available to children with intellectual and developmental disabilities contingent on separate responses, the most preferred stimuli supported higher response rates than did the less preferred ones (Roscoe, Iwata, & Kahng, 1999). When the less-preferred stimuli were tested individually, however, most children responded at rates indistinguishable from those maintained in the concurrent arrangement by the high-preference stimuli. Thus, although some stimuli may draw higher levels of response allocation than others in concurrent arrangements, it does not follow that the less-preferred stimuli will not serve as reinforcers.

These results are again reminders that researchers cannot base reinforcer assessments on response rates but must also consider the resistance of responding to change, as when introducing reinforcement of an alternative response. These are different properties of behavior that depend on different variables. We speak of preference in terms of relative rates of responding, as in accounts of matching within concurrent performances (Fisher & Mazur, 1997; Killeen, 1972), whereas we speak of reinforcer effectiveness in terms of resistance to change or, in Nevin's account (e.g., Nevin, 1992), momentum. Given a choice, $1,000 would ordinarily be preferred to $500, but if either were the only consequence arranged for a single response, distinguishing between the reinforcing effectiveness of these two amounts would probably be difficult. Someone who could earn money by pressing a button would probably press as quickly for $500 as for $1,000. In fact, presses that produced only $10 or $100 might be as rapidly emitted. Yet if the button stopped working, pressing that had produced just $10 would probably cease more quickly than pressing that had produced far larger amounts.

Two reinforcers that generate similar rates with modest response requirements may not support such rates under more stringent contingencies, as when PR schedules require more responding with each successive reinforcer. The PR break point is the schedule requirement beyond which responding is no longer maintained. Across participants with intellectual disabilities, preference assessments were well correlated with PR break points (DeLeon, Frank, Gregory, & Allman, 2009). In educational settings, perhaps the most important question is whether one reinforcer or reinforcement arrangement results in more rapid mastery of relevant tasks than another.

Reinforcer Choice and Variation

Successful reinforcer assessments predict the reinforcing stimuli that can immediately be integrated into instructional or work contexts. Why then should researchers be concerned with whether lower ranking stimuli function effectively as reinforcers? One answer is that having a variety of effective stimuli available is useful. Both humans (e.g., Tiger, Hanley, & Hernandez, 2006) and nonhumans (e.g., Catania & Sagvolden,1980) prefer conditions with opportunities to choose among contingent reinforcers (free choice) over those with only a single contingent reinforcer available (no choice), even with reinforcers matched across free- and no-choice conditions. Reinforcing effects can be enhanced by providing reinforcer choice or variation, as when constant versus varied edible reinforcers were contingent on correct responding during an academic task with three individuals with developmental disabilities (Egel, 1981; see also DeLeon et al., 2001; Graff & Libby, 1999, for other methods of stimulus variation). During constant reinforcement, the same edible was contingent on every correct response, but during varied reinforcement, successive reinforcers varied over three different edibles. Responding decreased during constant reinforcement but not during varied reinforcement. Reinforcer choice or variation does not, however, always enhance performance (e.g., Geckeler, Libby, Graff, & Ahearn, 2000; Lerman et al., 1997), so researchers need to know more about the cost–benefit trade-offs of providing choice.

Praise and Social Reinforcers

Praise and other forms of social reinforcement offer advantages relative to the edible and tangible stimuli often used in nonhuman research. For example, praise is more natural and less intrusive in classrooms, need not interrupt ongoing responding, can be delivered with little delay, obviates the cost and effort required to deliver other reinforcers, and may be less subject to satiation effects. Some have argued that praise can increase intrinsic interest in the task (Eisenberger & Cameron, 1996). Still, praise is not universally effective, particularly in special-needs populations (e.g., Lovaas et al., 1966; Stahl, Thomson, Leitenberg, & Hasazi, 1974), so it should be assessed along with other potential consequences before incorporation into a program.

Unlike tangible stimuli, social reinforcers are not easily tested with preference assessments because they may be difficult to represent in a stimulus array. A child may easily understand that reaching for or pointing to a food item on a table results in delivery of that item, but what can the child with limited abilities reach for to produce the attention of a caregiver? Preference assessments have thus resorted to names or pictures of options in efforts to include social stimuli and other less tangible outcomes (Conyers et al., 2002; Graff & Gibson, 2003; Kuhn, DeLeon, Terlonge, & Goysovich, 2006). Such procedures are sometimes effective, but relative to separate assessments with tangible stimuli, the success of those using verbal or pictorial representations varies across individuals. For example, verbal, pictorial, and tangible preference assessments with children capable of complex visual and auditory discriminations provide better predictors of reinforcers than similar assessments conducted with children who have less sophisticated abilities (Conyers et al., 2002). More promising, brief reinforcer assessments have sometimes conveniently demonstrated which social consequences can be effective reinforcers, as when 1-minute test periods were each associated with 2 seconds of different potential social reinforcers, such as praise, tickles, or head rubs (Smaby, MacDonald, Ahearn, & Dube, 2007).

Effects of praise may vary as a function of its content and context. Some texts suggest that praise should mention specific praiseworthy aspects of the praised performance. For example, rather than delivering a generic "well done," a teacher might specify exactly what was well done, as in "You did an excellent job applying your multiplication facts." Although this recommendation is supported by face validity and conventional wisdom, few studies have actually evaluated it, and behavior-specific praise has sometimes been confounded with other interventions such as error correction (e.g., Fueyo, Saudargas, & Bushell, 1975). A related issue is whether praise targets personal attributes or performance. Compared with children praised for their intelligence, fifth graders asked to complete a moderately easy task and praised for their effort were more likely to choose more difficult tasks that would allow them to display new abilities than easier tasks that might display their intelligence (Mueller & Dweck, 1998). Furthermore, children praised for effort were rated as more persistent in performing later, more difficult tasks and rated those tasks as more enjoyable.

Token Reinforcement Systems

Preference and reinforcer assessments have been used primarily with special populations for whom it might otherwise be difficult to identify, a priori, effective reinforcers. Other populations enter applied settings or experimental environments with readily established reinforcers. Monetary rewards come immediately to mind, as do various other consequences available in organizational settings for typically developing humans. In educational and other therapeutic contexts, token reinforcement systems often approximate the mechanics of monetary reward. When primary reinforcers cannot be easily arranged, token reinforcement takes advantage of conditional reinforcers correlated with other, more effective reinforcers.

Mechanics of token reinforcement. In token reinforcement, responses produce tokens according to a token production schedule (e.g., in FR 10, every 10th response produces a token; in FI 1 minute, the first response after 1 minute produces a token). The token may then be exchanged for other reinforcers (as when money put in a vending machine produces a can of soda). The exchange between tokens and these other reinforcers is also determined by a schedule. In other words, the behavior that produces tokens according to one schedule is embedded in a higher order schedule that specifies when tokens are exchanged for other reinforcers (Bullock & Hackenberg, 2006; Byrd & Marr, 1969; Hackenberg, 2009; Webbe & Malagodi, 1978; Yankelevitz, Bullock, & Hackenberg, 2008).

As with behavior maintained by simple schedules of reinforcement, behavior maintained by token reinforcement schedules is sensitive to schedule type and to schedule contingencies for both token production and token exchange (Foster et al., 2001; Hackenberg, 2009). Interactions between token production and token exchange schedules have been studied in some detail with pigeons (Bullock & Hackenberg, 2006); for example, increasing the token exchange ratio sometimes dramatically reduced the responding maintained by token production (see also Foster et al., 2001).

Behavior maintained by token reinforcement schedules is functionally comparable to behavior maintained by monetary consequences (Pietras, Brandt, & Searcy, 2010), and as with loss of money, contingent token loss can serve as a punishing aversive consequence that reduces responding (Raiff, Bullock, & Hackenberg, 2008).

In one variation of a token reinforcement schedule, pigeons could exchange individual tokens or could accumulate up to 12 tokens (Yankelevitz et al., 2008). Consider individuals who are paid after completing some task and can either immediately spend their earnings at a store or can accumulate more earnings. If they must walk to the store, whether they spend immediately or save will depend on how far they must walk. The longer the walk, the greater the cost of exchange or, here, the cost in travel time. Analogously, pigeons accumulated multiple tokens rather than spending them immediately when exchange requirements became large.

Advantages of token reinforcement. Token reinforcement schedules have been used extensively in clinical settings, probably because they have several practical advantages over the primary reinforcers for which they can be exchanged. For example, they are often more portable and durable than other tangibles, and unlike edibles they are reusable. Perhaps most important, they maintain their effectiveness in the face of circumstances that diminish the effectiveness of many other reinforcers, including the stimuli for which they can be exchanged. Increasing the number of commodities that tokens can buy makes responding relatively independent of motivational variations. For example, money can buy food but will typically remain an effective generalized reinforcer even after a satiating meal. The reinforcers produced by the tokens still matter, however. When children with intellectual disabilities could exchange tokens for only a few types of reinforcers, token production depended on the highest valued reinforcer available and varied with the satiation level for the reinforcers for which they were exchanged (Moher, Gould, Hegg, & Mahoney, 2008).

Studies of temporal discounting have suggested that as a function of delay, the reinforcing effectiveness of money (a generalized conditioned reinforcer) is discounted, or decreases less steeply, than that of directly consumable reinforcers (Charlton & Fantino, 2008; Estle, Green, Myerson, & Holt, 2007; Odum & Rainuad, 2003). That is, as delay increases, money retains its value to a greater extent than food. Charlton and Fantino (2008) suggested that it may be useful to conceptualize reinforcers as falling along a continuum with directly consumable and metabolized reinforcers that are steeply discounted by delay at one end and reinforcers such as money that are later exchangeable for other reinforcers at the other. Although largely untested in applied settings, the implication for arranging reinforcement contingencies is that token reinforcers may better maintain their effectiveness despite delays than the directly consumable reinforcers for which they may be exchanged.

REINFORCER EFFECTIVENESS AND THE RELATIVITY OF REINFORCEMENT

Reinforcer effects must be assessed within the context in which they are embedded. One cannot talk about reinforcer efficacy in absolute terms. For example, if one reinforcer is preferred to another, it does not follow that the latter will be ineffective. Reinforcers preferred in one context may not be preferred in others. The effectiveness of reinforcers fluctuates across time, so allowing choices among reinforcers and variations within classes of reinforcers makes it more likely that some will remain effective across a range of circumstances. We now consider how the context in which reinforcers are delivered can influence their effectiveness.

Unit Price and Behavioral Economics

Reinforcers that support small response units may not support larger ones. The relation between a response and its reinforcing consequences is analogous to that between money and what it purchases. For that reason, some response–reinforcer contingencies have been described in the language of economics. Behavioral economics has interpreted reinforcement effects in terms generally available within U.S. culture and has sometimes highlighted relations that might otherwise have been overlooked. Economics, however, analyzes systems created by human cultures, and for our purposes the behavioral relations underlying those systems are more fundamental. In any case, behavioral economics is treated in more detail in Chapter 8 (this volume), so we restrict ourselves here to a few examples bearing specifically on reinforcer effectiveness.

The behavior that produces a reinforcer can be regarded as its unit price, given by the ratio of cost (responses or effort required) to benefit (amount of reward or commodity). Demand for a commodity is typically measured in terms of consumption (reinforcers produced) as a function of unit price. The economic law of demand states that as the unit price for a commodity increases, demand for (consumption of) that commodity decreases. Furthermore, the effect of price changes on consumption varies across commodities. Two commodities may be consumed equally at low cost, but if price increases for both, consumption of one may fall off more rapidly than consumption of the other (consumption of the first is said to be more elastic). For example, rhesus monkeys consumed roughly equal numbers of saccharin water and food pellet reinforcers when either required 10 responses (FR 10), but with larger ratios, consumption of saccharin water declined far more rapidly than that of food pellets (Hursh, 1991). With small response requirements, these reinforcers seemed equivalent, but increases in their unit prices demonstrated that one supported more behavior than the other over a range of conditions.

The function relating reinforcer effectiveness to response requirement or cost is relevant in applied educational or therapeutic contexts because learners must sometimes be weaned from artificially rich contingencies to more stringent response requirements. To establish appropriate performance rapidly as treatment begins, the therapist often starts with reinforcing every response. For reasons of time, effort, or resources, maintaining such rich contingencies is usually impractical, so once the response class is established, the change agent often moves quickly toward increasingly intermittent reinforcement schedules.

Here the distinction between open and closed economies has special relevance. This distinction is based on whether current reinforcers are also available outside of the experimental or therapeutic context (open economy) or are available only within that context (closed economy). For example, teachers who offer reinforcers readily available outside of the classroom may have less effective reinforcers on hand than those who dispense reinforcers available nowhere else. Thus, whether an economy is open or closed may determine how more stringent response requirements influence reinforcer consumption. Other things being equal, consumption declines more rapidly with cost increases in open than in closed economies (e.g., G. A. Hall & Lattal, 1990; Hursh, Raslear, Bauman, & Black, 1989; Roane, Call, & Falcomata, 2005), so reinforcers may remain more effective during schedule thinning if they are not also available in other contexts.

Reinforcer consumption across increasing response requirements is also affected by what is concurrently available. In a classic example, rats' consumption of mixed-diet pellets decreased both with increasing ratio requirements and with the availability of either sucrose or mixed-diet pellets contingent on a separate response (Lea & Roper, 1977). Similar effects have been demonstrated among people with intellectual disabilities (DeLeon, Iwata, Goh, & Worsdell, 1997; Tustin, 1994). The implication is that during schedule thinning in academic or therapeutic contexts, reinforcer efficacy may vary as a function of other and perhaps unscheduled sources of reinforcement. For example, off-task behavior is an oft-reported problem in school settings, presumably because other forms of stimulation compete with the reinforcers maintaining on-task behavior (as when talking to a peer competes with attention to classroom assignments). Teacher praise and attention for on-task behavior may displace behavior maintained by peer attention if both teacher and peer attention are delivered on dense schedules, but the shared properties of teacher and peer attention may make the effects of teacher attention fragile if on-task behavior is later reinforced according to an increasingly lean schedule. It may be beneficial if reinforcers arranged for targeted behavior are dissimilar from other reinforcers concurrently available.

Detailed treatments of trade-offs between costs and benefits as analyzed in terms of unit price have shown that decreased responding as a function of increasing costs demanded by practical considerations may be avoided by increasing benefits to offset increases in response requirements (see Delmendo, Borrero, Beauchamp, & Francisco, 2009; Madden et al., 2000; Madden, Dake, Mauel, & Rowe, 2005; Roane et al., 2003). Such relations have implications for applications in both academic and work settings but are beyond the scope of this chapter.

Incentive Shift Phenomena

As already noted, value is not an inherent property of a stimulus; it depends on the context in which that stimulus is delivered. Perhaps no preparation has shown this more clearly than the incentive shift experiments of Perone and colleagues. For example, rat or pigeon behavior well maintained by small reinforcer magnitudes is disrupted when randomly alternating with larger reinforcer magnitudes (Perone & Courtney, 1992). This disruption occurs after a large reinforcer when a stimulus signals that the upcoming reinforcer will be small. Animals stop responding for disproportionately long periods in such rich-to-lean transitions, compared with other transitions such as lean to lean. When pigeons could escape from the stimulus signaling the upcoming reinforcer amount, they did so predominantly at rich-to-lean transitions (Perone, 2003). In other words, these transitions became aversive. The paradox is that they were aversive only in contexts in which smaller reinforcers alternated with larger ones. Access to lean schedules of reinforcement or to small reinforcer magnitudes is a reinforcer when the alternative is no reinforcers or equivalent reinforcers, but if juxtaposed with richer schedules or larger reinforcers, these conditions become aversive. Similar effects have been observed in individuals with intellectual disabilities (Williams, Saunders, & Perone, 2011).

Motivational Antecedents

Motivational events are those that alter the reinforcing effectiveness of stimuli and thus the likelihood of the responding those stimuli maintain (Laraway, Snycerski, Michael, & Poling, 2003; Michael, 1982). Some examples involve learned behavior (e.g., one's car breaking down increases the reinforcing effectiveness of tools required to fix the car), but the simplest cases involve relative states of deprivation or satiation with respect to that stimulus. For example, water deprivation increases both the effectiveness of water as a reinforcer and responding that has in the past led to water (e.g., searching for a water fountain). Deprivation and satiation effects have been demonstrated in preference assessments using food (Gottschalk, Libby, & Graff, 2000) or access to activities (McAdam et al., 2005) with both typically developing children and individuals with intellectual disabilities. Relative to control conditions, both food and activities were generally selected less often after their continuous access and more often after their prolonged unavailability.

Preference assessment hierarchies have limitations. Despite conventional wisdom, do not assume that reinforcers lose their effectiveness after meals or other events sometimes regarded as satiating, and when concerned about potential satiation effects, test for individual differences because such effects may be highly idiosyncratic. For example, for adults with intellectual disabilities, deprivation had more consistent effects than satiation with food assessments conducted before or after meals and with music and attention assessment conducted after continuous access or restricted access (Vollmer & Iwata, 1991; see also Zhou, Iwata, & Shore, 2002). Significantly, in many tests satiation did not reduce responding, suggesting that reinforcers often remain effective in applied settings under conditions conventionally thought to make them ineffective.

Changes in Preference and Effectiveness Across Extended Time and Experience

Stimulus preferences and reinforcer effectiveness are dynamic across time and experience. The motivational effects just discussed may influence reinforcer effectiveness locally but may not be relevant to the long-term effectiveness of a reinforcer. Studies that examined consistencies of preference assessments across months (Ciccone, Graff, & Ahearn, 2007; Zhou, Iwata, Goff, & Shore, 2001) have shown that consistency may be highly idiosyncratic—preference hierarchies for some individuals remain fairly stable, whereas for others those at one time are very different from those at a later time. What sorts of experiences with relevant stimuli might produce such altered preferences? Two possible variables are the events correlated with stimulus access and their overall accessibility from day to day. Given that mere interaction with stimuli can have effects, even how often an activity is chosen in a preference assessment might make a difference. For example, preference for an activity may be enhanced when engaging in that activity is reinforced after it has been chosen (Hanley, Iwata, & Lindberg, 1999) or when already preferred stimuli are delivered according to response-independent schedules during engagement in that activity (Hanley, Iwata, & Roscoe, 2006; Hanley, Iwata, Roscoe, Thompson, & Lindberg, 2003). Unrestricted daily access to an activity (open economy) reduces its selection during preference assessment (Hanley et al., 2006). Moreover, effects of assessment procedures are often transient, as when effects of unrestricted daily access are quickly reversed after daily access is restricted (closed economy).

Stimulus preference may also be influenced by the effort historically required to produce those stimuli. In an effect called *within-trial contrast* (Zentall & Singer, 2007), "reinforcers that follow relatively aversive events become preferred over those that follow less aversive events" (Singer, Berry, & Zentall, 2007, p. 275). One example sometimes discussed in terms of work ethic is that stimuli reliably preceded by more effortful behavior may become preferred over those preceded by less effortful behavior (e.g., Clement, Feltus, Kaiser, & Zentall, 2000; Friedrich & Zentall, 2004; Kacelnik & Marsh, 2002; Klein, Bhatt, & Zentall, 2005; but see Arantes & Grace, 2008; Vasconcelos & Urcuioli, 2009; and Vasconcelos, Urcuioli, & Lionello-DeNolf, 2007, for replication failures).

Work ethic effects have usually been studied when responses involving different efforts produce the same reinforcer but are associated with distinct stimuli (e.g., with pigeons, when high-effort and low-effort responses each produce the same amount of grain, one option signaled by one key color and another signaled by a different key color). Preference is shown for discriminative stimuli associated with higher effort requirements, such as the key color historically associated with greater effort. From an applied standpoint, a more pertinent question is whether these effects occur with reinforcers that are, themselves, qualitatively distinct (e.g., high-effort responding produces one reinforcer, whereas low-effort responding produces another). Some evidence has suggested that the effort historically required to produce a distinct reinforcer is positively related to the subsequent effectiveness of that reinforcer in both humans (Birch, Zimmerman, & Hind, 1980; DeLeon et al., 2011) and nonhumans (Johnson & Gallagher, 2011).

These findings may have implications for reinforcer selection in applied settings. First, reinforcers for which more effort is required may remain more durable relative to those that require less effort. It is therefore important to know whether interventions based on response-independent reinforcer deliveries are likely to lose their effectiveness more rapidly than those in which reinforcers are earned (notice that this distinction is similar to one we invoked in interpreting the hidden costs of reward and related misunderstandings of the properties of reinforcement). Another research question is whether weak reinforcers can be strengthened by manipulating response requirements, thereby expanding the range of available reinforcers. Consider also the implications for situations in which one may want to shift preferences. It might seem odd to want to do this, but in some circumstances it may prove beneficial. For example, many children display extreme food selectivity, including both those who are typically developing and those who have developmental delays. From a nutritional perspective, this often favors undesirable food choices that contribute to obesity, diabetes, and other adverse health outcomes. Manipulations of effort expenditure have helped to enhance the value of lower calorie foods in mice (Johnson & Gallagher, 2011). Can an understanding of the variables that determine preferences help researchers to shift preferences away from less nutritious foods and toward more nutritious ones (see, e.g., Horne et al., 2004; Lowe, Horne, Tapper, Bowdery, & Egerton, 2004)?

CONCLUSION: WHY DID THE SO-CALLED REINFORCEMENT CONTINGENCY NOT WORK?

In our clinical work, parents, teachers, and other caregivers have occasionally reported, "I tried positive reinforcement but it didn't work. The behavior didn't change." In formal terms, of course, this never happens. Reinforcement is defined by its effect on the response on which it is made contingent. What those educators, clinicians, and parents actually observed is that although a stimulus was delivered, perhaps contingent on a desired response or response property, responding remained the same or maybe even decreased. None of this, obviously, invalidates the concern that the response or response dimension was not altered by the contingency. Assuming the contingency was executed with fidelity, this may have happened for any of several reasons. Some have to do with contrived external contingencies in which contingencies were not needed, as described in our treatment of the detrimental effects of extrinsic reinforcement on intrinsic motivation. Some involve procedural mismatches between the response and its outcome. We outline a few potential candidates here; our list is, of course, not exhaustive.

1. The stimulus used was not a reinforcer (calling a stimulus a reinforcer does not make it one). It was perhaps chosen arbitrarily or based on conventional wisdom but never directly evaluated for its reinforcing efficacy. It was then plugged into the relevant contingency and failed to produce an increase. This may happen often, for example, with social praise. A teacher or other change agent may assume that praise is a valuable commodity across the board, but if that individual's history is not one in which praise has at least periodically been accompanied by other reinforcers, then praise alone may simply be ineffective. Preference, reinforcer assessment, or both should be used to systematically determine or at least estimate the likely effectiveness of the stimulus as a reinforcer before it is incorporated into the relevant context.
2. The stimulus was not a reinforcer under the specific conditions within which it was arranged. That is, the item delivered contingent on the target response was insufficiently effective relative to that response, such as when a toy is effective during an assessment but cannot compete with a computer game available in the learning situation. It may have been tested for reinforcer effectiveness under separate (perhaps less stringent) conditions and found to be effective, but that efficacy did not extend to the current conditions. In the given condition it was too little, too late, or too inconsistent. It may therefore be important not only to test reinforcer effects but also to test them under conditions that approximate the conditions of their use in the relevant context.
3. The stimulus used was no longer a reinforcer under these conditions. It was once a reinforcer under these conditions, but its effectiveness has since been altered by some other event or events, such as satiation or developmental changes. The use of ineffective stimuli in the relevant context can be avoided by repeated preference assessments across time.
4. A response–reinforcer contingency was arranged but was not contacted. For example, the requisite performance was too difficult or too effortful to meet reinforcement requirements, so it rarely occurred. Smaller, less stringent steps may be needed to shape and bring the behavior into contact with the contingency.
5. The stimulus followed the wrong response. For example, researchers have on occasion tried to increase on-task behavior by arranging contingencies for responses that formally fit the usual definition of on-task behavior, such as sitting at one's desk or looking at work materials. Such responses can occur without any concomitant increase in actually doing the work, which for the strengthening of on-task behavior is the crucial target. The reinforcer must depend directly on the behavior of interest rather than on other behavior that is incidentally correlated with it.

In light of these considerations, the need to balance reinforcer effectiveness and the practical necessities of arranging reinforcement contingencies, and some of the previously mentioned advantages and disadvantages of different classes of consequences, Figure 3.1 shows one possible decision tree for selecting reinforcers in applied settings. It assumes that reinforcers that require fewer resources are the most practical (e.g., social reinforcers), but that practicality must also be balanced with effectiveness. Because social reinforcers are readily available, inexpensive, and involve few (if any) negative side effects from consumption, they are the first-tier reinforcer in an applied setting. If initially ineffective, the advantages of social reinforcers are so plentiful that one may try to increase their effectiveness

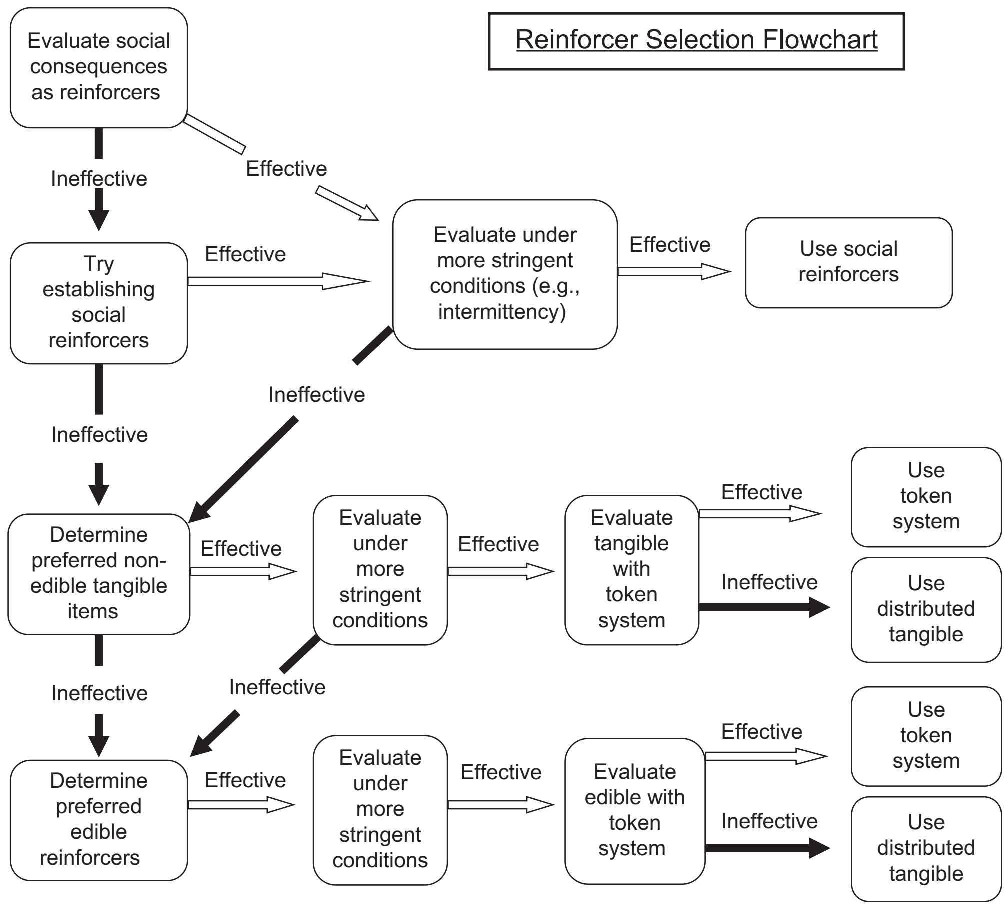

FIGURE 3.1. A decision flowchart for selecting reinforcers in applied settings.

through stimulus-stimulus pairing or other arrangements designed to establish them as reinforcers. The decision tree also assumes that the most useful reinforcers are those that maintain their effectiveness across increasingly stringent response requirements (as when schedules are thinned to make them feasible in applied settings) or over lapses in the integrity of a schedule (as when circumstances cause some reinforcers to be delayed). If social consequences are ineffective, however, then attempts should be made to identify activity-based tangible (nonedible) reinforcers. A candidate activity reinforcer should be evaluated under intermittent conditions and, if it remains effective, should be embedded within a token system. Use of a token system allows for minimization of the interrupting effects of reinforcer deliveries to ongoing behavior. If a token system is ineffective, the activity reinforcer can be delivered in a distributed fashion (after each schedule completion). Edible reinforcers, owing to their impracticality in applied settings, should be the last resort. Similar to the process used with activity reinforcers, any candidate edible reinforcer should be evaluated under intermittent conditions and, if possible, embedded within a token system.

Reinforcement Parameters and Response Acquisition

Applied research has yet to thoroughly explore the effects on behavior acquisition of many of the variables we have considered. Much translational work has retained the dependent measures of basic research, such as relative response allocation and rates of established responses rather than the course of acquisition of new behavior. In academic settings, reinforcement contingencies are often arranged to promote learning, that is, the acquisition of previously unlearned responses. Whether manipulations such as providing more highly preferred stimuli, conducting frequent preference assessments, or arranging for reinforcer choice will meaningfully affect the acquisition of educational targets remains to be seen. For example, just because a high-preference stimulus and a low-preference stimulus support equal responding in FR schedules, it does not follow that these stimuli will be equally as effective in shaping or otherwise establishing new behavior. Just because more responding is allocated toward free choice than toward no choice within concurrent schedules, it does not follow that the availability of free choice will enhance shaping or other procedures for establishing new behavior. We need to know more about how these variables may influence the creation of novel behavior.

Individualized Learning Arrangements in Applied Settings?

We began this chapter by noting that researchers must attend to each component of the three-term contingency when arranging reinforcement contingencies. We have seen how changes in each component can affect various measured outcomes. We also know that different individuals may respond differently to changes in any term of the contingency. In theory, one should be able to optimize arrangements on the basis of such individual differences. For example, some children are relatively more sensitive to reinforcer delay, whereas others are relatively more sensitive to reinforcer rate (Neef & Lutz, 2001; Neef, Shade, & Miller, 1994). Extending the analysis of individual differences to all aspects of instruction is eminently reasonable. The details of behavior in a learning trial can be broken down on the basis of variations in prompting procedures, variations in pacing, the presence of distractor stimuli, the interspersal of previously mastered tasks, variations in consequences, reinforcement of prompted responses, and so on. Some children require physical guidance, but others balk at being touched. For some children, rapid trial presentations promote rapid learning, but for others a slower pace is better. From the nonhuman laboratory to the applied human setting, organisms come with varied histories and varied capacities. One size does not fit all, so in classrooms as in any applied setting, interventions must be individually tailored. Thus, obvious tasks for translational and applied behavior analysis are designing and developing assessments and other tools that help educators, practitioners, and caregivers to arrange optimal contingencies for each learner.

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CHAPTER 4

OPERANT EXTINCTION: ELIMINATION AND GENERATION OF BEHAVIOR

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In recounting his early research agenda, Skinner (1956) described the serendipitous event that led to the discovery of operant extinction curves. The pellet dispenser on his apparatus jammed, leaving lever pressing unreinforced. The cumulative record obtained under this defective procedure was nonetheless orderly. Lever pressing did not stop immediately when reinforcement was withdrawn. Rather, it continued for a while, decreasing as exposure to the new contingency proceeded. As Skinner noted, the record was one of "pure behavior" (p. 226), uninterrupted by food delivery or consumption. He recalled, too, his excitement on observing this first extinction curve, suggesting to him that he "had made contact with Pavlov at last!" (p. 226).

Skinner's serendipitous finding not only made contact with Pavlov, but it turned out to be one of the most reliable effects in the study of learned behavior. Furthermore, the effect has considerable generality. Extinction is found across classical and operant conditioning, in basic and applied research, and in practice. It also is widespread in the animal kingdom, having been reported in organisms ranging from invertebrates (e.g., Abramson, Armstrong, Feinman, & Feinman, 1988) to *Homo sapiens*.

The effects of extinction, however, are neither unidimensional nor simple. Eliminating reinforcement can diminish not only the previously reinforced response, but also others that are related to it. Although responding is eliminated in the sense that it is no longer observed, the extinguished response is quickly reestablished under appropriate circumstances, leading some to describe extinction in terms of discriminative stimulus control and others to consider it as evidence for a learning–performance distinction (e.g., Hull, 1943). Skinner's subsequent research on extinction (e.g., 1933b) revealed something of its synergistic relation to other contingencies of reinforcement. When he alternated periods of reinforcement and nonreinforcement, the result was the familiar scalloped pattern of responding, and the fixed-interval (FI) schedule was born—a direct descendant of operant extinction. Its sibling, the variable-interval (VI) schedule, was created by substituting variable for fixed interreinforcer intervals (IRIs). Other analyses of the synergistic relation between extinction and other events in the organism's proximal and distal histories have elaborated the generative effects of extinction. This chapter is a review of research from basic and applied behavior analysis bearing on both the eliminative and generative effects of the extinction of operant behavior.

HISTORY OF THE STUDY OF EXTINCTION

The physiologist Sherrington (1906) used *extinction* as a synonym for *elimination*. He suggested that the extinction of a reflex could be achieved either by changing the physical properties of the stimuli or by interrupting the nerve connection. Pavlov (1927) was the first to give a precise definition of *extinction* in terms of both a procedure and an effect or result. He noted that the "phenomenon of a rapid and more or less smoothly progressive weakening of the conditioned reflex to a conditioned stimulus which is repeated a number of times without reinforcement

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may appropriately be termed **experimental extinction of conditioned reflexes**" (p. 49). For Pavlov, in extinction the "positive conditioned stimulus itself becomes . . . negative or inhibitory" (p. 48), which he contrasted to external inhibition, in which some other stimulus reduces the probability of the conditioned reflex. Thus, for Pavlov, as for many who subsequently studied it, extinction was an active process whereby the response previously established by reinforcement was inhibited.

As Pavlov's research became accessible in the United States (e.g., Watson, 1916; Yerkes & Morgulis, 1909), the term *extinction* began to appear in psychology textbooks. Pavlov's definition of *extinction,* however, was not clarified for English speakers until Anrep's translation of Pavlov's work appeared in 1927 (Humphrey, 1930). For example, Watson (1924, p. 29) mentioned briefly that a conditioned reflex could be extinguished under two conditions: the lack of practice and the very rapid repetition of the stimulus. After the procedural definition of extinction was clarified, it became more broadly integrated into research on learning, although others continued to equate extinction with fatigue or negative adaptation (e.g., Symonds, 1927; Winsor, 1930).

Following Pavlov's lead, Hull (e.g., 1929) suggested that the conditioned reflex was composed of an excitatory or positive phase during conditioning and an inhibitory or negative phase during extinction. Skinner (1933a, 1933b) described extinction simply as a decrease in the strength of the conditioned reflex by removing the consequence of the conditioned response. He subsequently (Skinner, 1935) distinguished respondent, or Pavlovian, and operant conditioning, in part on the basis of a distinction between involuntary and voluntary behavior.

Although Skinner (1938) applied Pavlov's terminology to voluntary, or emitted, behavior, he rejected the concept of inhibition: "Extinction of a conditioned reflex of Type R occurs when the response is no longer followed by the reinforcing stimulus. The change is merely a decrease in [the] previously reinforced response" (p. 74). Thus, for Skinner, rather than the distinct learning process that is implied by assigning inhibitory properties to extinction, the effects of extinction were a reflection of the effects of reinforcement. This was the basis of Skinner's concept of the reflex reserve, whereby reinforcement builds the reserve that then is depleted as a function of the previous conditions of reinforcement when such reinforcement is discontinued. Skinner later dropped the reflex reserve, but the notion of resistance to extinction as an index of the effects of reinforcement on operant behavior persists (e.g., Nevin, 1974, 1979).

In an early application of extinction to socially relevant problems, Fuller (1949) first established raising to a vertical position the right arm of a vegetative 18-year-old man by reinforcing such movements with a warm sugar–milk solution squirted into the man's mouth. After four training sessions, reinforcement was discontinued, but responding was maintained for the first 30 min of extinction. Thereafter, "the rate decreased until by the seventieth minute . . . it approached zero" (p. 590). Fuller also observed that during extinction "*S*'s movements gradually became more generalized; the left arm, which had moved very little in the last two sessions, moved more frequently after the rate of movement of the right arm noticeably decreased" (p. 590). After Fuller's demonstration, applied extinction research continued to examine the degree to which extinction effects reported with nonhumans could be replicated and extended with human participants (e.g., Bijou, 1957, 1958; Mech, 1952).

Contemporary research on extinction in both research and application has strengthened, questioned, and qualified some of the historical findings and assumptions about the nature of extinction. Before turning to these contemporary developments, however, a consideration of the definitions of extinction is in order.

DEFINITIONS AND GENERAL CHARACTERISTICS OF EXTINCTION

The term *extinction* refers to both procedures and the effects of those procedures. The extinction procedure can both eliminate and generate behavior. Neither effect typically is permanent. Rather, they are circumstantial. In this section the general characteristics of extinction are addressed.

Procedural Dimensions

A general procedural definition of *extinction* is the discontinuation of the reinforcement of a response. With responding that has been positively reinforced, this conventionally means removing the previously established positive reinforcer. Another way of discontinuing positive reinforcement, however, is to remove the response–positive reinforcer dependency. The reinforcer continues to occur, albeit independently of responding (Rescorla & Skucy, 1969). With responding that has been negatively reinforced, three extinction procedures have been used: (a) The negative reinforcer (i.e., the stimulus previously avoided or escaped from; cf. Catania, 1991; Cooper, Heron, & Heward, 2007) is made noneliminable, that is, responses do not terminate or postpone it; (b) the negative reinforcer is terminated intermittently, independently of responding; and (c) the negative reinforcer is removed by, for example, turning off a shock generator after training on a free-operant avoidance schedule. Each of these procedures are elaborated and discussed in the sections that follow.

Procedurally, too, extinction often is a chronic preparation. That is, once implemented, it remains in effect for an indefinite period or until some behavioral criterion of response elimination is reached. Extinction, however, also may be more acute and local. In an FI schedule, for example, the initial part of each individual FI is always extinction in that responding is never reinforced during that time. As is discussed later, reducing the rate of reinforcement programmed by a schedule (so-called schedule leaning or thinning) also can be considered an instance of local extinction because the likelihood that responses previously meeting the reinforcement criterion now go unreinforced is increased.

A final procedural consideration is the term *extinction* applied to punishment. In line with the preceding discussion, either the elimination of a punisher or the removal of the dependency between a response and a punisher could be construed as extinction. Doing so, however, invites confusion in light of the long history of using extinction in the context of reinforced responding (cf. Catania, 1991). For that reason, punishment is not considered in this chapter (see Volume 1, Chapter 21, this handbook).

Functional Dimensions

Procedural definitions describe only operations, not the functional outcomes that are critical to any useful definition of extinction. Both Pavlov's and Skinner's definitions included a statement of the functional effects: Responding is reduced or eliminated when the procedure is implemented. As used here, *elimination* means reducing responding to zero or near zero in the context in which it previously was reinforced. It does not mean that the probability of the response has been permanently reduced to zero such that when contexts or circumstances change, there is little to no chance that the extinguished behavior will recur if extinction subsequently is discontinued.

The applied technique of planned ignoring (e.g., Buck, 1992) illustrates the types of problems that ensue from using a procedural as opposed to a functional definition of extinction. In planned ignoring, the problem behavior of a child evokes no reaction from the caregiver. The procedure assumes a priori that some aspect of the caregiver's behavior is responsible for the misbehavior in the first place. The failure of such a treatment, based on a procedural definition of extinction, led to an emphasis in treatment on a functional definition of extinction and a focus on eliminating the de facto (functional) reinforcer (Iwata, Pace, Cowdery, & Miltenberger, 1994).

Response Generation and Functional Dimensions of Extinction

The effect of extinction depends on where one is looking. Conventionally, the previously reinforced response is the focus, and its decrease functionally defines extinction. As measurement has extended from the recording of a single operant to variations in operant topography (e.g., Antonitis, 1951), to multiple operants (e.g., Lowry & Lachter, 1977), or to behavior in addition to the operant (e.g., Kelly & Hake, 1970), the generative function of extinction has become more evident. Generative effects such as extinction-induced variability, extinction-induced responding, and reinforcement of alternative behavior were discovered as a result of examining the effects of extinction on extended and other classes of behavior.

The generative function of extinction may come into play in different ways in application. First, there is no guarantee that alternative behavior generated by extinction will be more adaptive or socially appropriate than the response being extinguished. This is especially true if no specific alternative response is selected for reinforcement. Lieving, Hagopian, Long, and O'Connor (2004), for example, demonstrated that extinction of one form of disruptive behavior resulted in the emergence of other, sometimes more severe forms of disruption. Second, extinction may generate new responses that then can be reinforced (e.g., Grow, Kelley, Roane, & Shillingsburg, 2008). In procedures involving the differential reinforcement of successive approximations (shaping), for example, the variability created by extinction may generate the desired successive approximation to the terminal response. If, however, the desired alternative response is not one generated by extinction, then the generated responses may compete with the selected alternative response.

Stability and Functional Dimensions of Extinction

Even though extinction decreases the frequency of the previously reinforced response, it often maintains the structure of that previously reinforced response. That is, even though extinguished, the form of the response may remain stable or intact, at least in the short term but often in the longer term (Rescorla, 1996; see Volume 1, Chapter 13, this handbook). Responses completely eliminated by extinction in one context, for example, often recur under other conditions (see, e.g., Reinstatement and Resurgence sections; Lerman, Kelley, Van Camp & Roane, 1999; Uhl & Garcia, 1969). Nevin (1967), for example, trained pigeons to peck the brighter of two keys presented simultaneously during a discrete-trials procedure. When intermittent food delivery following correct choices was discontinued, key pecking decreased, but the accuracy of the responses that did occur was unchanged.

An experiment by Neuringer, Kornell, and Olufs (2001) suggests a possible rapprochement between the seemingly contradictory functions of extinction in maintaining response stability or integrity over time while also increasing response variability. They reinforced three-response sequences of rats only if the sequence had been emitted less than 5% of the time, weighted for recency. When reinforcement of these response sequences was discontinued, response rates and sequences completed per minute decreased, but the probability of each of the 27 possible sequences remained nearly constant. There was, however, a small but consistent increase in the probability of the least likely sequences relative to their baseline levels during the reinforcement baseline. Neuringer et al. observed that the result of extinguishing the response sequences was

> to significantly raise variability but not so much as to affect the hierarchies. It is as if the subjects generally bet on what had worked in the past but occasionally probed to see whether anything better might appear by doing something completely different, a combination of conservative and radical behavioral strategies. The combination is presumably functional in a world in which reinforcers are sometimes intermittent and other times depleted . . . but the two cases may be difficult for an animal to discriminate; therefore, the combination of conservative and radical strategies. (p. 92)

But what of some applied situations in which extinction does appear to eliminate the target response permanently? Most likely, other responses have been reinforced as the extinction procedure was implemented. Thus, a differential-reinforcement-of-alternative-behavior contingency may be responsible for the elimination of the response rather than such elimination being a direct outcome of extinction. Athens and Vollmer (2010), for example, reduced responding during differential reinforcement procedures, in the absence of programmed extinction for problem behavior. For all participants, problem behavior was reduced or eliminated when the (alternative) reinforcement contingency favored compliance or appropriately requesting a desired outcome, even though problem behavior would have been reinforced.

ELIMINATIVE EFFECTS OF EXTINCTION

The most consistent effect of the extinction procedures defined above is a reduction of response rates to low levels, often eventually to zero. The following sections delineate the dimensions of these eliminative effects.

Extinction of Positively Reinforced Responding by Removing the Positive Reinforcer

Because positive reinforcement is the most common behavioral process, it is not surprising that the effects of extinction in eliminating behavior previously maintained by positive reinforcement have been those most commonly studied. In this section we review such extinction effects.

Methodological considerations. Three methods have been used to evaluate the functional relations between different parameters of positive reinforcement and operant extinction. In early experiments, different groups of subjects were exposed to different values of the selected parameter of reinforcement. Following Skinner (1938) and Sidman (1960), a second method appeared in which each of a few subjects were exposed during successive conditions to different values of the selected parameter, each followed by extinction. One difficulty with this latter design is a temporal confound such that resistance to extinction may diminish with repeated exposure to it. This effect amounts to the formation of a discrimination across conditions on the basis of the presence or absence of reinforcement. Thus, the effects on extinction of the second-studied parameter may be confounded by a prior history of extinction, which in turn may decrease responding independently of the effects of the second parameter. A third method is the multiple-schedule or alternating-treatments design (Volume 1, Chapter 5, this handbook). In it, two or more different conditions of reinforcement, each correlated with distinct stimuli, alternate within or across successive sessions. It thus is possible to compare the relative changes in responding when extinction is imposed more or less simultaneously in all components. A potential limitation of using multiple schedules is that the order of the components during extinction can affect the course of extinction. That is, as responding diminishes in the first-presented component, associated with one of the reinforcement conditions, such reduction may affect responding in the second component, associated with the other reinforcement condition, independent of the reinforcement parameter under study. For example, the results might reveal Parameter 1 to be more resistant to extinction if it appeared first but Parameter 2 to be more resistant if it appeared first. There is no uniform solution to such potential order effects in comparing the effects of different parameters on resistance to extinction. Rather, they are simply a drawback of the design that must be weighed relative to its merits and in comparison with other procedures for examining the effects of different reinforcement parameters on extinction.

Extinction of schedule-maintained responding. One of the earliest reported effects of intermittent reinforcement was that it resulted in relatively greater resistance to extinction than did continuous reinforcement (CRF). This effect is variously described as "Humphreys' paradox," or the partial reinforcement extinction effect. Humphreys (1939) first demonstrated it with Pavlovian conditioning, but it subsequently was replicated with operant behavior in both laboratory (e.g., Notterman, Schoenfeld, & Bersh, 1952; Zarcone, Branch, Hughes, & Pennypacker, 1997) and applied research (Lerman, Iwata, Shore, & Kahng, 1996). The effect depends on whether responding is measured in absolute or relative terms (e.g., Lerman et al., 1996) and has been accounted for in different ways (see Nevin, 1988).

Response patterning during extinction reflects the schedule under which the operant response was maintained before extinction (Reynolds, 1968), although systematic research on this subject is limited. Reynolds (1968) noted that responding in extinction after VI training tends to occur regularly but at progressively lower rates as extinction proceeds. By contrast, extinction after fixed-ratio (FR) or variable-ratio (VR) training is characterized by progressively decreasing bursts of responses followed by progressively longer periods of nonresponding. During extinction after FI training, responding tends to occur in positively accelerated patterns but with longer periods of pausing and increasingly shallow scallops (or break-and-run patterns, if the FI schedule has been in effect for an extended period; cf. Schneider, 1969) as time in extinction proceeds.

Extinction within conditions/schedules of reinforcement. Response shaping is one of the most common procedures for establishing a target response. In shaping, reinforcement and extinction occur within a dynamic framework whereby the criteria for reinforcement are constantly in flux, changing as behavior approaches the criterion response. Over time, previous criterion responses are no longer sufficient for reinforcement and undergo extinction as closer approximations to the target response are reinforced (cf. Athens, Vollmer, & St. Peter Pipkin, 2007; Galbicka, 1994; Platt, 1973; Smeets, Lancioni, Ball, & Oliva, 1985).

Periods of nonreinforcement occur when responding is reinforced intermittently (local extinction). These periods of local extinction are inherent in schedules of reinforcement such as FI and FR, in which responding is reinforced only after a fixed point in time or a fixed number of responses, respectively. This reinforcement pattern results in oscillations between distinct periods of responding and its absence, yielding the pause–respond pattern reported with both FI and FR (Felton & Lyon, 1966; Ferster & Skinner, 1957; Schneider, 1969).

Alternating periods of extinction and reinforcement characterize other schedules as well, albeit more subtly. Catania and Reynolds (1968), for example, noted that the smallest IRI on a VI schedule denotes a period of absolute nonreinforcement. As a result, the postreinforcement pause corresponds to the minimum IRIs, such that longer minimum intervals result in longer mean postreinforcement pauses on VI schedules. Blakely and Schlinger (1988) reported parallel findings for VR schedules: The postreinforcement pause varied as a function of the smallest ratio requirement within the VR.

In differential-reinforcement-of-low-rate (DRL) schedules, a response is never followed by a reinforcer until after the specified value of the DRL has lapsed. As a result, the responses (and reinforcers, too) could serve as discriminative stimuli for periods of nonreinforcement (an S−), thereby contributing, along with the differential reinforcement of long interresponse times, to the relatively low response rates that characterize performance on this schedule.

Other parameters of reinforcement and extinction. Responding previously maintained on multiple schedules of positive reinforcement is more resistant to extinction when reinforcers are more frequent, of larger magnitude, and less delayed from the responses that produce them (Cohen, Riley, & Weigle, 1993; Nevin, 1974, 1979). Using a multiple schedule in which different components arranged different numbers of reinforcers, Hearst (1961), for example, found that responding during extinction was a monotonically increasing function of the number of reinforcers (Experiment 1). Also using a multiple schedule, Shettleworth and Nevin (1965) found that responding during extinction was more frequent after training with 9-s access to the reinforcer than after 1-s access.

A somewhat different picture of the effects on extinction of different parameters of reinforcement emerges, however, when extinction follows training on single reinforcement schedules instead of components of a multiple schedule. Cohen et al. (1993) maintained responding of rats and pigeons on VI, FI, FR, or VR schedules. Over successive sessions, responding was stabilized at a given reinforcement rate, followed by extinction. The sequence of schedule-maintained responding followed by extinction was repeated, using different reinforcement rates with the specified schedule. Cohen et al. found no systematic relation between resistance to extinction and reinforcement rate with any of the schedules. Lerman, Kelley, Vorndran, Kuhn, and LaRue (2002) did not find systematic differences in the effects of reinforcer magnitude on problem behavior either during training or during extinction. Using a reversal design, Fisher (1979) found reliable effects of reinforcer magnitude on resistance to extinction but in the opposite direction to that reported under multiple schedules of reinforcement. That is, when toothbrushing was reinforced with either one or five tokens, the responding of 11 of 13 participants was more resistant to extinction after reinforcement with one token than it was after five tokens. This finding, however, is difficult to interpret because for each participant, the larger magnitude reinforcer always preceded the smaller magnitude reinforcer.

Little other applied research has examined parameters of reinforcement affecting resistance to extinction during the treatment of problem behavior. This relative paucity may be related in part to difficulties in controlling reinforcement parameters. For example, it may be difficult to manipulate experimentally the number of reinforcers delivered for problem behavior in a controlled way, because problem behavior typically has a long history of extraexperimental reinforcement before it is referred for intervention. The additional reinforcers provided in an experimental arrangement, in relation to the larger context of the extraexperimental history, may be insufficient to produce systematic changes in resistance to extinction (Lerman & Iwata, 1996).

Repeated exposure to extinction. When successive reconditioning and exposure to extinction occurs, responding generally decreases more rapidly across replications. Reductions in responding (i.e., diminishing resistance to extinction) during successive periods of extinction have been reported in pigeons after both continuous and intermittent reinforcement (e.g., Anger & Anger, 1976; Bullock, 1960; Jenkins, 1961). For example, Bullock exposed different pigeons to 18 sessions of either an FR 20 or an FI 26-s schedule of reinforcement. Within each of these sessions, after 20 reinforcers were delivered, responding was extinguished for 60 min and then the session terminated. Responding during extinction decreased monotonically across successive extinction sessions for each pigeon. Anger and Anger (1976) repeated, either six or 12 times, a cycle composed of two daily sessions of conditioning followed by eight daily sessions of extinction. They used a discrete-trial modified autoshaping procedure in which the first key peck during each trial both ended the trial and was reinforced with a probability of .20. Response rates decreased across successive exposures to the extinction cycles, but the decrease occurred only during the first sessions of extinction in each cycle. During the last extinction sessions in each cycle, after first decreasing from that occurring during the previous reinforcement portion of the cycle, responding increased slightly across successive cycles. These findings suggest that the absence of reinforcement during extinction serves as a discriminative stimulus controlling behavior other than the defined response. As extinction progresses, however, the discriminative control of not responding exerted by the absence of reinforcement may asymptote or even diminish, as reflected by the increases in responding during later sessions of each cycle. This analysis is hypothetical, however, because the other behavior is not measured.

The effects of repeated exposures to extinction have not been examined systematically in applied research. Lerman et al. (1996) speculated that repeated exposures to extinction may have been responsible for the decrease in responding for one of their three participants, but they did not have evidence of this effect with the other two. Although the applied literature is replete with examples of extinction in reversal designs, extinction typically is combined with some other treatment procedure, such as differential reinforcement. The use of extinction as part of a treatment package thus makes it difficult to determine the extent to which the repetition of extinction is a causal variable in response reduction.

Sudden versus gradual introduction of extinction. Following earlier research by Skinner (1938, pp. 203–206) and Schlosberg and Solomon (1943), Terrace (1963) reported differences in the number of responses made to an S− as a function of how the stimulus and accompanying periods of nonreinforcement were introduced. For one group of pigeons, sudden introduction of the S− after responding had been well established in the presence of an S+ resulted in many (unreinforced) responses during the S− presentations. For a second group, the S− was introduced simultaneously with the commencement of training to respond in the presence of the S+, but at low intensity and initially for very brief durations. Over successive presentations, the duration and brightness of the S− was increased gradually, and care was taken to not reinforce responses in S− by immediately presenting the S+ after such responses. The method yielded few responses to the S− throughout training and during the steady-state S+–S− discriminative performance.

The more general term used to describe this procedure is *fading* or *stimulus fading,* and it can refer to either the fading in or the fading out of stimuli, including reinforcers. The procedure commonly is used in applied behavior analysis, particularly when teaching new skills to learners with disabilities. Sidman and Stoddard (1967) obtained results with children similar to those found with pigeons by Terrace and others (e.g., Rilling, 1977). Birkan, McClannahan, and Krantz (2007) used a fading procedure to teach a young child with autism to read printed words aloud. In their procedure, photographs of corresponding objects were displayed behind the printed words and gradually faded until the participant could read the words presented alone.

Terrace (1966) observed that establishing a discrimination between an S+ and an S− by using a fading procedure resulted in an S− that differed functionally from one that was established without fading (i.e., by extinguishing responding through contact with nonreinforcement). He suggested that allowing unreinforced responses to S− increased behavioral contrast, inhibitory stimulus control, aggression toward a target animal, and escape or avoidance of the S−, effects that were either not present or greatly diminished when the S− was established using a fading procedure. Rilling (1977) qualified some of these differences, replicating some, but not others. Thus, the nature and differential effects of fading continue to invite further experimental analysis.

Schedule leaning or thinning and extinction. The gradual reduction over time in the number of reinforcers delivered is labeled *schedule leaning* or *thinning,* the former more commonly used in basic research; the latter, in applied research. Schedule leaning or thinning may be considered a type of fading in which the rate of reinforcement scheduled for some response is reduced gradually. Unlike Terrace's (1963) stimulus fading, there are no changes in the accompanying stimuli as the rate of reinforcement is reduced. Nor are the gradual changes in reinforcement rate necessarily related to changes, or the absence thereof, in behavior. In applied research, the reinforcement rate rarely is thinned to extinction. Reducing that rate, however, can be considered as implementing periods of local extinction in that previously reinforced responses go unreinforced as the reinforcement frequency decreases. Such thinning typically maintains response rates similar to those established during the initial intervention, despite the diminishing reinforcement (e.g., Hagopian, Fisher, & Legacy, 1994; Kahng, Iwata, DeLeon, & Wallace, 2000; Lalli, Casey, & Kates, 1997; Marcus & Vollmer, 1996).

The gradual reduction in reinforcement rate toward the total elimination of reinforcement also has been suggested to reduce undesirable generative effects of extinction such as extinction bursts and extinction-induced problem behavior (see the Generative Effects of Extinction section). Lerman, Iwata, and Wallace (1999), for example, found that extinction bursts and aggression were attenuated when extinction initially was implemented as part of a treatment package that provided reinforcement for behavior other than the extinguished response, as opposed to extinction as the sole intervention. Relatedly, Vollmer et al. (1998) found that time-based reinforcement schedules reduced extinction-induced problem behavior compared with conventional extinction alone.

Given that reduced reliance on artificially arranged reinforcers is often a goal of applied behavior-change procedures, demonstrations of the maintenance of responding when reinforcement is reduced gradually (but not necessarily eliminated) are promising. Hanley, Iwata, and Thompson (2001) compared three methods of reducing the rate of reinforcement of communicative responses trained as alternatives to self-injurious behavior. When delays of reinforcement for communication were introduced, rates of communication decreased to near zero. Thinning from continuous reinforcement of communication to an FI 25-s schedule increased communication to socially unacceptable rates, but thinning to a multiple FR 1 extinction for communication resulted in maintenance of low, steady rates of communicative responding. St. Peter Pipkin, Vollmer, and Sloman (2010) gradually thinned the reinforcement rate of a laboratory analogue of appropriate responses by decreasing the percentage of these responses that were reinforced but without accompanying stimulus changes. Participants continued to respond appropriately as the schedule was thinned from FR 1 to VR 5; however, rates of appropriate responding decreased with reinforcement rate reductions.

Neither Hanley et al. (2001) nor St. Peter Pipkin et al. (2010) compared schedule thinning with conventional extinction. The body of research reviewed thus far suggests that nonreinforced responding would cease. Thus, sustained responding as a function of reinforcement thinning would depend on either the reduced reinforcement rate being sufficient to maintain responding or, if the reinforcers were completely eliminated, whether alternative reinforcers (e.g., what Herrnstein [1970] would call R_e) would come to substitute for the other reinforcers thus eliminated. For example, Kazdin and Polster (1973) maintained social greetings after a change from FR 1 to an intermittent reinforcement schedule. It is likely, however, that the greetings had come under the control of naturally occurring reinforcers in social interactions.

Extinction in combination with punishment. Skinner (1938, pp. 154–155) punished rats' lever pressing by having the response lever spring back when depressed, delivering a slap to the rat with each lever press. Responding first was reinforced with food. At the same time that food reinforcement was discontinued, the first few responses in extinction were punished. Then punishment too was removed. The rats' responding eventually recovered such that the overall responding was equivalent to rats exposed to extinction without punishment. By contrast, Hagopian, Fisher, Sullivan, Acquisto, and LeBlanc (1998) compared the outcomes of several clinical cases, four of which involved reinforcement of appropriate behavior and extinction and punishment of problem behavior in various combinations at different times over the course of treatment. In three of these four cases, the greatest reductions in problem behavior occurred when reinforcement of appropriate behavior was combined with extinction and punishment of problem behavior, suggesting that in some clinical cases, punishment may be a critical component of response reduction (cf. Azrin & Holz, 1966).

Extinction of Positively Reinforced Responding by Removing the Response–Positive Reinforcer Dependency

Removal of the response–positive reinforcer dependency after responding has been reinforced usually decreases responding (Rescorla & Skucy, 1969; Zeiler, 1968). The extent and speed with which responding decreases is in part a function of such variables as the delays between responding and delivery of the previously established reinforcer (Zeiler, 1968, but see Rescorla & Skucy, 1969), the reinforcement schedules changed from and to (Lachter, 1971), and other historical variables (Lattal, 1972; Zeiler, 1968). Removal of the response–reinforcer dependency has the disadvantage that responding can be adventitiously reinforced if it is followed closely by reinforcer delivery (Herrnstein, 1966). Its advantage is that by removing only the response–reinforcer dependency, the context during extinction does not change from reinforcer present to reinforcer absent (see Reinstatement section), thereby reducing the stimulus change occurring with extinction.

In applied behavior analysis, response reduction or elimination by removal of the response–reinforcer dependency is used frequently. Typically, the procedure decreases responding when the response–reinforcer dependency is either eliminated or degraded (cf. Lattal, 1974). Unlike nonhuman studies, in applied research removing the response–reinforcer dependency most often is concurrent with increases in the nominal reinforcer rate. Many such studies, for example, start the response-independent phase by providing continuous access to the reinforcer (Hagopian et al., 1994). As a result, response rate decreases obtained when the response–reinforcer dependency is removed under such conditions could be the result of some combination of extinction and the abolishing operation of satiation (e.g., continuous attention to forestall attention-maintained problem behavior). (This confounding typically is not a problem in basic research, however, because removing the response–reinforcer dependency is not accompanied by increases in reinforcement rate.)

Kahng, Iwata, Thompson, and Hanley (2000) investigated the relative contributions of satiation and extinction in reducing problem behavior during response-independent stimulus deliveries. Participants were three adults with severe or profound intellectual disabilities whose problem behavior was maintained by attention or bits of food. Brief periods of extinction (withholding of the reinforcer) were implemented after periods in which the reinforcer was delivered independently of responding on escalating fixed-time (FT) schedules. Kahng et al. reasoned that if response reduction during the FT condition resulted from extinction, responding would remain at low or zero levels once conventional extinction was introduced. If satiation were the determining variable, responding would increase when the reinforcer was withdrawn during conventional extinction. Suppression of responding for one subject was due to satiation (the one with the food reinforcer); for another, to extinction; and for the third, initially to satiation but later to extinction. This mixed outcome suggests that the effects of response-independent reinforcer delivery may be idiosyncratic across individuals, perhaps as a result of different reinforcement histories or treatment contexts.

Vollmer, Iwata, Zarcone, Smith, and Mazaleski (1993) examined the contributions of satiation and extinction to the reductive effects of FT schedules in a different way. Participants were three adults with severe or profound intellectual disabilities and self-injurious behavior that was maintained by social attention. During baseline, each response was followed by 10 s of attention, and participants responded at rates that yielded near-continuous access to reinforcers. When attention subsequently occurred independently of responding, response rates decreased dramatically, remaining at near-zero rates as the schedule was thinned from FT 10 s (given that the reinforcer access duration was 10 s, this schedule resulted in continuous access to the reinforcer) to FT 5 min. The reduction in problem behavior seemed to be the result of neither satiation nor extinction alone. Satiation was unlikely because participants continued to respond at high rates throughout baseline sessions of equal duration. For two of the three participants, response rates were higher during a differential-reinforcement-of-other-behavior (DRO) schedule than during FT. This outcome is noteworthy because fewer reinforcers were delivered during DRO than during FT, suggesting that extinction was not solely responsible for the decrease in responding during FT. Additionally, more extinction-induced behavior (e.g., aggression; see Extinction-Induced Behavior section) occurred during DRO than FT for two of the three participants.

Comparison of Positive Reinforcer Removal and Removal of the Response–Positive Reinforcer Dependency

A few experiments have examined the functional differences between extinction as stimulus removal and extinction as removal of the response–reinforcer dependency. Lattal (1972) compared the effects of a conventional extinction procedure to removal of the response–reinforcer dependency training on FI and VI schedules programmed as components of a multiple schedule with two outcomes. First, responding was more persistent after the response–reinforcer dependency was removed than after reinforcement was eliminated (cf. Rescorla & Skucy, 1969). Second, responding was more persistent after removal of the response–reinforcer dependency from the FI than after its removal from the VI schedule, but FI- and VI-maintained responding was reduced equally when food delivery was discontinued. Some combination of the discriminative stimulus properties of food delivery and adventitious reinforcement (Herrnstein, 1966) likely accounts for the more persistent responding when the response–reinforcer dependency is removed.

Extinction of Negatively Reinforced Responding by Making the Negative Reinforcer Noneliminable

This procedure parallels the extinction of positively reinforced responding by eliminating access to the positive reinforcer. Sidman (1966), for example, serendipitously found that shocks delivered independently of responding because of an equipment failure initially increased responding, but "eventually led to extinction" (p. 194). Davenport and Olson (1968) substantially reduced lever pressing by eliminating the response–shock removal contingency in a signaled avoidance procedure by presenting the shock at the end of the signal independent of responding.

In application, with the techniques of response flooding (Baum, 1970) and escape extinction, the negative reinforcer is noneliminable, that is, it continues to occur independently of whether the target response occurs or not. Escape extinction is effective in reducing food refusal. With one such procedure, called *nonremoval of the spoon,* the caregiver continues to present the food item until a bite is accepted and swallowed (e.g., Ahearn, Kerwin, Eicher, & Lukens, 2001; Patel, Piazza, Martinez, Volkert, & Santana, 2002). Thus, the food, presumably a negative reinforcer, is constantly present, independent of the problem behavior that previously resulted in its removal (escape). Such escape extinction has been suggested to be a critical component of establishing food acceptance (Piazza, Patel, Gulotta, Sevin, & Layer, 2003; Reed et al., 2004).

Extinction of Negatively Reinforced Responding by Response-Independent Termination of the Negative Reinforcer

This procedure parallels the removal of the response–positive reinforcer dependency (cf. Rescorla & Skucy, 1969). Hutton and Lewis (1979) delivered response-independent electric shocks to pigeons every 3 s. Pecking a transilluminated key occasionally suspended shocks and changed the key color for 2 min. The rate of the pigeons' escape responding decreased as the number of shock-free periods delivered independently of responding increased.

Applied behavior analysts sometimes also arrange for escape to occur independently of responding, a procedure often mislabeled *noncontingent escape.* This procedure typically involves demand removal on a time-based schedule (e.g., Vollmer, Marcus, & Ringdahl, 1995), and it typically results in immediate and substantial reduction in response rates. Disruption of the response–escape dependency through response-independent escape has several potential advantages over the escape extinction procedure described in the preceding section (see also Geiger, Carr, & LeBlanc, 2010). First, it ensures contact with the reinforcer maintaining the problem behavior, potentially reducing or preventing aggressive or emotional responding typically associated with escape extinction. Second, time-based delivery of escape reduces problem behavior even when response-dependent escape continues to occur (Lalli et al., 1997). Finally, removal of demands on a time-based schedule does not require problem behavior to occur to be effective and thus may be a preventive strategy.

Extinction of Negatively Reinforced Responding by Removing the Negative Reinforcer

One interpretation of this extinction procedure is that it is the extreme of the Hutton and Lewis (1979) procedure described in the preceding section. That is, removing the negative reinforcer is tantamount to continuously delivering all negative-reinforcer–free periods, independent of responding. Another interpretation is that eliminating the negative reinforcer by, for example, discontinuing shock delivery after training on a free-operant avoidance schedule may be considered an abolishing operation in the same way that allowing continuous access to a positive reinforcer abolishes it as a reinforcer.

Shnidman (1968) eliminated shock delivery after training of rats during 4-hr sessions. Free-operant (Sidman) avoidance schedules, in which each response postponed shock delivery in different conditions for 20 s or 40 s, or a discriminated avoidance procedure, in which a 5-s tone preceded shocks, were in effect in different conditions of the experiment. Once responding stabilized on each avoidance procedure, the shock was discontinued and responding declined to zero within a single 2- to 3-hr session. Shnidman suggested a comparison of extinction arranged by shock elimination and by rendering the response ineffective in terminating shocks, but this comparison was not undertaken. Ayres, Benedict, Glackenmeyer, and Matthews

(1974) compared extinction by shock elimination after training a head-poke or lever-press response under unsignaled (free-operant) or signaled (discriminated) avoidance schedules. Responding previously maintained under the free-operant avoidance schedule extinguished within a 2-hour session, regardless of the operant response topography, and was considerably lower than under the discriminated avoidance procedure. The finding that responding extinguished more rapidly under unsignaled than signaled avoidance was counter to that reported by Shnidman and may be the result of procedural differences between the two experiments.

Comparisons of Different Procedures for Extinguishing Negatively Reinforced Responding

After training college students to avoid a signaled air blast delivered behind the ear, Meyer (1970) compared responding during extinction implemented as air-blast removal or as unavoidable response-independent air-blast presentation after the signal. Responding was more resistant to extinction in the former condition. Responding during the signal when the air blast was unavoidable resulted in immediate contact with that contingency. By contrast, when the air blast was removed, continued responding during the signal continued to have the same effect as before (no air blast), thus prolonging responding. This finding was replicated in rats avoiding shocks in a shuttle box (Bolles, Moot, & Grossen, 1971) and in children avoiding the termination of a song (Moffat & McGown, 1974). Results from experiments in which unsignaled avoidance was used, however, are inconsistent with those obtained when the two extinction procedures are compared using discriminated avoidance. Coulson, Coulson, and Gardner (1970), for example, trained rats on an unsignaled avoidance procedure. In one extinction condition, shocks were presented at the same frequency as in the previous avoidance condition but independently of the rats' behavior. In another extinction condition, the shocks were never presented. Responding was more resistant to extinction when the shocks were presented independently of responding than when they were not presented (see also Powell, 1972). The shocks were suggested to function as a discriminative or eliciting stimulus for continued responding in this situation (Baron, 1991; Morse & Kelleher, 1977). Powell (1972) found that after training rats in an unsignaled avoidance procedure, responding during extinction (implemented as response-independent shock presentations) continued for long periods at a rate that was related directly to the frequency and intensity of the shocks.

The way in which the extinction procedure is structured results in different response patterns over the course of extinction, which can influence the choice of procedure in application (Geiger et al., 2010). Eliminating the negative reinforcer or breaking the response–reinforcer dependency through infrequent presentation of the negative reinforcer may be advantageous because these procedures typically reduce responding immediately, but they have the disadvantage of reduced exposure to the negative reinforcer (which can be problematic when that stimulus is an academic demand or the presentation of food). In contrast, extinction by making the negative reinforcer noneliminable may have advantages associated with increased exposure to the negative reinforcer, including better promoting the development of appropriate responses when combined with other procedures. The latter procedure may be limited in that continuous presentation may be more likely to evoke emotional responding (e.g., Lerman & Iwata, 1995).

Response-Elimination Procedures With Extinction-Like Properties

In this section, the discussion is confined to comparisons between conventional extinction of positively reinforced responding and schedules with extinction-like properties, unless otherwise noted. Conventional extinction is procedurally a period of nonreinforcement initiated independently of the organism's behavior. The period of extinction is indefinite and typically occurs in the presence of the same stimuli in effect when the response had been reinforced. Other procedures also involve the elimination of reinforcement but do so as a function of the organism's responding. Such responding results in a time-limited elimination of the opportunity for reinforcement. These response-produced periods of nonreinforcement sometimes are and sometimes are not correlated with distinct stimuli.

DRO. The DRO contingency is defined negatively in that reinforcement depends on the omission or nonoccurrence of the targeted operant response for a specified period of time. The label *DRO,* coined by Reynolds (1961), leaves the other response unspecified, making it an unmeasured hypothetical entity. Other terms have been proposed to describe DRO (Uhl & Garcia, 1969; Zeiler, 1977b), but none is without drawbacks. Reynolds's term is retained in this chapter.

Conventional extinction of positively reinforced responding and DRO are indistinguishable from one another from the time they are implemented until a pause sufficiently long to meet the DRO requirement occurs. Only after responding has extinguished to the point that such a pause occurs can DRO and extinction differentially affect the measured operant. Extinction therefore is a necessary feature of the DRO contingency.

Two temporal parameters define DRO: the interval by which each response delays a reinforcer (the response–reinforcer or R-S^R interval) and the interval between successive reinforcers in the absence of intervening responses (the reinforcer–reinforcer or S^R–S^R interval). In both basic and applied settings, the most common procedure is to equate these two intervals. That said, DROs have been arranged in other ways, such as with variable S^R–S^R intervals. For example, Lattal and Boyer (1980, Experiment 2) exposed pigeons concurrently to an FI schedule of key-peck reinforcement and a DRO schedule. The DRO was arranged such that the first 5-s pause after the lapse of a variable S^R–S^R interval resulted in food delivery. As the rate of reinforcement for pausing increased (in different conditions, from once every 300 s on average to once every 30 s on average), the amount of the session time allocated to key pecking decreased. Thus, key pecking was negatively punished by the response-dependent presentation of time-limited periods of nonreinforcement of key pecking (cf. Zeiler, 1977a).

Lattal and Boyer (1980, Experiment 1) found no systematic effect of the pause duration required for reinforcement (cf. Zeiler, 1977a) on response rates; however, Cowdery, Iwata, and Pace (1990) reported such an effect when applying a DRO procedure to eliminate self-injurious scratching by a 9-year-old boy. Initially, tokens exchangeable for snacks and play materials were dependent on the absence of scratching for 2 min. Scratching continued to be absent as the DRO intervals were increased to more than 4 min. The Cowdery et al. experiment, however, confounded changes in DRO duration and session duration. Thus, the changes attributed to the longer DRO could have been in part the result of longer exposure to treatment resulting from the fact that the longer DROs required longer treatment sessions.

Response-produced time-outs. Response-produced time-outs differ procedurally from conventional extinction because of their relative brevity and because the periods of nonreinforcement typically are correlated with an S–. The latter is most often, with pigeons, a darkening of the chamber; with rats, it often is removal (retraction from the chamber) of the operandum. In application, time out is a response-produced period of nonreinforcement accompanied by a stimulus change such as the withdrawal of the therapist, removal of the client from the situation, or presentation of another stimulus, as with a time-out ribbon (Foxx & Shapiro, 1978). The context in which response-dependent time outs are arranged determines their behavioral effects. Arranged in a context of positive reinforcement, the typical effect is response reduction or elimination. Response-dependent time outs from free-operant avoidance schedules function as positive reinforcers (e.g., Perone & Galizio, 1987; Plummer, Baer, & LeBlanc, 1977)

Applied research has suggested that response-dependent time out from positive reinforcement reduces problem behavior. Such effects are not strongly influenced by the time-out parameters, such as its duration or frequency (for a review, see Hobbs & Forehand, 1977), although it is possible that response rate and schedule of time out may interact, such that high-rate responses require more frequent use of time out (Calhoun & Lima, 1977). Response-dependent time outs often can be removed from treatment packages without negative side effects or reemergence of the target behavior (Iwata, Rolider, & Dozier, 2009). As such, response-produced time outs might function differently than conventional extinction.

Eliminating Responding With Extinction Compared With Other Response-Elimination Procedures

Among the first to compare operant extinction with other response elimination procedures were Holz and Azrin (1963), who examined the relative efficacy of different techniques in eliminating pigeons' key pecking in terms of whether the technique had an immediate, enduring, and irreversible effect and whether it produced complete suppression. The techniques compared were stimulus change (a change in key color from red to green for 60 min that occurred 30 min into a 2-hr session), eliminating reinforcement (extinction), satiation, physical restraint, and punishment. By their criteria, punishment was the most effective means of response elimination, and the only technique that received a response of "yes" to each of these effects. The response-reducing effects of conventional extinction were more gradual than those of satiation, which produced abrupt reductions in responding immediately on implementation. Holz and Azrin cited the gradual onset of effect as the greatest weakness of extinction as a means of response elimination. Since this initial evaluation, several studies have examined the relative effects of extinction and other procedures in eliminating responding.

Comparisons of DRO and conventional extinction. Comparisons of the relative efficacy of DRO and conventional extinction in reducing responding have yielded mixed results. Uhl and Garcia (1969) found no significant differences between the two, but Rescorla and Skucy (1969) found that conventional extinction reduced lever-press responding of rats to a lower level than did a DRO 5-s schedule after 5 days of training on a VI 2-min schedule. Zeiler (1971) reported the opposite outcome. After pigeons' key pecking stabilized on a multiple FR 25–FR 25 schedule of food reinforcement, pigeons were exposed to a multiple extinction DRO 30-s schedule. During the DRO, each response reset the 30-s IRI, and in the absence of responding, reinforcers were delivered every 30 s. For each pigeon, response rates were reduced more quickly and to lower levels in the DRO component. After 3-day periods when sessions were not conducted, more spontaneous recovery occurred in extinction than in the DRO component.

Other experiments have been no more definitive in yielding consistent across-experiment effects. Lowry and Lachter (1977) used a multiple schedule to compare pigeons' rates of key pecking under different response-reduction procedures. After a baseline in which VI 128-s schedules were in effect in each of four components, the VIs were replaced with an FT 32 s, a differential-reinforcement-of-alternative-behavior (DRA; extinction of pecking on the VI key while reinforcing responding on a second key on an FI 32-s schedule), DRO 32 s, and extinction. Response rates were lowest under the DRA and highest under FT. Similar to the findings of Uhl and Garcia (1969), extinction and DRO were equally effective in reducing responding.

Consistent with Rescorla and Skucy (1969), R. H. Thompson, Iwata, Hanley, Dozier, and Samaha (2003) found that extinction decreased responding more rapidly than did DRO with clinical populations. They suggested that responding continued during DRO because the reinforcer delivery occasioned responding by functioning as a discriminative stimulus for further responding (cf. Franks & Lattal, 1976). This account holds, however, only after the response contacts the DRO contingency; until that contact occurs, as has been noted, extinction and DRO are identical. By that point, too, as a function of the DRO duration, the reinforcer may begin to function as a discriminative stimulus for not responding, leaving the interpretation somewhat unclear.

The mixed findings concerning the relative efficacy of DRO and extinction in eliminating responding seem more likely to be the result of procedural and parametric differences between experiments. For example, both Rescorla and Skucy (1969) and Uhl and Garcia (1969) provided only a few days' training on the reinforcement schedule before implementing extinction or DRO, whereas Zeiler (1971) achieved stable responding under the baseline schedule before proceeding to the next condition. Zeiler did not specify whether the DRO or extinction components appeared first when the FR schedules were replaced, but the order of schedule presentation in the multiple schedule could affect the relative speeds with which responding in the two components decreased (see the Methodological Considerations section). Other variables contributing to the mixed outcomes may be the use of different species; parameters of the DRO schedule, which differed among the various experiments; and the use of within- versus between-subject designs.

The role of parametric differences was underlined by Rieg, Smith, and Vyse (1993). Using a between-subjects design with rats, they compared response reduction under extinction and DROs with different combinations of R–S^R and S^R–S^R intervals. S^R–S^R intervals of 10 and 20 s were scheduled after training on FI 10 and FI 20 s, respectively. These two intervals were combined with R–S^R intervals of 2, 6, and 18 s and 4, 12, and 36 s respectively, yielding R–S^R:S^R–S^R ratios of 0.2, 0.6, and 1.8. During the first few response-elimination sessions, the effects of the DROs and extinction did not differ. As these sessions progressed, however, the 1.8 ratio resulted in lower rates of responding under DRO than under extinction, and the 0.2 ratio resulted in higher rates of responding under DRO than under extinction. These results support the notion that before the first reinforcer is delivered under a DRO, the schedule is functionally equivalent to extinction. After the first reinforcer is delivered, if the R–S^R interval is relatively short, responding can be reestablished because the reinforcer may retain vestigial discriminative stimulus control of responding. If the R–S^R interval is relatively long, two processes may complement one another. First, the reinforcer may come to function as a discriminative stimulus for behavior other than the now-forbidden response. Second, other behavior can be adventitiously reinforced, making the schedule functionally similar to a DRA, which has been shown to control lower rates of responding than either DRO or extinction (e.g., Lowry & Lachter, 1977). Another possibility is that these DRO effects reflect delay of reinforcement gradients.

Comparison of DRO and removal of the response–reinforcer dependency. Davis and Bitterman (1971) compared the effects of DRO and a yoked VT schedule on lever pressing previously maintained by a VI schedule of food reinforcement. Groups of rats were exposed to a DRO 30-s schedule or to a yoked VT schedule that was equated for the number and temporal distribution of reinforcers arranged by the DRO schedule. Responding decreased to lower levels and decreased more rapidly under DRO than under VT. Rescorla and Skucy (1969), however, found no significant differences in response reductions produced by a DRO 5-s or a VT schedule. The elimination conditions followed only 5 days of training of the previously naïve rats on a VI 2-min schedule. Such minimal baseline training makes it difficult to compare the results with more standard operant preparations in which stable baseline responding is obtained first (cf. Zeiler, 1971).

GENERATIVE EFFECTS OF EXTINCTION

Even though the operant response may be diminished or even reduced to zero during extinction, extinction is not a behavioral Aigues Mortes, a period in which all behavior simply is dead in the water. Rather, as the rate of the previously reinforced response decreases, other responses emerge. The generation of other responses often begins during the transition to response elimination and can continue after the former operant response has been eliminated. These generated responses are the subject of this section.

Response Bursts at the Onset of Extinction

Keller and Schoenfeld (1950) noted that the extinction curve of a response previously maintained on a CRF schedule "begins with a steeper slope (higher response rate) than that during [CRF]" (p. 71). Anecdotally, response bursting is commonplace at the onset of operant extinction, yet there are few systematic data on the effect. A problem is that a response burst is ill defined, both qualitatively and quantitatively. Nor are there many systematic data on the regularity of its occurrence. An exception is the meta-analyses of Lerman and Iwata (1995) and

Lerman, Iwata, and Wallace (1999). They examined, respectively, published data sets and their own data in which extinction was implemented either alone or in combination with some other procedure (differential reinforcement; response-independent, time-based reinforcer delivery; or antecedent manipulations). Extinction bursts were more common when extinction was implemented alone, rather than in combination with other interventions. Even when implemented alone, bursting (defined as response rates in the first three sessions of extinction exceeding rates in the last five sessions in the previous phase) was far from universal but did occur in two thirds of the cases from their own laboratory.

It is difficult to draw firm conclusions about the prevalence of extinction bursts from these meta-analyses combining results from several different preextinction procedures. With both human and nonhuman subjects, response bursts in extinction likely vary as a function of other differences in pre-extinction conditions of reinforcement, such as the operant response, the reinforcement schedule, and other parameters of reinforcement. Yet another complexity is that the period over which extinction bursts are measured, in both basic and applied research, may not be consistent. Responding averaged across an entire session may obscure an extinction burst that occurred more locally, for example, during the first few minutes of extinction.

Comparing extinction bursts across multiple experiments may be fraught with other complexities. Keller and Schoenfeld (1950), for example, suggested that one reason for extinction bursts may be that "responses are no longer separated by eating time" (p. 71). At least some of the differences in the occurrence of extinction bursts as reported earlier may be related to the type of reinforcer used. In applications, especially, different reinforcers can vary considerably in their consumption time (e.g., a simple "good" vs. 30 s of attention).

Increased Variability of Response Topography During Extinction

When an operant response is extinguished, response variability increases. Antonitis (1951; see also Eckerman & Lanson, 1969) reinforced a nose-poking response of rats on a 50-cm-long opening along one wall of an operant conditioning chamber. A nose poke at any location along the slot, defined by photobeam breaks, produced a food pellet. Even though nose poking was reinforced at any location, responding occurred primarily in a restricted location in the slot. When reinforcement was discontinued, responding at other locations along the slot increased. That is, extinction induced greater variability in responding, at least in the short term. Increased variability during extinction also occurs across other response dimensions, such as response duration (Margulies, 1961), force (Notterman & Mintz, 1965), reaction time (Stebbins & Lanson, 1962), number (Mechner, 1958), displacement (Herrick, 1965), and sequences (Mechner, Hyten, Field, & Madden, 1997).

Response variability during extinction can extend to responses that previously were unreinforced but are related topographically to the previously reinforced response. Skinner (1938), for example, recorded a continuum of response force and duration, reinforcing only responses that exceeded a predefined criterion. When the required minimum force or duration required for reinforcement was increased (thus placing the previous responses on extinction), the force of the responses varied within a few minutes. This variation included responses that reached forces not previously observed, with some sufficient to reach the new criterion for reinforcement. Skinner concluded that when a previously reinforced response is extinguished, responses that fall outside the criterion for reinforcement will increase. Such responses that fail to reach or exceed the reinforcement criterion can be described as instances of response generalization or response induction (Catania, 1998; Skinner, 1938) and thus can be conceptualized as representing a continuum of response variability during extinction. The terms *induction* and *response generalization* both describe the generation of responses that are similar to, but not isomorphic with, the previously reinforced operant when that operant is extinguished. The terms can be confusing because induction also describes responding brought about by extinction that may not be topographically similar to the previously reinforced response (see Extinction-Induced Behavior section) and, in multiple schedules in particular, to topographically similar or dissimilar responses in the presence of stimuli other than those associated with extinction.

Other studies have extended and elaborated the analysis of response variability in extinction. For example, Hefferline and Keenan (1963) measured the amplitude of small thumb-muscle movements of humans. During a baseline, most responses were of low amplitude. Reinforcement of responses only within a specified range of amplitudes led to a predominance of responses within that range. During the first 10 min of extinction for the two subjects after 85 to 90 min of CRF training, the frequency of all amplitudes increased. For the other two subjects exposed to CRF training for only 60 min, only the one or two lowest amplitudes increased; the others were unchanged from the CRF training. Increasing response strength via longer exposure to CRF thus also increased response variation during extinction.

The experiments discussed in this section have shown that the eliminative effects of extinction on the target response are accompanied by the generation of responses that previously were unreinforced but are related topographically to the reinforced response. This generative effect of extinction is important during response differentiation (e.g., shaping) because it enables adaptation to changes in the requirements for reinforcement (e.g., Keller & Schoenfeld, 1950; Segal, 1972). That is, these extinction-generated variations in the operant can become new targets for reinforcement. As with any response, of course, these extinction-generated variations must be reinforced to persist.

Research by Grow et al. (2008) illustrates this latter point. They exposed children with developmental delays to extinction after first reinforcing problem behavior. When the problem behavior subsequently was extinguished, Grow et al. observed a variety of appropriate responses that had not occurred in previous sessions. They selected one of these novel responses as the new criterion for reinforcement, replacing problem behavior with an appropriate response. These results suggest that extinction-induced variability extends to responses not previously observed within the operant class (see also Morgan & Lee, 1996).

Extinction-Induced Behavior

As noted in the preceding section, responding induced by extinction may or may not be similar topographically to the extinguished operant. Aggressive responses induced by extinction illustrate the point. T. Thompson and Bloom (1966) found that rats' biting a response lever increased when the lever-press response was extinguished. They suggested that the response bursting often seen at the onset of extinction could be extinction-induced aggressive responses directed toward the operandum. With one pigeon restrained at the rear of an operant chamber, Azrin, Hutchinson, and Hake (1966) exposed other pigeons to a multiple CRF extinction schedule during which the two components alternated every 2 minutes throughout each session. During the CRF component, pigeons pecked the response key and consumed the reinforcers thereby produced. The restrained pigeon was ignored. When, however, the component changed to extinction, each pigeon ceased pecking the response key and initiated a bout of aggressive pecking at the restrained pigeon. This attack continued intermittently until the stimulus correlated with the CRF schedule was re-presented. At that point, aggressive responding ceased, and the pigeon returned to key pecking. Kelly and Hake (1970) obtained a similar result with adolescent boys earning monetary rewards by pulling a plunger. When plunger pulling was extinguished, seven of nine subjects vigorously hit an electronic padded punching cushion. Of the six subjects returned to the reinforcement schedule after extinction, three reverted to baseline rates of plunger pulling. Extinction-induced aggression has been replicated and extended many times in both laboratory animals (e.g., Pitts & Malagodi, 1996) and human subjects (e.g., Goh & Iwata, 1994; Lerman, Iwata, & Wallace,1999). In some cases, the topography of the aggressive response is similar to the extinguished operant response, but in others it is not, for example, in the Kelly and Hake experiment or in cases in which extinguishing inappropriate behavior (such as self-injury) leads to increased aggressive responses toward others (e.g., Goh & Iwata, 1994).

Schedule-induced drinking or polydipsia (Falk, 1961) provides another example of the induced response not being topographically similar to the extinguished operant response. During the nonreinforcement period (postreinforcement pause) on FR or FI schedules, for example, rats given access to a water source drink large amounts. The amount exceeds what the rat would consume if an equivalent amount of food to that earned in a session were given to the animal en masse (e.g., Roper, 1981). In general, schedule-induced behavior, also labeled *adjunctive behavior,* occurs during periods of chronic or local nonreinforcement as a function of having an appropriate stimulus object present. Licking a stream of compressed air, pica, wheel running, and even stereotyped motor patterns such as neck stretching and presenting or grooming have all been shown to occur during periods of nonreinforcement (e.g., Staddon, 1977).

Extinction-induced behavior also has been reported with human participants. For example, polydipsia has been found when the responding of young children is reinforced according to an FI schedule (Porter, Brown, & Goldsmith, 1982). Adults with and without developmental disabilities engaged in increased durations of stereotyped behavior during interval and time-based schedules as the schedule values increased (e.g., Hollis, 1973; Wieseler, Hanson, Chamberlain, & Thompson, 1988). Such induced responding has been suggested to be a mechanism through which increases in drug taking might occur. Human participants, for example, drank more beer while playing a gambling game when game play is reinforced according to a FI 90-s schedule than during an FI 30-s schedule (Doyle & Samson, 1985), and smokers took puffs as a bitonic function of the schedule value (Cherek, 1982). There is generally a bitonic relation between reinforcement rate and the rate of induced responding: As reinforcement decreases, schedule-induced responding increases to a point and thereafter decreases.

Stimulus Generalization and Extinction

Stimuli similar to those in effect during extinction may control lower rates of responding than stimuli less similar to the extinction-correlated stimuli. Tests of stimulus generalization gradients around the S− typically use an S− that is on a different dimension than the S+. Thus, for example, with pigeons one might use a red key light as the S+ and a black vertical line on a white background as the S−. If, after training a discrimination, variations in the angle of the line are superimposed on the red background (e.g., 75°, 60°, 45°, 30°, 15°, and 0° of line tilt), responding typically increases the more dissimilar the line is to the original S− (the vertical line). That is, stimuli less like the S− are more likely to generate responding (e.g., Farthing & Hearst, 1968). This stimulus generalization gradient also has been interpreted by some to suggest that extinction also induces a tendency to not respond to stimuli that are more like the S− (i.e., inhibition; Hearst, Besley, & Farthing, 1970). Thus, children whose responding is extinguished in one classroom may tend to be, other things being equal, similarly unresponsive in similar settings.

Positive Behavioral Contrast

When two or more schedules of reinforcement are in effect either successively (a multiple schedule) or concurrently, extinguishing responding on one of them increases responding in the unchanged component relative to the preceding baseline (Reynolds, 1961; see Williams, 1983, for a review). This effect is labeled *positive behavioral contrast* (hereinafter, *contrast*). Although such behavioral contrast often is described as an increase in responding in the unchanged component in the context of response decreases in the other component, this description is something of a misnomer because its controlling variable is not response rate but (largely) reinforcement rate (e.g., Halliday & Boakes, 1971; Terrace, 1966).

The time course of contrast has been the subject of several experiments. When Terrace (1966) removed reinforcement from one component of a multiple VI–VI schedule, response rates in the unchanged component increased substantially relative to the preceding condition, but this effect dissipated over the following 60 sessions. An absence of contrast was observed when extinction was faded in Terrace (1963), leading Terrace to conclude that introducing extinction through a fading procedure (see the Sudden Versus Gradual Introduction of Extinction section) was functionally different than allowing responding to occur in the presence of the S−. Williams (1983) noted that experiments showing contrast to be a sustained effect and not a transient one (Hearst, 1971; Selekman, 1973) undermine Terrace's conclusion "that contrast is a byproduct of discrimination learning in which the negative stimulus (S−) acquires aversive properties because of its association with nonreinforced responding" (p. 358).

Contrast obtained with pigeons as subjects is an exceptionally reliable and robust finding, particularly when extinction is used in the alternate condition. It occurs across a variety of reinforcement conditions, including both positive (e.g., Reynolds, 1961) and negative reinforcement (Wertheim, 1965). It also has been observed in rats and humans, but, as Williams (1983) has cautioned, because so much of the research on behavioral contrast involved pigeons, the question remains open as to whether contrast effects reported in other species yield the same functional relations as do those with pigeons.

Only a few studies have examined contrast in the context of application, and they typically have yielded weak, transient, or no contrast. For example, Koegel, Egel, and Williams (1980) found only transient contrast. Kistner, Hammer, Wolfe, Rothblum, and Drabman (1982) found no evidence of contrast in the context of classroom token economies. This general absence of contrast in applied settings could be related to the nature of the responses under study and the inclusion of multiple treatment components in these investigations. Even human behavioral contrast in laboratory studies with nonclinical participants, which precludes both of these elements, is generally weak in comparison to the findings with pigeons (e.g., Edwards, 1979; Hantula & Crowell, 1994; Tarbox & Hayes, 2005; but see Waite & Osborne, 1972). Contrast, of course, is not the only phenomenon in which there are differences between humans and nonhumans, and the question remains as to whether these effects are functional or procedural (e.g., Perone, Galizio, & Baron, 1988).

Despite the paucity of demonstrations of behavioral contrast in humans, laboratory demonstrations of the effect have implications for using extinction in applied settings because the conditions that produce contrast in the laboratory also occur in extralaboratory settings. For example, during a child's school day, one teacher might reinforce appropriate behavior, but another teacher might stop doing so (appropriate behavior would be placed on extinction). During this arrangement, contrast might be expected to occur as an increase in appropriate behavior in the former classroom. Similarly, a teacher might reinforce problem behavior while the parents judiciously implement extinction for that behavior. The teacher may see an increase in problem behavior at school after the parents start extinction at home, even though the reinforcement contingencies at school remain unchanged. Such findings were reported by Wahler, Vigilante, and Strand (2004).

Spontaneous Recovery

Spontaneous recovery, the recurrence of the previously reinforced response at the onset of successive periods of extinction, has been reported widely (e.g., Rescorla, 2004). Skinner (1933a) initially labeled the effect as a loss of extinction, but subsequently he too labeled it spontaneous recovery (Skinner, 1938).

Skinner (1950) accounted for spontaneous recovery in terms of stimulus control, specifically, in terms of the discriminative stimuli present at the beginning of each experimental session. During conditioning, responses are reinforced after handling the organism and placing it in the experimental situation. When present during extinction, he reasoned, these same stimuli result in increased responding. Skinner proposed that extinction without spontaneous recovery could be achieved only if the organism is exposed to these presession stimuli in conjunction with extinction over several occasions.

Support for Skinner's (1950) analysis has been mixed. Consistent with this analysis, D. R. Thomas and Sherman (1986, Experiment 1) found spontaneous recovery only when the handling stimuli during extinction were the same as those during conditioning (see also Welker & McAuley, 1978). In another experiment (D. R. Thomas & Sherman, 1986, Experiment 2), however, pigeons tested after normal handling before an extinction session showed no more spontaneous recovery than pigeons that remained in the experimental chamber before the extinction session. Furthermore, in a third experiment, spontaneous recovery increased if the pigeon was transported to the chamber before the extinction session in a different cage than the one used to transport it during conditioning. These latter two experiments suggest that the stimuli associated with handling during conditioning might play a minimal role in spontaneous recovery.

Kendall (1965), by contrast, provided support for Skinner's (1950) interpretation by showing that spontaneous recovery can be found at any time during a session if the discriminative stimuli resemble those in the training condition. Kendall first maintained key pecking of pigeons on a VI schedule with the chamber and key lights on. Next, he alternated periods of time out, during which all the lights in the chamber were off, and time in, during which the chamber lights were identical to those used during the VI training. Extinction was in effect in both time out and time in. Kendall reasoned that responding was extinguished in the time-in periods only after the presentation of the time out. So, after responding was eliminated, he tested for spontaneous recovery by alternating periods of time out and time in during the first 45 min of the session, followed by removal of the time-out periods. Removing the time-outs increased time-in responding, as would be expected with spontaneous recovery. When the time-out periods were removed, the discriminative stimuli uniquely correlated with extinction were eliminated and responding recurred (cf. Reynolds, 1964).

This mixed evidence has precluded general acceptance of Skinner's (1950) account of spontaneous recovery. Rescorla (2004), for example, observed that the finding that spontaneous recovery is larger with longer times between exposure to extinction and the spontaneous recovery test (e.g., Quirk, 2002) cannot be explained by appealing to stimuli present at the onset of extinction. As Rescorla noted, additional research is necessary to identify the variables responsible for spontaneous recovery.

Lerman, Kelley, et al. (1999) reported spontaneous recovery of problem behavior (screaming) when a relatively small-magnitude reinforcer (10-s access to toys) was discontinued in extinction. Little spontaneous recovery occurred, however, when a large reinforcer (60-s access to toys) was used. In a related experiment, Homme (1956) exposed groups of rats to one conditioning session in which 15, 50, 100, or 250 water reinforcers were delivered according to a CRF schedule. Spontaneous recovery during five sessions of extinction increased between groups as the number of reinforcers increased. There also was more spontaneous recovery when 250 reinforcers were delivered across five sessions of conditioning than when the same 250 reinforcers were delivered in a single session. Waller and Mays (2007) suggested that when extinction-induced aggression occurs, it is actually the spontaneous recovery of previously reinforced aggression. Without additional data, however, it is difficult to say whether such aggression is most usefully categorized as an instance of spontaneous recovery, reinstatement, or resurgence (the latter two topics are discussed next).

Resistance to Reinforcement

Even though a response is reduced to zero or near-zero probability as a function of nonreinforcement, the response typically recurs under appropriate conditions (see also the Stability and Variability Functions of Extinction section). It is thus of interest to assess whether different conditions of extinction result in differential recurrence or regeneration of the eliminated response. Just as resistance to extinction after some condition of reinforcement indexes the effectiveness or strength of a reinforced response (e.g., Hull, 1943; Nevin, 1974, 1979; Chapter 5, this volume), resistance to reinforcement after extinction has been proposed to index the strength of a nonreinforced response. For example, after establishing stimulus control around a vertical line S−, Hearst et al. (1970) reinforced responding in the presence of all stimulus configurations. During the first four sessions, the gradient had the classic inhibitory stimulus control V form, but thereafter the gradient flipped such that it formed an inverted V, ending with peak responding at S−. The results during the first four sessions attest to the persistence of the suppressive effects of the S− in the face of reinforcement. Hearst et al. concluded that "the resistance to reinforcement technique is both a feasible and sensitive procedure for studying generalization along a dimension of S−" (p. 396).

As a part of their comparison of the relative resistance to reinforcement of extinction and DRO, Uhl and Garcia (1969) reintroduced a VI schedule after first reducing responding of two groups of rats to near zero with one of the two procedures. When the VI schedule was reintroduced, there was no attempt to induce or otherwise evoke the formerly reinforced lever-press response. When a lever press occurred, however, it was and continued to be reinforced according to the VI schedule. Although responding was more resistant to reinforcement for the group previously exposed to DRO than to extinction, the differences between the conditions were not statistically significant. The analysis was confounded, however, because response rate increased across the 5-minute periods. The analysis of variance used to compare response rates after extinction and after the DRO was based on means for the entire time period, with a variance that included changes in responding from the beginning to the end of the 20-min period. In another experiment, however, using a similar design, responding on a VI schedule increased more slowly after exposure to DRO than to conventional extinction. A statistically significant interaction between the effects of the previous schedule, either DRO or extinction and the number of sessions of exposure to extinction, substantiated this result.

Rieg et al. (1993) found that responding eliminated by using longer (18- or 36-s) DRO values to eliminate lever pressing by rats was more resistant to reinforcement than responding eliminated by using shorter (2- or 4-s) DRO values. A potential obstacle in using resistance to reinforcement as a test of the efficacy of extinction in eliminating behavior is that of understanding the variables that might cause a previously eliminated response to recur. Perhaps some of the research on variables controlling response acquisition with delayed reinforcement (e.g., Lattal & Gleeson, 1990) in the absence of any form of response training might be useful in isolating some of the controlling variables of renewed responding of extinguished responses.

Reinstatement

Reinstatement is similar to the resistance-to-reinforcement test, the difference being that reinstatement involves the response-independent delivery of what previously functioned as a reinforcer for the response; in resistance-to-reinforcement tests, the delivery is response dependent. Franks and Lattal (1976) maintained lever-press responding of rats on a VR schedule before reinforcement was eliminated and the response extinguished. Then an FT 30-s schedule was introduced. After the first food pellet, responding increased rapidly and remained high for some time before eventually slowing to a low rate. The entire sequence then was repeated, but instead of using a VR schedule during the reinforcement condition, a DRL schedule was used. When the food pellets were delivered independently of responding after extinction of the lever-press response, responding was reinstated, but at a much lower rate than occurred when the VR schedule was used in training. Franks and Lattal interpreted the different reinstated response rates as evidence that the food pellets functioned as discriminative stimuli controlling the previously reinforced response rates (cf. R. H. Thompson et al., 2003). That is, during the reinforcement phase, the food pellets functioned as discriminative stimuli for continued high- or low-rate responding, depending on whether the schedule was VR or DRL. Reinstating the pellets after extinction therefore reinstated the discriminative stimulus for different rates of response, with the results just described. Similar effects were reported earlier when children with developmental delays were exposed to similar conditions by Spradlin, Girardeau, and Hom (1966) and Spradlin, Fixen, and Girardeau (1969).

A variation of reinstatement is renewal (Bouton & Bolles, 1979), in which responding in one environment is reinforced, followed by extinction of the operant response in a second environment. When returned to the original environment, the response recurs (e.g., Nakajima, Tanaka, Urshihara, & Imada, 2000). Thus, in both renewal and reinstatement, discriminative or contextual stimuli previously associated with reinforcement are re-presented. In renewal, it is replacement in an old environment, and in reinstatement, it is reinstating the previous reinforcer, albeit independently of responding.

Exposure therapies used to treat phobic behavior (e.g., Dirikx, Hermans, Vansteenwegen, Baeyens, &

Eelen, 2007) or drug-seeking behavior (e.g., See, 2002; Shaham & Miczek, 2003; Shalev, Erb, & Shaham, 2010) also exemplify reinstatement. In these contexts, reinstatement typically refers to the reemergence of undesired behavior when reintroduced to stimuli in the presence of which the response previously occurred. (The term *reinstatement* is used in a different way to describe some treatment procedures promoting positive behavior. Under these circumstances, however, the reinstatement refers not to a response but to a response-dependent reinforcer after a hiatus during which reinforcement was omitted; e.g., Hoyer, Kafer, Simpson, & Hoyer, 1974).

Resurgence

Resurgence is the recurrence of previously reinforced responding when a more recently reinforced response is extinguished. The procedure involves three phases. In the first, reinforcement, phase, a response is reinforced. Reinforcement of the first response then is discontinued concurrently with the reinforcement of a second response in the second, alternative reinforcement, phase. When the second response is extinguished in the third, resurgence, phase, resurgence is manifest as a transient reoccurrence of the first response, even though it is not reinforced. Another procedure involves continuously recording patterns of responding (e.g., keystrokes on a keyboard in humans) during conditioning and then comparing them with the patterns observed during extinction. In this case, resurgence is manifest as the reappearance of patterns reinforced during the earlier exposure to conditioning, but not of patterns occurring during more recent exposure (Carey, 1951; Mechner et al., 1997). Resurgence may be considered a generative effect of extinction in that the extinction of a response is likely to bring about, at least transiently, the recurrence of previously reinforced responses. The provenance of these resurged responses is presumably the organism's past experiences.

The responding that occurs during the resurgence phase depends on events in each of the aforementioned phases (see Lattal & St. Peter Pipkin, 2009, for a review). Responding established in the first, reinforcement phase is the basis for the resurgence. The importance of the parameters of the reinforcement phase was demonstrated by da Silva, Maxwell, and Lattal (2008), who used a concurrent VI 1-min–VI 6-min schedule in the reinforcement phase. After eliminating responding to both by using a DRO contingency in the alternative reinforcement phase, the two responses resurged differentially in terms of absolute response rates, as a function of the schedule in effect during the reinforcement phase. The effects of the duration of the reinforcement phase are less clear. Bruzek, Thompson, and Peters (2009, Experiment 2) examined resurgence of caregiving responses of human subjects who were instructed to provide care to a simulated infant. Two responses were reinforced by successfully terminating crying. The first-established response was reinforced until the participant engaged in the response for 5 consecutive min across three sessions. The second-established response had a relatively shorter reinforcement history (until the participant engaged in the response for 5 consecutive min in one session). During the resurgence phase, five of eight participants showed more resurgence of the first and longer trained response in the reinforcement phase. None of the participants showed greater resurgence of the second, more briefly trained response (see also Leitenberg, Rawson, & Mulick, 1975). Lieving and Lattal (2003), however, did not find systematic differences in resurgence as a function of five or 30 sessions of training the response in the reinforcement phase with pigeons.

An important question in assessing the resurgence effect is whether resurgence is simply an artifact of a failure to extinguish (to zero) the response trained in the reinforcement phase during the alternative reinforcement phase. Cleland, Foster, and Temple (2000) replicated an earlier finding of Leitenberg, Rawson, and Bath (1970), suggesting that extinguishing the response trained in the reinforcement phase attenuates resurgence. Epstein (1983), however, extinguished key pecking of pigeons established in the reinforcement phase before reinforcing an alternative response in the second phase, as did Lieving and Lattal (2003) and Bruzek et al. (2009). Despite the extinction of the first-established response, resurgence was still manifest when the second response was extinguished in the resurgence phase of the experiment. Related to this, after establishing key pecking in the reinforcement phase, da Silva et al. (2008) used a DRO schedule in the second phase such that the key-peck response was functionally extinguished until it reached the point that a pause occurred that was sufficiently long to meet the DRO contingency. Responding resurged in the third phase, even though the key-peck response was eliminated in the second phase. These experiments together present a mixed picture of the role of extinguishing or failing to extinguish the first response on subsequent resurgence. It does appear, however, that under some conditions resurgence is not simply a result of the first-established response failing to extinguish in the second phase.

Resurgence occurs most reliably when the second response is extinguished, as opposed to having its rate of reinforcement reduced. Lieving and Lattal (2003) found that only small, temporary increases in response rates occurred when the reinforcement schedule for the alternative response was changed from a VI 30-s to VI 360-s schedule. Resurgence occurred to a much greater extent, however, when both responses were extinguished. Volkert, Lerman, Call, and Trosclair-Lasserre (2009) used a procedure similar to that of Lieving and Lattal, but with children with developmental disabilities who engaged in problem behavior. In addition, Volkert et al. reinforced behavior on FR 1 schedules during the reinforcement and alternative reinforcement phases. The resurgence test consisted of abruptly thinning the reinforcement schedule for appropriate behavior from FR 1 to FR 12. Rates of problem behavior increased for all three participants, but an extinction condition that immediately followed was not conducted, so relative magnitudes of resurgence could not be assessed.

Lattal and St. Peter Pipkin (2009) observed that in application, the behavior that resurges can be either beneficial or detrimental. On one hand, resurgence has been described as the crucible of creativity and problem solving (Epstein, 1985a, 1985b) in that the extinction of well-established behavior patterns generates responses that can serve as the basis for a creative or novel solution to a problem that was intransigent to previously successful solutions. On the other hand, extinguishing a response can lead to the resurgence of problem behavior that has in the past been reinforced.

Extinction as an Establishing Operation for Other Behavior

Depending on the circumstances, extinction can serve as an establishing operation for responding that eliminates, postpones, or produces periods of nonreinforcement. Both J. R. Thomas (1965) and DeFulio and Hackenberg (2007) provided evidence that escape or avoidance responding by a pigeon can be maintained if the response allows escape from or postponement of a period of nonreinforcement that otherwise would be imposed during a schedule of positive reinforcement maintaining a second response. Because the necessary condition for the escape or avoidance response is the period of nonreinforcement of the other response, the extinction period may be described as an establishing operation for maintaining such escape or avoidance.

By contrast, Perone and Galizio (1987) maintained responding using a shock-avoidance schedule. They then arranged a contingency such that responding on a second operandum produced a discriminated period in which the negative reinforcement schedule was suspended (a time-out or extinction period). Thus, the extinction period made available in this way established and then maintained an operant response that produced it.

CONCLUSION

The experimental analysis of operant extinction has methodological, theoretical, and applied implications extending beyond the findings of any particular experiment reviewed in this chapter. Methodologically, many extinction processes related to both elimination and generation of responding epitomize what Sidman (1960) called a *transition state*. Transition states characterize not only extinction and acquisition of simple operant responses but also describe many significant behavioral processes in everyday life, such as acquiring new skills, kicking bad habits, making new friends, and ending bad relationships. The methods of analysis of transitional processes of extinction hold the promise of offering new methods for studying other important, but often neglected, transition states.

Three theoretical comments are suggested by the experimental investigations of operant extinction that have been discussed. First, extinction has been defined in different ways with, unsurprisingly, varied behavioral effects. Second, extinction effects generally are contextual and situational and not permanent, although research in applied behavior analysis, in particular, has suggested ways of achieving more permanent behavior change through variations on extinction and extinction in combination with other behavioral techniques. The third theoretical point concerns the attribution of response elimination and generation to the extinction operation per se. Extinction operations may strengthen or weaken responses directly, but they also may have, or fail to have, their effects indirectly as a result of or in concert with other processes such as discriminative stimulus control or adventitious reinforcement (as with removal of the response–reinforcer dependency) or satiation (in the case of FT schedules in some applications).

The implications of extinction research for application are both broad and myriad, making extinction ripe for still further translational research. In undertaking such research, the devil remains in the details. As was noted throughout the chapter, extinction incorporates a number of procedures and behavioral effects in both basic and applied research in behavior analysis that preclude a singular characterization of it. This makes it essential that the processes being translated correspond to the "original text," that is, to specific extinction operations in the basic science and not to extinction as a generic construct.

The roots of extinction extend both to the beginning of behavior analysis (recall, e.g., that extinction was at the serendipitous birth of the FI schedule) and well beyond the bounds of contemporary behavior analysis into other psychological and neurophysiological scientific worldviews. The research reviewed in this chapter attests to its impact on both the elimination and the generation of behavior, both historically and contemporaneously. Despite its longevity and the wealth of data on its effects, operant extinction continues to be a wellspring of new research problems and new promises for understanding the reinforcement process and its translation into useful applications.

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CHAPTER 5

RESPONSE STRENGTH AND PERSISTENCE

John A. Nevin and David P. Wacker

The notion that responses vary on a dimension called *strength* goes back to the very beginning of behavioral psychology. Thorndike (1911) identified the strength of a learned connection between a stimulus situation and a response with the probability that the stimulus would occasion the response. To distinguish between the strengths of two responses, both of which occurred with a probability of 1.0 in their respective situations, Thorndike (1913) suggested that strength could also be identified with resistance to distraction or persistence through time (i.e., resistance to forgetting). Pavlov (1927/1960) identified the strength of a conditional response with its amplitude and latency, but he also referred to the persistence of the response during disruption by a novel stimulus or its resistance to experimental extinction as an indicator of strength. Thus, in foundational work on learned behavior nearly 100 years ago, the notion of strength included the persistence of a response as well as its amplitude, latency, or probability.

Skinner (1938) argued that probability of response was the proper measure of its strength, and because of his emphasis on free operant behavior, for which probability is not directly measurable, he identified response strength with response rate. As research on operant behavior advanced during the second half of the 20th century, emphasis shifted from changes in response rate during acquisition or extinction to the steady-state properties of responding after extensive exposure to schedules of reinforcement, and the identification of strength with response rate became less useful. For instance, if reinforcers are contingent on responses that are closely spaced or widely separated in time, subjects respond at or near the required rates of responding (e.g., Blackman, 1968). Likewise, if a subject is required to respond with high or low force on the operandum to obtain reinforcers, its responses generally conform to the contingency (e.g., Notterman & Mintz, 1962). As a result of these and many related observations, effects of reinforcers on various aspects of steady-state performance, including response rate and amplitude, were interpreted in terms of differentiation and selection by contingencies rather than as reflections of a unitary construct of strength (see Morse, 1966, for a review of basic research on contingencies of reinforcement and steady-state operant behavior).

Skinner (1938) also suggested that reinforcers create a "reflex reserve" that could be evaluated by discontinuing reinforcement—that is, extinction. Although Skinner later disavowed the concept of the reserve, his work set the occasion for hundreds of studies on the relation between the conditions of reinforcement and subsequent resistance to extinction. For example, in an early parametric study, Wilson (1954) varied the fixed interval between

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reinforcers from 0 seconds (every response was reinforced; continuous reinforcement) to 360 seconds (first response emitted after 360 seconds was reinforced) during training across groups of rats. He found that average response rate during extinction after training at a fixed interval of 0 seconds was lower than after any of the other fixed-interval schedules—an instance of the well-known partial reinforcement extinction effect—and that across all fixed-interval schedules, resistance to extinction was negatively correlated with response rate during training. The general implication is that response rate during training with a given contingency and resistance to extinction when training ends cannot both reflect a single attribute of behavior that encompasses response strength and persistence and is related in an orderly way to the conditions of reinforcement (see Kling, 1971, for a summary of relevant research).

SEPARATING THE DETERMINERS OF RESPONSE RATE AND PERSISTENCE

A series of articles by Nevin and his colleagues distinguished between response rate in the steady state and the persistence of responding during disruption or extinction by way of a metaphorical extension of Newtonian physics (see Nevin & Grace, 2000, for a review). The rate of steady-state operant responding was taken to be analogous to the velocity of a body moving under constant conditions, and an independent aspect of behavior analogous to inertial mass was inferred from the resistance to change of response rate when a disruptor analogous to an external force was applied. By analogy to Newton's Second Law, behavioral momentum theory proposes that changes in response rate are directly related to the magnitude of the disruptor and inversely related to behavioral mass, which in turn depends directly on the rate of reinforcement.

Most of the research on resistance to change has used multiple schedules of reinforcement in which two or more different conditions of reinforcement are presented in successive components, signaled by different stimuli, within an experimental session. Each component makes up a discriminated operant defined by the stimulus, the response, and the conditions of reinforcement, which Skinner (1969) suggested as a fundamental unit for the analysis of behavior. Methodologically, this procedure permits an experimenter to compare the effects of the conditions of reinforcement on steady-state response rate and resistance to change within subjects and sessions.

The independence of response rate in the steady state and its resistance to change in the components of multiple schedules may be illustrated by comparing the results of Nevin, Mandell, and Atak (1983) with those of Fath, Fields, Malott, and Grossett (1983). Both studies used pigeons as subjects in two-component multiple schedules in which the components were 1 minute long and separated by 30-second intercomponent intervals (ICIs). Nevin et al. (1983) arranged standard variable-interval (VI) schedules with different rates of reinforcement in two components, whereas Fath et al. (1983) arranged so-called pacing contingencies requiring different response rates with equally frequent reinforcement in two components. In occasional sessions, steady-state responding was disrupted by presenting response-independent food during ICIs; Nevin et al. varied the rate of ICI food, whereas Fath et al. varied its duration. The results of these studies are compared in Figure 5.1. Baseline response rates are presented in the upper panels, showing that Nevin et al. obtained similar baseline response rates in the VI components despite the difference in reinforcer rates, whereas Fath et al. obtained substantially higher baseline response rates in the high-rate pacing component despite the similarity of reinforcer rates.

To remove differences in baseline rate from comparisons of resistance to change between components and studies, response rates in ICI food sessions were expressed as proportions of baseline in the immediately preceding sessions. Proportions of baseline are presented in the lower panels of Figure 5.1, showing that proportions were consistently greater in the component with the higher reinforcer rate in the Nevin et al. (1983) data, whereas proportions of baseline were similar in the Fath et al. (1983) data; if anything, response rates were proportionately lower in the high-rate component. Taken all together, these data suggest that baseline response rate depended on the response–reinforcer contingencies, which differed between components

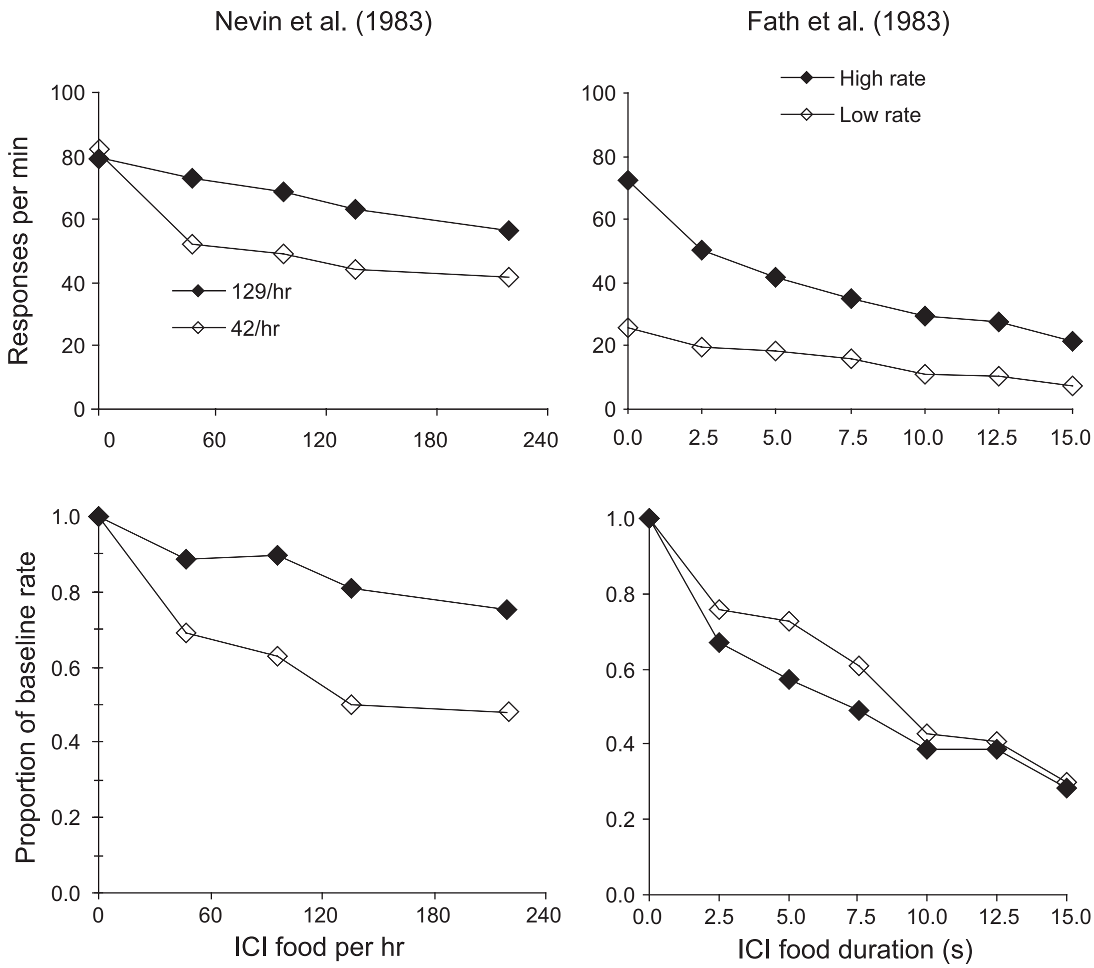

FIGURE 5.1. **Results of multiple-schedule studies by Nevin et al. (1983; left column), with different variable-interval schedules in the components, and Fath et al. (1983; right column), with the same variable-interval schedules but different contingencies on response rate in the components. The upper panels present average response rates in baseline (over 0 on the *x*-axis) and in 1-hour tests of resistance to change with response-independent food during intercomponent intervals (ICIs). In the lower panels, the ICI food data are expressed as proportions of the preceding baseline response rates in each component. Comparison across studies suggests that resistance to change depends on rate of reinforcement independent of response–reinforcer contingencies. From "An Integrative Model for the Study of Behavioral Momentum," by J. A. Nevin, 1992, *Journal of the Experimental Analysis of Behavior, 57,* p. 303. Copyright 1992 by the Society for the Experimental Analysis of Behavior, Inc. Adapted with permission.**

for Fath et al., whereas resistance to change relative to baseline depended directly on reinforcer rates, which differed between components for Nevin et al.

The latter result—greater resistance to change in the richer of two multiple-schedule components—has been replicated with humans, goldfish, monkeys, rats, and pigeons as subjects, with several different reinforcers, and with disruptors including deprivation change, punishment, signaled shock, increased effort, and extinction (for reviews, see Nevin, 1979, 1992).

The direct relation between persistence and reinforcer rate may, however, depend on frequent within-session alternation of signaled conditions of reinforcement, as in multiple schedules. A thorough series of experiments by Cohen, Riley, and Weigle (1993) compared resistance to change on single and multiple schedules with rats and pigeons as subjects. They found that on single schedules including VI, variable ratio, fixed interval, and fixed ratio, resistance to prefeeding or to concurrent response-independent food was largely independent of reinforcer rate, and resistance to extinction was inversely related to reinforcer rate. By contrast, when similar schedules were arranged in multiple-schedule components, resistance to prefeeding, to ICI food, and to extinction were greater in the richer component, replicating the findings described earlier. Cohen (1998) subsequently showed that the usual findings depended on frequent within-session alternation of signaled reinforcer rates, as in conventional multiple schedules. Cohen's findings challenged the generality of the relation between persistence and reinforcer rate, but a direct relation between persistence and reinforcer rate has been obtained in translational studies, discussed later, that arranged successive conditions. Therefore, the difference between single and multiple schedules is a problem to be addressed by parallel analyses in basic and translational settings; its resolution may depend on identifying stimulus–reinforcer relations in single schedules (see Pavlovian Determiners of Persistence section).

Resistance to extinction poses a separate problem. Although several studies, including Nevin (1974), Nevin et al. (1983), and Cohen et al. (1993), obtained greater resistance to extinction in the richer of two multiple-schedule components with relatively infrequent intermittent reinforcement, the result must be qualified by the well-known *partial reinforcement extinction effect* (PREE; see Chapter 4, this volume). PREE refers to the observation that resistance to extinction is usually greater after intermittent reinforcement than after continuous reinforcement (as noted earlier for the study by Wilson, 1954). The PREE is contrary to the usual direct relation between persistence and reinforcer rate because continuous reinforcement is the highest possible reinforcer rate and nevertheless leads to more rapid extinction when reinforcement is terminated.

For disruptors such as deprivation change, punishment, signaled shock, and increased effort, reinforcement schedules can remain in effect, and the magnitude of the disruptor is the same for both rich and lean conditions of reinforcement. This may be approximately true for extinction when reinforcers are infrequent in both components, and many experiments have found that resistance to extinction is greater in the richer of two components when both arrange intermittent schedules such as VI 1 minute versus VI 3 minute. When one component arranges continuous reinforcement, however, the transition to nonreinforcement entails a substantially greater change in the stimulus situation than does the transition from intermittent reinforcement. If situation change is construed as a disruptor, then the magnitude of the disruptor is greater for continuous than for intermittent reinforcement, and comparisons of resistance to extinction between continuous and intermittent reinforcement require that this difference in magnitude of the disruptor be taken into account. Nevin and Grace (2000) proposed a way to quantify the disruptive effects of reinforcer omission; their model was subsequently developed and tested by Grace, McLean, and Nevin (2003); Nevin and Grace (2005); and Nevin, McLean, and Grace (2001). The model accounts for the PREE and shows that more rapid extinction after continuous reinforcement can be consistent with the notion that the inertial mass of behavior—the tendency to resist change—is directly related to reinforcer rate.

PAVLOVIAN DETERMINERS OF PERSISTENCE

The results of several experiments have suggested that the rate of responding maintained in the steady state by a schedule of reinforcement—that is, its velocity in the momentum metaphor—depends on the operant response–reinforcer contingency, whereas its persistence during disruption—that is, its behavioral mass—depends on the Pavlovian stimulus–reinforcer relation. The results displayed in Figure 5.1 are consistent with this proposition, but the most direct demonstration is critically important for translation to applied settings, and we consider it in some detail.

Nevin, Tota, Torquato, and Shull (1990, Experiment 1) trained pigeons on a multiple schedule of reinforcement in which two distinctive stimuli—red and green keylights—were presented alternately for 3 minutes each to signal different operant and Pavlovian contingencies (see Figure 5.2). In both Components 1 and 2, key pecks were reinforced according to a VI 1-minute schedule (60 reinforcers per hour). In Component 1, food was also presented independently of responding according to a variable-time (VT) 30-second schedule (120 reinforcers

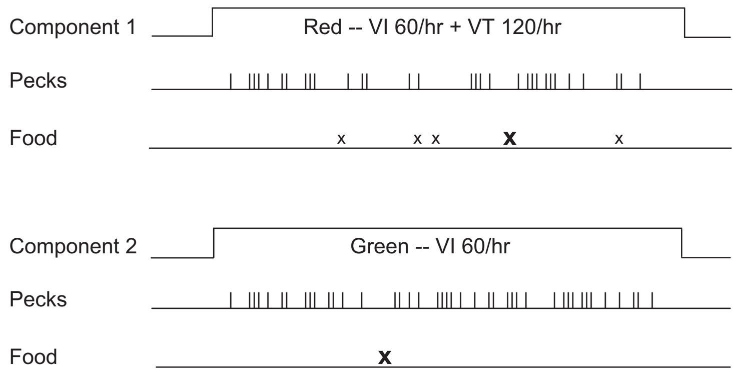

FIGURE 5.2. Timeline diagram of multiple-schedule components with variable-interval (VI) 60 seconds (60 reinforcers per hour) contingent on responding in both components and with variable-time (VT) 30 seconds (120 reinforcers per hour) added in Component 1 independently of responding. A capital X designates a VI reinforcer and lowercase x designates a VT reinforcer. From "Stimuli, Reinforcers, and the Persistence of Behavior," by J. A. Nevin, 2009, *Behavior Analyst, 32*, p. 286. Copyright 2009 by the Association for Behavior Analysis International. Adapted with permission.

per hour). Thus, the operant response–reinforcer contingency was stronger in Component 2 because all reinforcers were response dependent. At the same time, the Pavlovian stimulus–reinforcer contingency was stronger in Component 1 because its stimulus was correlated with a higher reinforcer rate.

After extensive baseline training, all three pigeons exhibited lower response rates in Component 1 than in Component 2 (left panel of Figure 5.3), consistent with the expected effects of added variable-time reinforcers (Nevin et al., 1990). However, when food reinforcers were discontinued altogether, responding was more resistant to extinction in Component 1. The right panel of Figure 5.3 presents the data for extinction expressed as proportions of baseline (see also Figures 5.4 and 5.5). Although the data exhibit a fair amount of variability, all pigeons exhibited greater proportions of baseline, averaged over sessions, in the component with added variable-time reinforcers. Similar results were obtained when the pigeons were given presession feedings in their home cages before regular sessions.

The findings of Nevin et al. (1990, Experiment 1) suggested that when conditions are altered so as to disrupt ongoing behavior, the persistence of responding depends on total reinforcement obtained in a stimulus situation rather than on the reinforcers directly contingent on that response or the rate of responding before disruption, which in turn suggests that persistence depends on Pavlovian stimulus–reinforcer relations. This result has been replicated in similar experiments using a variety of responses, reinforcers, and species (children, Tota-Faucette, 1991; college students, Cohen, 1996; rats, Grimes & Shull, 2001; Harper, 1999; Shahan & Burke, 2004; goldfish, Igaki & Sakagami, 2004). Grimes and Shull (2001) and Shahan and Burke (2004) used qualitatively different consumables for contingent and noncontingent reinforcers and obtained results similar to those of studies that used reinforcers that were qualitatively the same; the latter findings are especially important for clinical applications in which alternative reinforcers may differ from those found to maintain problem behavior.

Perhaps surprisingly, Nevin et al. (1990, Experiment 2) obtained similar results when pigeons obtained added reinforcers for an explicit alternative response rather than independently of responding. The procedure arranged three multiple-schedule components, each of which was signaled by lighting two response keys with distinctive colors; interest centered on pigeons' pecks on the right-hand key. When both keys were green (Component 1), right-key pecks produced 15 food reinforcers per hour and

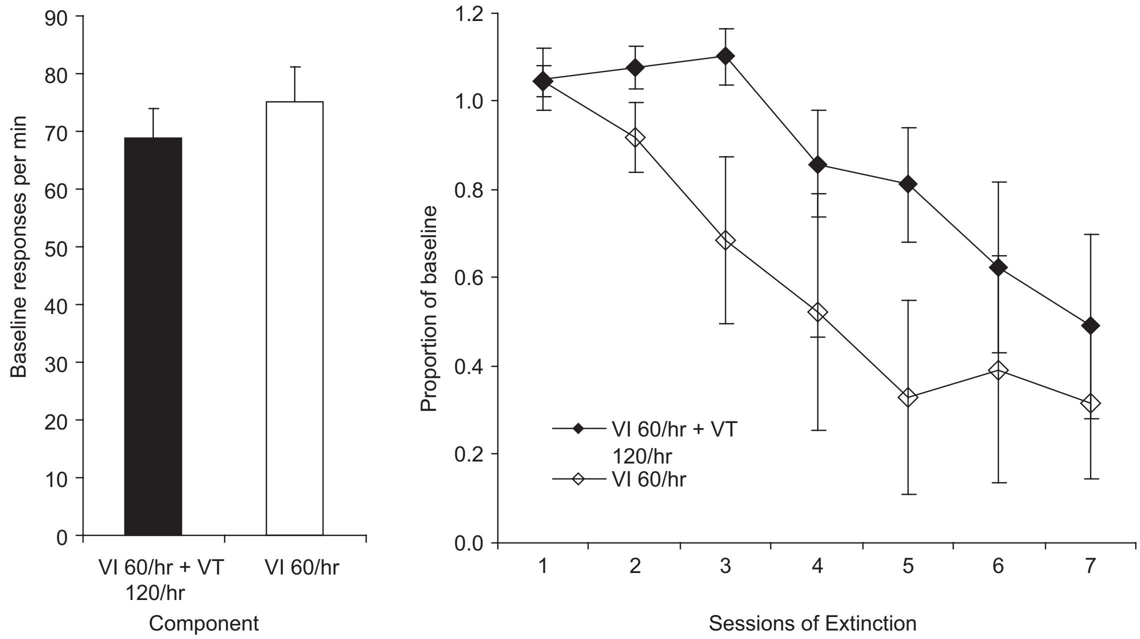

FIGURE 5.3. The left panel shows average response rates in multiple-schedule components with and without added variable-time (VT) food during baseline. The right panel shows proportions of baseline in those components during seven consecutive sessions of extinction. Although baseline rate was lower in the component with added VT food, resistance to extinction was greater. Error bars indicate the standard error of the mean. VI = variable interval. Reanalysis of data from Nevin et al. (1990, Experiment 2).

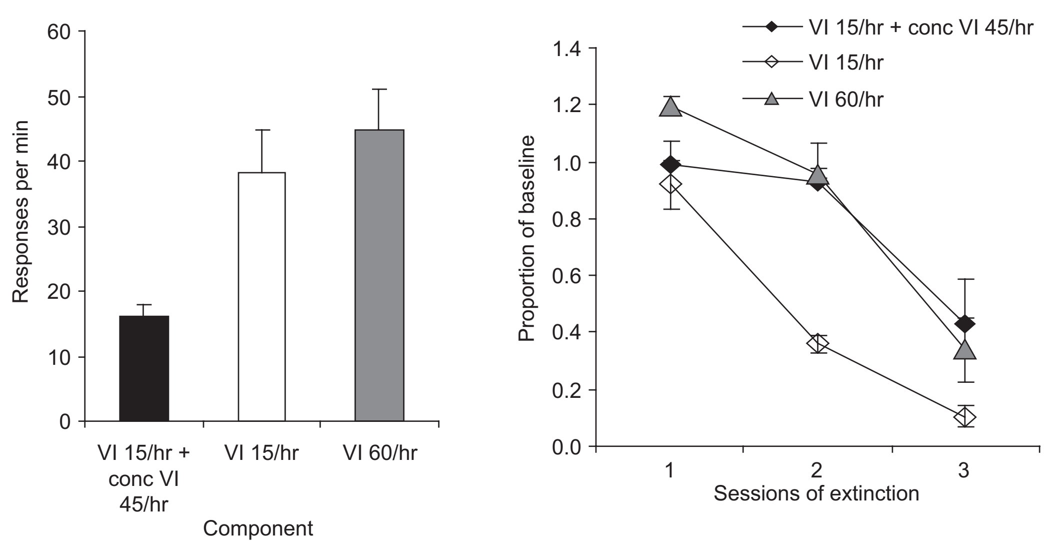

FIGURE 5.4. The left panel presents rates of responding on the right key of a two-key pigeon chamber in three multiple-schedule components when reinforcers were concurrently available on the left key in the first component; the reinforcer rates are indicated below the *x*-axis. The right panel shows the proportions of baseline for right-key responding in each component during extinction. Although right-key response rate was lower in a component with reinforcement for left-key responding, resistance to extinction was greater in that component than in components with no alternative reinforcers and was similar in components in which total reinforcement was the same. Error bars indicate the standard error of the mean. Data from Nevin et al. (1990, Experiment 1).

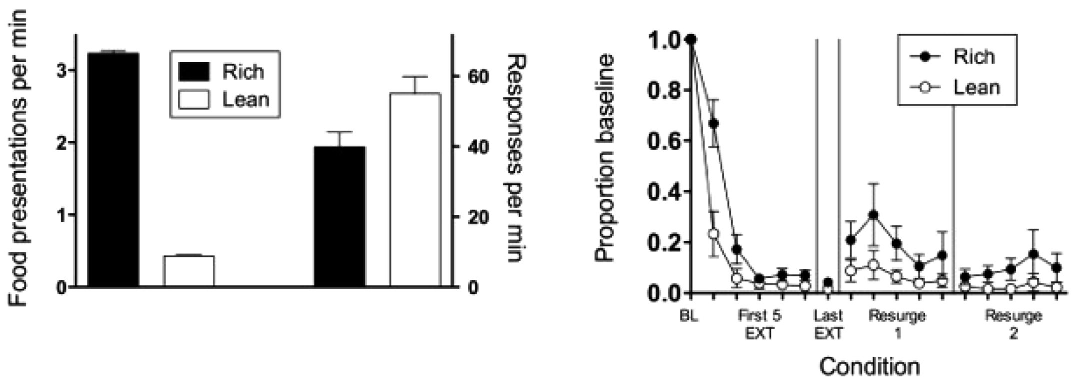

FIGURE 5.5. The left panel presents the obtained reinforcer rates (left set of bars) and baseline response rates (right set of bars) in a two-component multiple schedule with variable interval 120 seconds (30 per hour) in both components and variable time 20 seconds (180 per hour) response-independent food presentations (noncontingent reinforcers) in the *rich* component. The right panel presents mean proportions of baseline response rates from the first five sessions of extinction, the last session of extinction, and 10 sessions of the resurgence condition of Podlesnik and Shahan's (2009) Experiment 2. Error bars indicate the standard error of the mean. From "Behavioral Momentum and Relapse of Extinguished Operant Responding," by C. A. Podlesnik and T. A. Shahan, 2009, *Learning and Behavior, 37,* p. 170. Copyright 2009 by the Psychonomic Society. Reprinted with permission.

left-key pecks produced 45 food reinforcers per hour. When both keys were red (Component 2), right-key pecks produced 15 food reinforcers per hour, and left-key pecks were never reinforced. When both keys were white (Component 3), right-key pecks produced 60 food reinforcers per hour, and left-key pecks were never reinforced. Thus, Components 1 and 2 in Experiment 2 were similar to Components 1 and 2 in Experiment 1 (see preceding paragraph) in that all reinforcers were produced by a single response in Component 2, whereas additional reinforcers were available in Component 1.

The left panel of Figure 5.4 presents average steady-state baseline response rates on the right key, showing that response rate was lower in Component 1, in which alternative reinforcers were available on the left key, than in Components 2 and 3. The right panel shows that when food was discontinued altogether (extinction), proportions of baseline were higher and decreased more slowly in Component 1 than in Component 2—the same ordering observed in Experiment 1, in which alternative reinforcers were independent of responding. Moreover, proportions of baseline during extinction were similar in Components 1 and 3, suggesting that resistance to extinction depended on total reinforcers in a stimulus situation and not on their allocation between defined responses. Proportions of baseline were similarly ordered when resistance to change was evaluated by presession feeding or by satiation. The finding that the baseline rate of a target response is reduced but its resistance to extinction is increased by reinforcers for an explicit alternative response has been replicated with rats by Mauro and Mace (1996) and by Mace et al. (2010). These results join with those of Nevin et al.'s (1990) Experiment 1 and subsequent replications to demonstrate that the operant contingency between responses and reinforcers determined the steady-state rate of responding, but the Pavlovian relation between component stimuli and total reinforcers determined the persistence of that response rate during disruption. Persistence is not, however, purely Pavlovian. For example, Grace, Schwendiman, and Nevin (1998) found that when stimulus-reinforcer relations were equated between multiple-schedule components with immediate or delayed reinforcers, response rates were higher and more persistent in the immediate-reinforcer component. By contrast, Blackman (1968) and Lattal (1989) found that low-rate responding was more persistent than high-rate responding in components with equated reinforcement rates (cf. Fath et al., Figure 5.1). McLean, Grace, and Nevin (2012) have reported that when extreme reinforcer rates were arranged in multiple VI components, resistance to change was determined in part by obtained reinforcers per response. Thus, the effects of stimulus-reinforcer relations may be modulated by response-reinforcer relations in complex ways that can only be untangled by experimental analyses. Nevertheless, the basic finding that the persistence of responding in a stimulus situation is directly related to the total reinforcer rate in that situation is sufficiently general to guide application.

TRANSLATIONAL AND APPLIED ANALYSES

Although much of the foregoing material may seem terribly remote from translational research and application, the distinction between the determiners of steady-state responding and persistence has profound implications for applied settings in which reinforcement contingencies are used to treat problem behavior in people with developmental disabilities. Treatment is often preceded by a functional analysis that identifies effective reinforcers maintaining that behavior before an intervention is designed. For example, Iwata, Pace, et al. (1994) evaluated the determiners of self-injurious behavior (SIB) in 152 people with developmental disabilities and found that social positive reinforcement such as attention was effective in 26% of subjects, social negative reinforcement such as escape from task demands was effective in 38%, and automatic reinforcement such as sensory stimulation produced by SIB was effective in 26%; the remaining cases involved multiple controlling variables or were uninterpretable because of high variability in responding. Iwata, Pace, et al. also analyzed the data of 121 of these individuals for interventions using reinforcers that had been identified by functional analysis. For example, when attention was found to reinforce SIB, treatments included providing attention independently of responding (often termed *noncontingent reinforcement,* or NCR), contingent on some alternative behavior such as play (differential reinforcement of alternative behavior, or DRA), contingent on the nonoccurrence of SIB (differential reinforcement of other behavior, or DRO), or withholding attention altogether (extinction). If SIB was reinforced by escape from task demands, treatments included noncontingent removal of demands (NCR) or removal of demands contingent on appropriate behavior (DRA) as well as extinction. If SIB appeared to be maintained automatically by its sensory consequences, noncontingent access to toys (NCR) was provided during treatment. Pooling across all cases, treatments involving NCR, DRA, DRO, and extinction reduced the frequency of SIB to 10% or less of pretreatment levels in more than 80% of the participants. Comparable success rates were reported by Asmus et al. (2004) with 138 participants with developmental disabilities who engaged in problem behavior including aggression, disruption, or SIB when treatments including NCR, DRA, and extinction were arranged.

Although these success rates are impressive, these reviews do not present data on long-term outcomes when interventions involving NCR, DRO, or DRA are discontinued. Nevin et al.'s (1990) Experiments 1 and 2, and subsequent replications reviewed earlier, have suggested that these procedures, all of which increase the overall rate of reinforcement in the treatment setting, may have an undesired side effect—namely, an increase in the persistence of the self-injurious or aberrant behavior targeted for reduction by the intervention.

There is reason to believe that this problematic increase in persistence occurs in natural or treatment settings as well as in the laboratory. Mace et al. (1990) repeated Nevin et al.'s (1990) Experiment 1 with two adults with intellectual disabilities living in a group home. The response was sorting red or green utensils in multiple schedules with utensil color serving to define alternating components. Reinforcers were small cups of popcorn or coffee presented according to the same schedules as those used by Nevin et al. (1990). That is, in both components sorting was reinforced according to a variable-interval 1-minute schedule (60 reinforcers per hour), but one component included response-independent reinforcers on a variable-time 30-second schedule (120 reinforcers per hour)—the model of an NCR intervention. When response rates were stable, sorting was disrupted by presenting MTV programs on an adjacent TV set. As shown in Figure 5.6, both participants' baseline responding was lower in the component with added NCR, but during

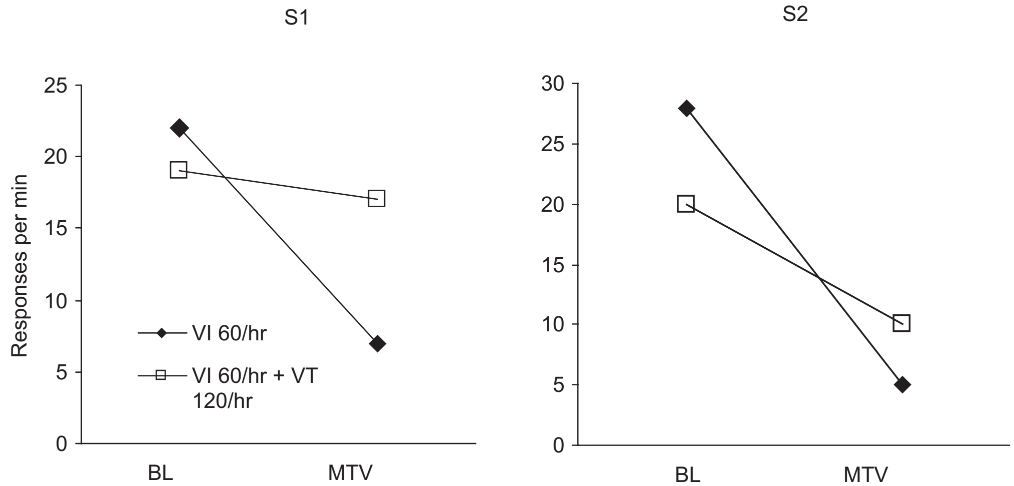

FIGURE 5.6. Rates of sorting dinnerware by two adult residents of a group home under multiple-schedule contingencies like those of Nevin et al. (1990, Experiment 1). Baseline (BL) response rate was lower and sorting was more resistant to distraction (MTV) in the component with added variable-time (VT) reinforcers. VI = variable interval. From "The Momentum of Human Behavior in a Natural Setting," by F. C. Mace, J. S. Lalli, M. C. Shea, E. P. Lalli, B. J. West, M. Roberts, and J. A. Nevin, 1990, *Journal of the Experimental Analysis of Behavior, 54,* p. 170. Copyright 1990 by the Society for the Experimental Analysis of Behavior, Inc. Reprinted with permission.

distraction, it decreased less and became higher than in the standard variable-interval component.

Mace et al. (2010) obtained similar results with three children with various developmental disabilities. Andy was a 7-year-old boy diagnosed with autism and severe intellectual disabilities who engaged in hair pulling. Tom was a 7-year-old boy diagnosed with Down syndrome and attention deficit/hyperactivity disorder who engaged in food stealing. Jackie was a 4-year-old girl with severe intellectual disabilities, microcephaly, and moderate hearing impairment who engaged in aggression and SIB. After baseline determinations of the frequency of problem behavior, all three children were exposed to treatment with DRA and extinction in various orders. For example, Andy received verbal reprimands for hair pulling in baseline. During DRA, reprimands for hair pulling continued; in addition, Andy was prompted to play with toys and received praise for doing so. During extinction, hair pulling was blocked, and all reinforcers were withheld. As shown in Figure 5.7, Andy's problem behaviors were reduced relative to baseline during the DRA interventions. A similar reduction was observed for Tom, but DRA did not reduce the frequency of problem behavior for Jackie. During extinction, however, problem behavior decreased more rapidly and to lower levels for all three participants when extinction followed baseline than when it followed DRA. For Andy and Jackie, DRA reinforcers were qualitatively different from the consequences of problem behavior. These results demonstrate that although DRA can be effective in reducing the rate of problem behavior in a clinical setting, it can also have the perverse effect of increasing the persistence of that behavior when DRA is discontinued, as suggested by the pigeon data of Nevin et al. (1990, Experiment 2; see Figure 5.4). Note that these clinical interventions with DRA were implemented in successive conditions rather than as within-session multiple-schedule components of the sort used in the research reviewed earlier. Thus, this perverse outcome is not limited to the multiple-schedule paradigm—an important finding because clinical treatment conditions are unlikely to use multiple schedules.

The studies by Grimes and Shull (2001) and Shahan and Burke (2004), cited earlier, have suggested that the problematic outcome of increased resistance to change produced by added alternative reinforcement is likely to arise in applied settings in which the reinforcer used for an intervention contingency differs from that maintaining problem

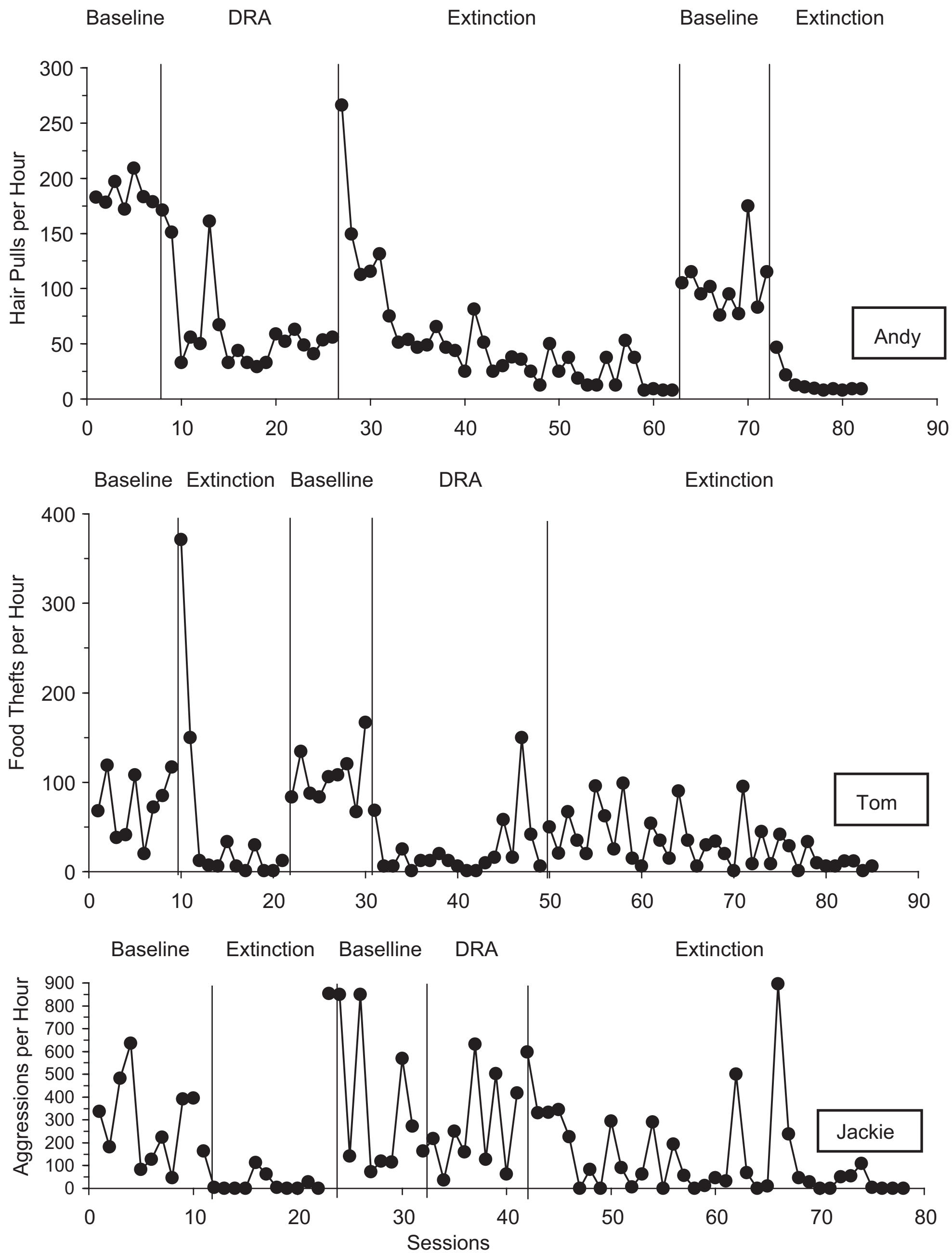

FIGURE 5.7. Rates of problem behavior in three children with intellectual disabilities during baseline, DRA intervention, and extinction. Although DRA was generally effective in reducing rates of problem behavior, responding was more persistent during extinction after DRA treatment than after baseline. DRA = differential reinforcement of alternative behavior. From "Differential Reinforcement of Alternative Behavior Increases Resistance to Extinction: Clinical Demonstration, Animal Modeling, and Clinical Test of One Solution," by F. C. Mace, J. J. McComas, B. C. Mauro, P. R. Progar, R. Ervin, and A. N. Zangrillo, 2010, *Journal of the Experimental Analysis of Behavior, 93,* p. 354. Copyright 2010 by the Society for the Experimental Analysis of Behavior, Inc. Reprinted with permission.

behavior, as for Andy and Jackie in Mace et al.'s (2010) study. Some instances of problem behavior may be maintained, at least in part, by sensory consequences that are tightly linked to the response itself, as in self-stimulatory behavior. So-called automatic reinforcement of this sort cannot be discontinued during an intervention, so that DRA or NCR necessarily involve qualitatively different reinforcers that are concurrent with reinforced problem behavior. Accordingly, an increase in persistence of that behavior is likely.

Ahearn, Clark, Gardenier, Chung, and Dube (2003) tested this prediction in a study with three children with autism who engaged in maladaptive stereotypy such as hand flapping and mouthing. Stereotypy was measured in two sequences of four sessions, with baseline conditions in the first and fourth sessions of both sequences; all sessions lasted 5 minutes, and both sequences were repeated three or four times. The results for all three participants are shown in Figure 5.8. In one sequence (left portions of each panel), the children were given noncontingent access to Toy A (NCR) in the second session; for two of the children, stereotypy was reduced relative to the preceding baseline during which no toy was available. The persistence of this level was evaluated by presenting Toy B as a distractor in the third session. All three children exhibited more persistent stereotypy in the third session of this sequence than in the corresponding session of the sequence that did not include NCR in the second session (right portion of each panel). Although the presentation of Toy B in the third session may be construed as additional NCR rather than as a distractor, the results demonstrate that NCR in the second session made stereotypy more resistant to further reduction in the third session. Thus, the persistence-enhancing effects of added reinforcers extend to cases of automatic, intrinsic reinforcement, and as shown also by the work of Mace et al. (2010), the result is repeatable in translational studies that arrange successive conditions as well as multiple schedules.

Dube, Ahearn, Lionello-DeNolf, and McIlvane (2009) have reviewed several translational studies with children with developmental disabilities in addition to the studies described earlier. They concluded that the increase in resistance to change of problem behavior as the density of reinforcement increases in the functional context, whether the context is defined by a treatment condition or a stimulus signaling a multiple-schedule component, is a general and reliable finding that is independent of whether all reinforcers are contingent on the target response.

POSTTREATMENT RECOVERY

In the study by Ahearn et al. (2003), treatment effects were transient: As shown in the rightmost columns of all panels of Figure 5.8, when baseline conditions were restored, the percentage of time spent in stereotypy returned to pretreatment levels. This result may not be terribly surprising given that treatment sessions were brief and intrinsic reinforcers for stereotypy could not be discontinued, but the same problem of posttreatment recovery may also apply in cases in which reinforcers for problem behavior can be identified by functional analyses and discontinued during a prolonged period of extinction.

When a reinforced operant is placed on extinction concurrently with reinforcement for an alternative response (DRA) and the alternative is then extinguished, the previously reinforced operant is likely to recur despite the absence of reinforcement. The term *resurgence* has been used to describe this process (e.g., Epstein, 1983, 1985; Lieving & Lattal, 2003), and a good deal of basic research with nonhuman animals has addressed its determiners. These studies typically have three phases: (a) baseline with reinforcement for a target response, (b) extinction of the target response with reinforcement for an alternative, and (c) extinction of the alternative response. The usual result is at least transient recurrence of the target response.

Resurgence is not merely a laboratory curiosity but is evident in treatment settings as well. For example, Volkert, Lerman, Call, and Trosclair-Lasserre (2009) observed resurgence of problem behavior in five children with autism or developmental disabilities who engaged in self-injury, aggression, or disruption. After functional analysis and baseline determinations (Phase 1), problem behavior was subjected to extinction, and the children were trained to request the reinforcer that had maintained their problem behavior by making an alternative response (i.e., a form of DRA known as functional communication training, or FCT; Phase 2). For all participants, problem behavior decreased to low levels and alternative behavior increased. In Phase 3, reinforcers for alternative behavior were discontinued or their frequency was sharply reduced; all participants exhibited resurgence of their original problem behavior. Thus, either extinction or reduced reinforcement for alternative

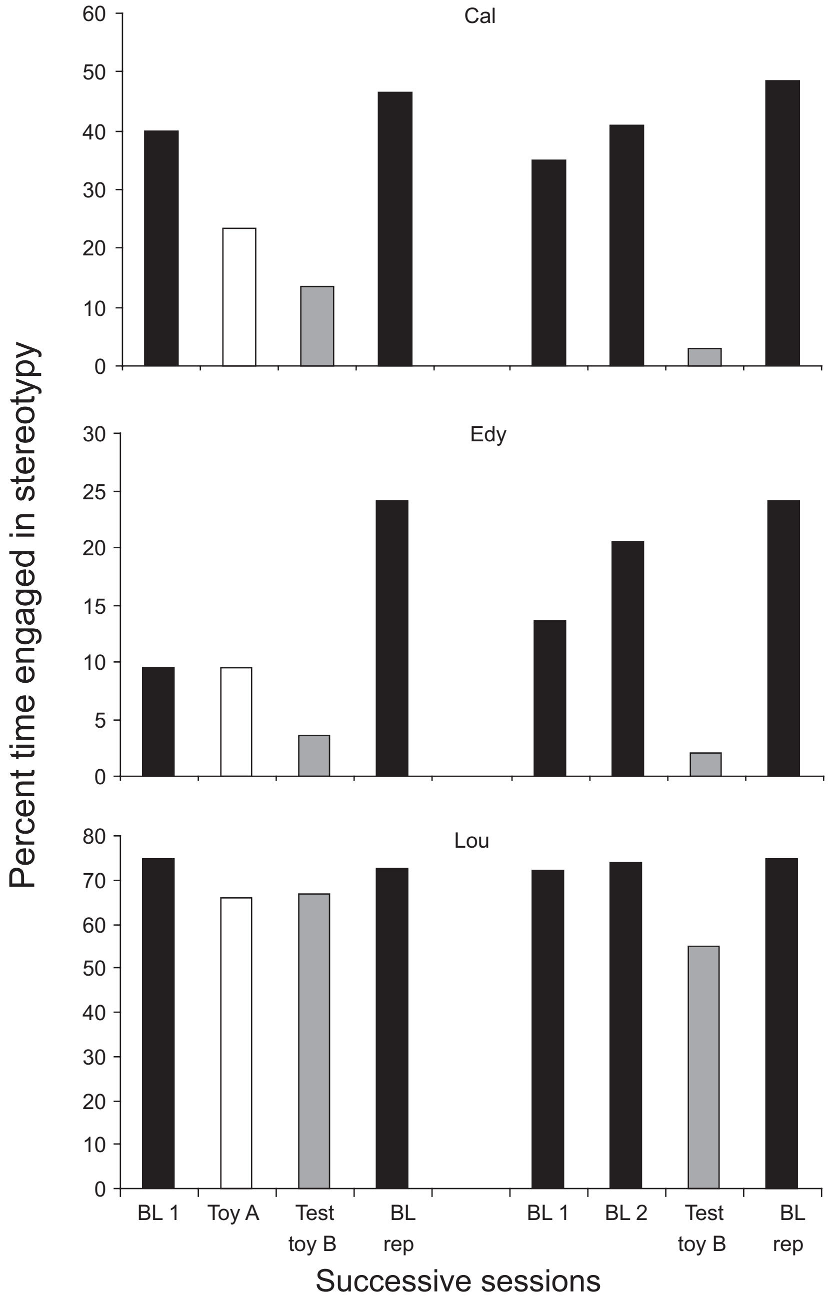

FIGURE 5.8. Percentages of time spent engaged in stereotypy by three children with autism in baseline conditions (BL; black bars), noncontingent toy presentation (Toy A, noncontingent reinforcement; white bar), and subsequent tests with an additional distractor test Toy B (gray bars). Data are averaged over replications. During distraction, the persistence of stereotypy was greater after noncontingent reinforcement (left panels) than after baseline only (right panels). Note also that stereotypy recovers to its pretreatment level on return to baseline conditions. Reanalysis of data from Ahearn et al. (2003).

behavior was sufficient to evoke previously extinguished problem behavior. These results are directly relevant to interventions with DRA in which treatment is terminated or reinforcers for alternative behavior are reduced because of changing circumstances or inadvertent omission by a caregiver.

Recent multiple-schedule research with pigeons by Podlesnik and Shahan (2009) has shown that the extent of resurgence is greater in a component with added NCR during baseline training before extinction of the alternative response. In Phase 1 of one experiment, Podlesnik and Shahan arranged food reinforcement for key pecking on identical VI 120-second schedules (30 reinforcers per hour) in alternating components of a multiple schedule; additional response-independent food presentations (NCR) were also delivered on a VT 20-second schedule (180 reinforcers per hour) in one component. Consistent with research summarized earlier, baseline rates of the target response were lower in the component with added NCR (left panel of Figure 5.5, right set of bars and right *y*-axis). During extinction of the target response with concurrent reinforcement of an alternative response (Phase 2), target responding was more persistent in the component with added NCR during Phase 1, extending the results of Nevin et al. (1990; see Figure 5.3) to extinction with concurrent alternative reinforcement (left segment of right panel). Finally, when alternative reinforcement was discontinued (Phase 3), target responding increased (resurgence), and the extent of resurgence relative to baseline was reliably greater in the component with added NCR during Phase 1 (right segment of right panel).

Podlesnik and Shahan (2009) conducted two additional experiments. In one, responding recovered when two reinforcers were presented in the first postextinction occurrences of each component, either contingent on or independent of responding (a reinstatement procedure). In another, different stimulus conditions were arranged during extinction, and responding recovered when the stimulus conditions were changed back to those used during training (termed *renewal*). In both experiments, responding recovered sooner and to a higher level in the component with added NCR even after its rate had decreased to near zero, as in Volkert et al.'s (2009) resurgence experiment, described earlier. Thus, the effects of NCR extend to postextinction reinstatement and renewal as well as resurgence.

Podlesnik and Shahan (2009) showed that their results were consistent with a model of extinction derived from behavioral momentum theory (Grace et al., 2003; Nevin & Grace, 2005; Nevin et al., 2001). More generally, these findings suggest that extinction does not eliminate the effects of a prior history of reinforcement on the persistence of responding. These findings are directly relevant to clinical settings in which problem behavior, presumed to have a long history of reinforcement, is addressed by alternative reinforcement: Discontinuation of alternative reinforcement, failures of treatment integrity including inadvertent reinforcement of problem behavior, or return to an earlier treatment setting could promote recovery of problem behavior.

LONG-TERM TREATMENT AND MAINTENANCE

All of the studies cited earlier, both translational studies with humans and basic research with nonhuman animals, used a single, relatively brief test of persistence after treatments lasting for relatively few sessions. Wacker and colleagues (Harding, Wacker, Berg, Lee, & Dolezal, 2009; Wacker et al., 2011) have extended this line of work by repeated evaluation of the persistence of both destructive behavior (self-injury, aggression, property destruction) and adaptive behavior (task completion, manding) in home settings over the long-term course of FCT (Carr & Durand, 1985). As noted earlier, FCT is a type of DRA procedure in which communicative responses (mands) are reinforced and destructive behavior is placed on extinction or produces punishment (Wacker et al., 1990). In most cases, a functional analysis is first conducted to identify the reinforcers that maintain destructive behavior. Functionally equivalent mands are then taught and reinforced during FCT. As an example, if parental attention is shown to maintain destructive behavior during the functional analysis, then the child is taught to mand *please* to obtain attention, and destructive behavior is ignored (see also Volkert et al., 2009, described earlier).

The participants in Wacker et al. (2011) were eight young children (six boys, two girls) who were enrolled in a federally funded research project (Wacker, Berg, & Harding, 2004). The children were 4 years old or younger (M = 3 years, 4 months; range = 2 years, 3 months–4 years, 4 months). All eight children had been diagnosed with either developmental delays (six children) or mild (one child) to moderate (one child) intellectual disability. Three of the children were diagnosed with autism, and one child was diagnosed with fragile X syndrome. All eight children displayed destructive behavior maintained by negative reinforcement in the form of escape from demands during a functional analysis.

All procedures were conducted in the children's homes by their parents, who received weekly coaching from project staff (Wacker et al., 2011). Procedures were conducted in a three-phase sequence: (a) functional analysis based on the procedures described by Iwata, Dorsey, Slifer, Bauman, and Richman (1982/1994); (b) baseline (demand) extinction probes; and (c) FCT. Baseline involved the presentation of a simple demand, such as stacking one block on top of another, during a 5-minute session. All responses, including destructive behavior, manding for a break, and task completion, were placed on extinction, meaning that prompts to complete the task continued for the entire 5 minutes. The initial baseline showed the level of destructive behavior after the completion of the functional analysis, in which destructive behavior was continuously reinforced.

FCT was conducted as a two-step chain. The child first needed to comply (e.g., stack two blocks) and then mand for a break. Manding involved touching a microswitch that, when pressed, activated the vocal request "Play." The child could also say *play* when the microswitch was placed in front of him or her. Thus, compliance produced the microswitch, and pressing the microswitch or saying *play* produced 20 to 30 seconds of negative reinforcement (DRA; discontinuation of task demands). Destructive behavior produced no differential consequences when emitted during the completion of a task and resulted in an immediate return to the task when it was displayed during task breaks. The baseline extinction probes and FCT were conducted within a reversal design such that baseline occurred (a) before FCT, (b) after an average of 8 weeks of FCT, and (c) during a final return to the baseline condition after an average of 35 weeks of FCT. The return to the baseline extinction condition after differing lengths of treatment permitted Wacker et al. (2011) to evaluate the relative persistence of destructive behavior, manding, and task completion over the course of treatment.

A case example from Harding et al. (2009) is provided in Figure 5.9. Andy was a 2-year-old boy who was diagnosed with Peter's anomaly, a genetic syndrome that resulted in blindness in his right eye and developmental delays. Andy's destructive behavior included property destruction (e.g., throwing objects, ripping books) and aggression toward his parents (e.g., pulling hair, hitting, scratching). Destructive behavior is shown in the top panel, manding in the middle panel, and task completion in the bottom panel. During the initial baseline extinction condition, destructive behavior persisted for four sessions, manding did not occur, and task compliance was low for three of the sessions. During the initial implementation of FCT, rapid reductions in destructive behavior and increases in both manding and task completion occurred by the third session and remained steady for the next seven sessions, even though demands were increased from two to four. The baseline extinction condition was then repeated after approximately 1 month of treatment, resulting in an immediate increase in destructive behavior (resurgence) and decreases in both mands and task completion. Thus, the elimination of destructive behavior during FCT did not generalize to altered conditions.

The same pattern of behavior was repeated during subsequent FCT and return-to-baseline conditions. FCT resulted in zero to near-zero levels of destructive behavior even as demands were increased and steady levels of manding and task completion occurred. The second return to baseline after 2 months of treatment again showed immediate increases in destructive behavior and decreases in mand and task completion (Harding et al., 2009).

A third period of treatment was initiated and continued for a total of 7 months. Destructive behavior rarely occurred during FCT, and manding and task completion again improved. When the return-to-baseline condition was repeated, destructive behavior failed to occur across three sessions. Manding also did not occur, and task completion showed a downward trend. In spite of the absence of mands and decreased task completion, destructive behavior remained at 0%. Thus, the effects of FCT on the persistence of destructive behavior were eliminated after extended treatment and repeated baseline tests, whereas adaptive alternative behavior became more persistent. In effect, DRA reinforcers strengthened adaptive behavior only, as though they occurred in a separate situation from destructive behavior.

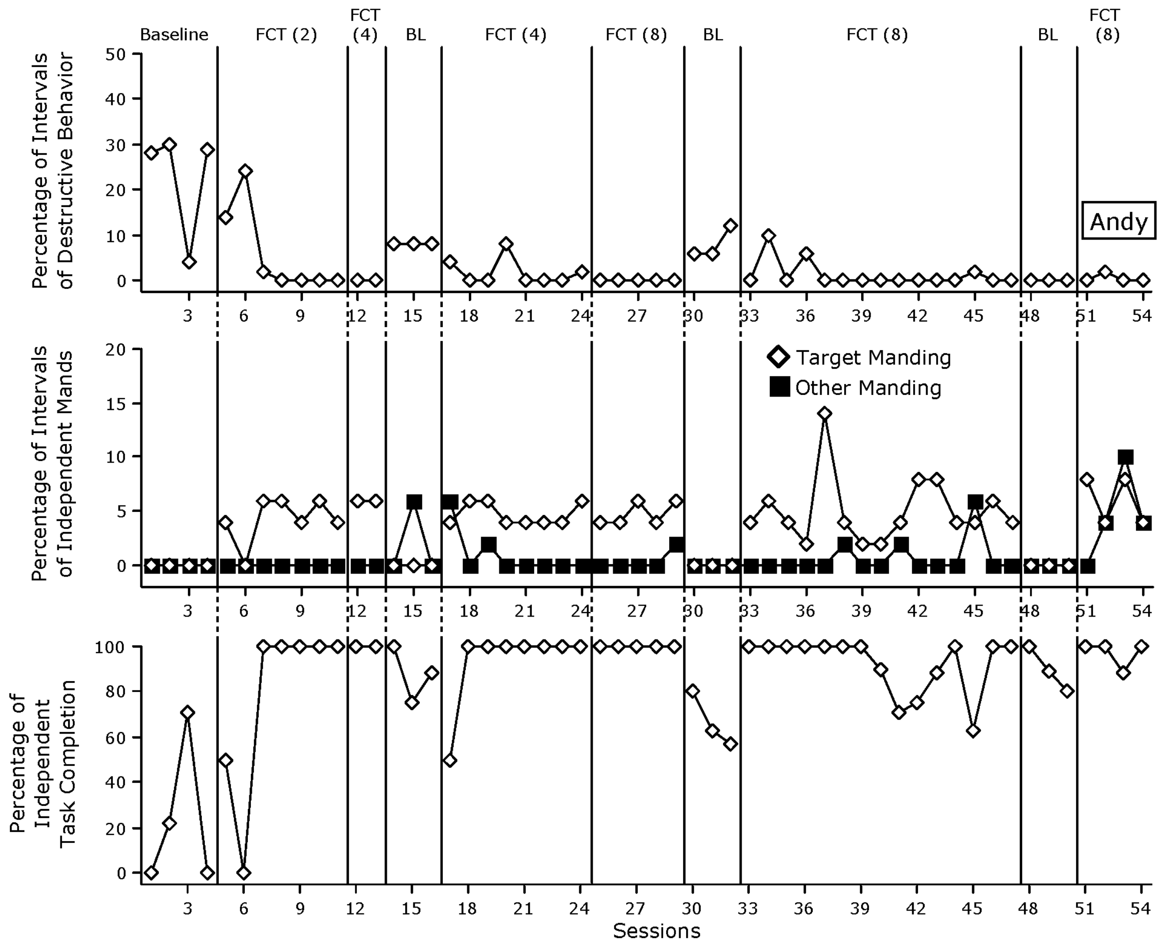

FIGURE 5.9. Persistence of destructive, manding, and task-completion behaviors over the long-term course of functional communication training (FCT). Target = pressing a microswitch; other = vocal requests. From "Conducting Functional Communication Training in Home Settings: A Case Study and Recommendations for Practitioners," by J. W. Harding, D. P. Wacker, W. K. Berg, J. F. Lee, and D. Dolezal, 2009, *Behavior Analysis in Practice*, 2, p. 29. Copyright 2009 by the Association for Behavior Analysis International. Reprinted with permission.

The findings from this longitudinal analysis suggested that procedures such as DRA may come at a cost. The contingent reinforcers provided during DRA treatments such as FCT often result in an immediate decrease in problem behavior but may also make destructive behavior more persistent when challenges to treatment (e.g., brief periods of extinction) are encountered over time (e.g., Mace et al., 2010). To avoid this increase in persistence, it may be necessary to continue DRA treatments for long periods of time before adaptive behavior persists and destructive behavior fails to reoccur during these challenges.

Maintenance is often defined as steady-state responding under the prevailing conditions of treatment (e.g., Stokes & Baer, 1977). Thus, in the applied literature, long-term treatment effects are evaluated primarily on the basis of steady-state responding under stable conditions over a period of time (e.g., Derby et al., 1997). Studies that have documented the consistent, long-term effects of treatments such as FCT are important because they show that the direct effects of an intervention can be sustained over time. However, in most applied situations, this is a necessary but not sufficient step toward maintenance. For maintenance to occur, the effects of treatment must persist when changes occur in both antecedent and consequent stimuli. The people, tasks, prompts, and consequences surrounding behavior change or vary over time. For long-term maintenance to be achieved, adaptive behavior must persist in the face of these challenges, and the theory of behavioral momentum (Nevin & Grace, 2000) provides a way to analyze behavioral resistance to change within functional contexts. The theory has been extended to account for resurgence (Shahan & Sweeney, 2011; Wacker et al., 2011).

A prevailing second-generation concern for applied researchers is how best to promote long-term maintenance, and perhaps one step in this process is to redefine what is meant by maintenance. Rather than focusing almost exclusively on behavior occurring under stable treatment conditions, researchers should also consider how various treatment conditions produce or inhibit persistence during challenges to the treatment.

In the case example of Andy (see Figure 5.9; Harding et al., 2009), durable treatment effects occurred only after about 7 months in treatment. These results suggest that destructive behavior was not fully weakened until long after the treatment appeared to be successful, as measured by reduction in frequency during treatment. As a result of continued treatment, including repeated extinction of destructive behavior, resurgence eventually failed to occur during the final extinction baseline challenges, which is when maintenance was defined as having been achieved.

Figure 5.10 provides evidence of maintenance for the eight children who participated in the project (Wacker et al., 2004) with Andy. The top panel shows the percentage of occurrence of destructive behavior at the initial baseline, after an average of 8 weeks of FCT and after an average of 35 weeks in treatment. The bottom panel shows task completion data. The FCT treatment was effective in reducing destructive behavior and improving task completion for this group of children, but these effects were not sustained when treatment was challenged by returning to extinction. However, by the end of treatment, durable change was achieved for both destructive behavior and task completion.

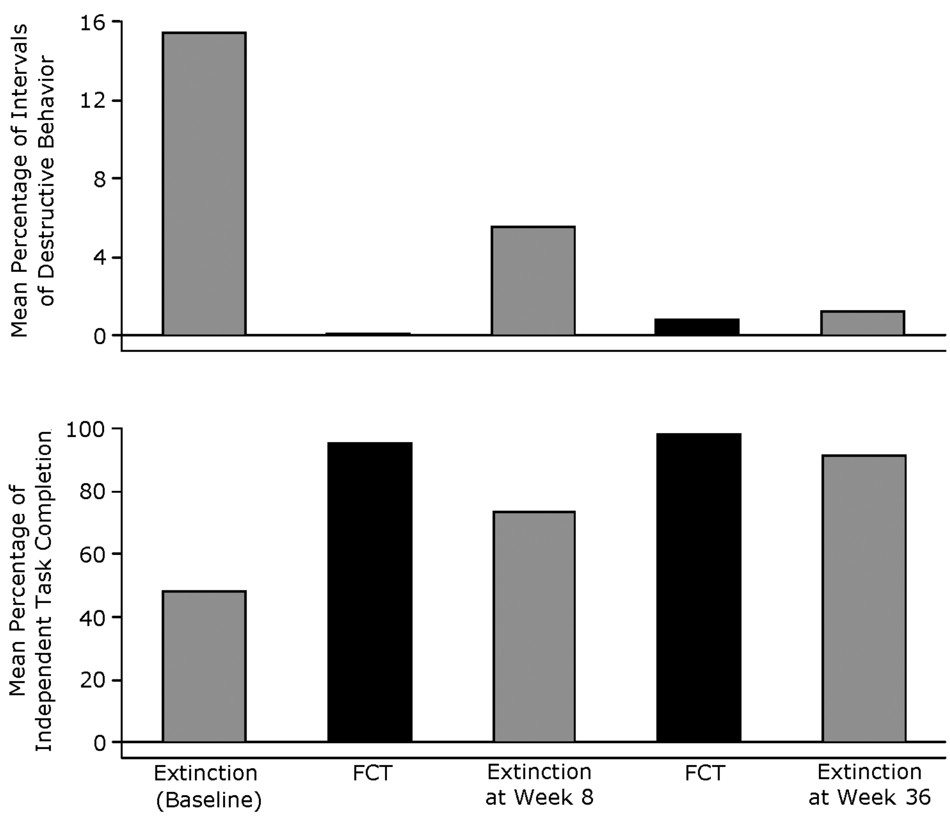

FIGURE 5.10. Mean occurrence of destructive and task-completion behavior for eight children during initial and long-term treatment, showing that recovery of problem behavior decreased across successive extinction tests, whereas task completion increased. FCT = functional communication training.

The results of this project suggest that treatments based on enriched contexts, such as DRA, need to be implemented for long periods of time before the desirable behavior becomes sufficiently resistant to changes such as lapses in treatment integrity (Wacker et al., 2011). The immediate effects of those treatments, although often quite positive, are not predictive of later effects if challenges to the treatment occur, so repeated testing may be required. In most applied situations, challenges will occur, and their effects should be anticipated and evaluated. In general terms, maintenance is fully achieved only when challenges to treatment do not disrupt the effects of treatment.

IMPLICATIONS FOR RESEARCH AND THEORY

Behavioral momentum theory does not include terms corresponding to the duration of treatment or repeated testing that were integral to the long-term outcomes obtained by Harding et al. (2009) and Wacker et al. (2011). We suggest that a sort of reverse translation from application to basic research is needed to provide an empirical base for such terms and to incorporate them into the momentum model (Nevin & Shahan, 2011). In one relevant study by Lentz and Cohen (1980), pigeons were trained to peck a key for food on a variable-interval schedule. A dish of free food was placed in the chamber during Sessions 6, 12, 24, 48, and 96. Typically, the birds ate for about 9 minutes and then pecked the key at low and variable rates. However, the average rate of key pecking in test sessions increased from about 3% of baseline in the first test to about 20% of baseline in the final tests, suggesting that key pecking had become more resistant to disruption by free food as a result of repeated exposure to the procedure. In that sense, the procedure and results parallel those of Wacker and colleagues (Harding et al., 2009; Wacker et al., 2011) for task completion, and the study should be repeated with an explicit concurrent DRA component and with other disruptors as in Experiment 2 by Nevin et al. (1990).

Behavioral momentum theory asserts that persistence depends on the relation between stimuli and reinforcers. In basic research, the stimulus situation can be defined and controlled with precision. Over the course of long-term treatment in a relatively uncontrolled home setting, however, the stimulus situation may be quite variable. Variation in the treatment context likely enhances generalization of treatment effects to new circumstances (Stokes & Osnes, 1989), and it may also contribute to long-term maintenance. Again, basic research could address this possibility by introducing controlled variation in the stimulus situation during long-term baseline training with interspersed tests of persistence.

Another issue arises in connection with a widely used method known as the "high-*p*" (i.e., high probability) procedure, which was characterized as behavioral momentum when it was introduced by Mace et al. (1988). In this procedure, a person who rarely complies with so-called low-*p* requests such as "Clear the table" is exposed to a sequence of so-called high-*p* requests that are easy to comply with, such as "Give me five," in which compliance is followed by social or consumable reinforcers. This high-*p* sequence is followed immediately by a low-*p* request. Mace et al. explored several variations on the procedure with adults with developmental disabilities and reported reliable increases in compliance with low-*p* requests involving daily activities in the group home. The high-*p* procedure has been used to establish compliance with parental requests in home settings (e.g., Ducharme & Worling, 1994; Strand, 2000) and with teachers' instructions in school settings (e.g., Lee, 2003; Lee, Belfiore, Scheeler, Hua, & Smith, 2004), to establish social interaction in children with severe disabilities (Davis, Brady, Hamilton, McEvoy, & Williams, 1994), and to improve adherence to medication regimens in adults with handicaps (Harchik & Putzier, 1990). Thus, the high-*p* procedure is effective with diverse participants, settings, and responses, and it appears frequently in Internet searches for "behavioral momentum" (e.g., http://www.usu.edu/teachall/text/behavior).

As noted by Houlihan and Brandon (1996), the high-*p* procedure differs in several ways from the methods of research on persistence described earlier. For example, basic and translational studies begin by establishing stable baseline performance in several sessions, usually with different reinforcement conditions in the components of multiple schedules, and the persistence of stable performance is usually evaluated by operations such as distraction or extinction that are separable from the behavior of interest. By contrast, the high-*p* sequence is brief (e.g., three to five requests), involves a single condition of reinforcement, and tests the persistence of compliance by presenting a more challenging low-*p* request. In effect, the use of a low-*p* request to evaluate the persistence of high-*p* compliance assumes that low-*p* and high-*p* responses belong to a common class called *compliance*; the only parallel in basic research is to increase response effort, a persistence test that has received little explicit attention (for discussion, see Nevin, 1996). Thus, the high-*p* procedure is not a direct translation of research under the rubric of behavioral momentum, although it may be seen as inspired by the momentum metaphor.

Both basic and translational research have found that behavior is more persistent in a situation with added alternative reinforcers, either independent of responding or contingent on an alternative response. Nevin (1996) suggested that low-*p* compliance might similarly be enhanced if response-independent reinforcers were presented in combination with the high-*p* request sequence. If compliance with low-*p* requests increases in a situation with added alternative reinforcers, but not in an alternated situation without alternative reinforcers, the results would suggest some functional similarity between the determiners of persistence in multiple schedules and in the high-*p* procedure despite numerous differences in methods and measures.

CONCLUSION

In behavioral momentum theory, the strength of responding is identified with its resistance to change, which in turn depends on the rate of reinforcement in the stimulus situation in which responding occurs. In translation to reinforcer-based interventions in applied settings, the identification of strength with resistance to change suggests that the effectiveness of an intervention should be defined as the persistence of treatment effects during challenges to the conditions that make up treatment. Analyses of persistence when distinct components of treatment are implemented or removed at different points in the course of treatment may identify those components that enhance or inhibit persistence. The results of these analyses may lead to an explicit technology of maintenance in poorly controlled or variable environments that would improve the long-term outcomes of treatments conducted in applied settings.

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Chapter 6

SIMPLE AND COMPLEX DISCRIMINATION LEARNING

William J. McIlvane

In its broadest sense, *discrimination* concerns the ability of organisms to vary behavior when stimulus conditions change. Discrimination learning in turn concerns the ability of organisms to vary their behavior adaptively as a function of experience. Although this volume is mainly concerned with the discipline of behavior analysis, discrimination and discrimination learning—both simple and complex—are not the exclusive subject matter of that discipline. This subject matter is highly relevant for virtually all behavioral and biobehavioral science disciplines. As just one of many possible examples, the field of psychophysics fundamentally addresses organismic ability to behave differentially to different stimulus conditions (e.g., as in audiological or visual acuity tests). As another example, the many fields addressing typical and atypical language development are concerned with how humans vary their behavior under changing circumstances in interpersonal communication. As yet another example, one role of the clinical psychologist in therapeutic situations is to help clients discriminate environmental triggers that have occasioned previous maladaptive behavior and to behave differently or adaptively in response to those triggers.

Although most behavioral and biobehavioral science disciplines address discrimination in one form or another, this topic (whether simple or complex) occupies an unusually central position in behavior analysis. Discrimination is conceptualized as one of a handful of irreducible fundamental behavioral processes that are the foundations for analysis in basic, translational, and applied behavior-analytic science (others include reinforcement, response differentiation, conditioned reinforcement, and perhaps stimulus equivalence class formation; cf. Catania, 1998). Studies of simple and complex discrimination are thus of interest in their own right as potentially relevant to the scientific analysis of a very broad range of adaptive behaviors.

OBJECTIVES

Given that this is a handbook, my goal is to provide a general introduction to current behavior-analytic perspectives and methodology concerning simple and complex discrimination. My intended audience is broad—professional scientists and clinicians of all disciplines who want an informed introduction to relevant behavior-analytic methods and theory, students who are in the process of becoming professional scientists or clinicians, teachers of behavioral science, and interested nonprofessionals who want to learn something about behavior analysis as a scientific discipline. Given my objectives and intended audiences, I will not try to explain highly technical

Preparation of this chapter and much of the research described here was supported by the National Institute of Child Health and Human Development, reflected currently in Grants HD04147 and HD25995. Thanks also to Bill Dube and Greg Madden, who provided very constructive and helpful comments on a preliminary version of this chapter. This chapter is dedicated to Murray Sidman, who taught me how to think scientifically through his writing and our too infrequent personal contacts over many years, and to Rita Sidman, who helped us both communicate more effectively than we might have otherwise. I am not certain that Murray would agree with everything I have written here, but I am fairly certain that he would agree that analyses such as these may help move our field forward.

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quantitative theory (e.g., Nevin, Davison, Odum, & Shahan, 2007). Rather, my goal is to present and discuss simple and complex discrimination learning from the perspective of a behavior analyst who has focused on (a) understanding discrimination learning in children and adults with and without intellectual or other developmental disabilities and in certain nonhumans and (b) translating research findings into instructional technology. Thus, I plan to travel a familiar path that has been set out by Skinner (1968), Keller (1968), M. Sidman (1971), and other leading figures of my discipline.

As I have discussed elsewhere (e.g., McIlvane, 2009), behavior analysis has had a particularly strong emphasis on what is typically termed *translational research* in other scientific fields, particularly in the biomedical and biobehavioral sciences. At least two streams of research translation can be identified in behavior analysis:

1. Initial extension of basic research findings and methodologies that were first addressed with laboratory animals (rats, pigeons, monkeys, etc.) to humans, typically in the direct or indirect service of making improvements in the human condition: This type of research translation seems especially well exemplified by behavior-analytic work on the technology of teaching (see also Chapter 16, this volume).
2. Translation of research findings and methodologies used exclusively or predominantly in basic behavior-analytic research with humans to model and potentially resolve problems of clinical, educational, or other real-world impact. Such research occupies a conceptual midpoint between (a) pure basic research done mainly to advance knowledge of behavioral processes and principles and (b) pure applied research done to solve an immediate real-world problem. Translational behavior analysis thus has objectives in common with both basic and applied behavior analysis (see McIlvane et al., 2011, for further discussion).

Many of the examples in this general introduction derive from translational behavior-analytic work from my own laboratory and the laboratories of close colleagues. This is in part for convenience in exposition and in part because doing so allows me to cover a fairly broad subject matter in an integrated fashion. I have been mindful that other chapters in this handbook address important topics that are directly relevant to simple and complex discrimination learning (e.g., Volume 1, Chapters 16 and 17). The availability of these chapters allows me to focus this chapter on the fundamentals of discrimination learning and to cover certain key issues comprehensively.

Given my objectives, I have tried to use a minimum of technical language that may be unfamiliar to readers from other disciplines. That said, I have not shied away from certain challenging technical issues. As the reader will find out shortly, the seemingly straightforward procedures used in laboratory research often mask subtle questions about basic behavioral processes. I have considered certain of these questions in part because they are rarely considered in other treatments and in part because I hope to inform colleagues from other disciplines about the complexities involved in even seemingly very simple procedures.

One of my objectives is to provide a reference for students of the neurosciences who want to adopt behavior-analytic methodologies. My goal is to give such readers a general introduction to a few of the most important considerations when designing simple and complex discrimination procedures. As a faculty member in a medical school, I often attend seminars given by colleagues who are interested in correlating neurobiological processes with behavioral processes in humans or nonhumans. Investigators with these interests who are not also students of behavior nevertheless seem comfortable using behavioral preparations with the presupposition that they have defined the behavioral processes of interest correctly and completely. Experience has shown me that this is often not the case.

I am particularly interested in applications to cognitive neuroscience (e.g., Haimson, Wilkinson, Rosenquist, Ouimet, & McIlvane, 2009). Investigators in this area are often interested in some aspect of simple or complex discrimination learning, often with only a very basic acquaintance with procedures used in behavioral science research and little or no understanding of issues that have challenged behavior analysts for decades. As such readers will discover, even seemingly simple discrimination procedures can mask analytical complexities. These complexities may introduce sources of unmeasured variability that may (a) render results of expensive cognitive neuroscience experiments difficult or impossible to interpret and (b) undercut the goal of correlating behavioral dependent variables with neurobiological variables.

For readers who are interested in theory, I have also tried to capture in a very general sense the essential features of prominent contemporary accounts of simple and complex discrimination learning. In doing so, I recognize that aspects of my perspective may differ in certain respects from the perspectives of others who identify themselves as behavior analysts. In this short chapter, however, I cannot cover all of the subject matter comprehensively, set up all of the subtle contrasts between theoretical perspectives, and convey all of the relevant research issues that merit consideration. My aim here is merely to present an overview of current behavior-analytic accounts of issues in simple and complex discrimination learning that I hope will prove useful and accessible to a broad audience of scientists, clinicians, educators, students, and other interested readers.

In presenting my analysis, I am mindful that the level of detail will go rather far beyond that which is typical in a chapter of this sort. One of my major purposes is to walk the reader through a careful technical consideration of stimulus control analysis in a manner that is done only very rarely—hoping to build on and extend prior efforts by my colleagues and teachers (e.g., M. Sidman, 1986). One difference between my treatment and others is an explicit focus on translational issues and examples that are intended to convey why analysis at this level is worth the effort for those interested in applications.

SIMPLE AND COMPLEX DISCRIMINATION: FUNDAMENTAL CONCEPTS

Discrimination always involves differential behavior to stimuli, whether they are environmental events that impinge on the five senses (exteroceptive stimuli) or events "within the skin" (interoceptive stimuli such as drug state). For this reason, I first consider how a behavior analyst defines the stimulus. This definition differs somewhat from that which would likely be offered by a behavioral scientist from another discipline.

Stimulus Defined

Since the earliest days (e.g., Skinner, 1935), behavior analysts have defined stimuli (and responses) generically in terms of their function rather than their physical topography or structure. Event X is a stimulus if it can be shown that a given behavior is more (or less) probable in its presence than in its absence. Behavior analysts also tend to define stimuli in terms of functional stimulus classes. If Events X, Y, and Z all influence behavior in a similar way, then these stimuli are termed *members of a functional stimulus class.*

Functional classes may be made up of physically similar stimuli from a single modality (termed *feature classes* by McIlvane, Dube, Green, & Serna, 1993, or *perceptual classes* by Fields et al., 2002). For example, all circular stimuli have a physical similarity that defines them as such. Functional stimulus classes may also consist of physically dissimilar stimuli from the same or different modalities. Classes of this type are sometimes termed *contingency classes* to emphasize that class membership is defined by equivalence of function in reinforcement contingencies and that class members are related despite physical dissimilarity. I prefer the terms *arbitrary classes* or *conventional classes,* however, because class membership is purely arbitrary and defined by convention (i.e., by prevailing contingencies of reinforcement). For example, a red traffic light, a stop sign, and a policeman's upraised hand all set the occasion for stepping on the brakes of one's car, even though these stimuli are not physically similar. Some behavior analysts go further in their definition of the functional stimulus class: (a) The stimuli must exhibit the same apparent function in the control of behavior and (b) operations that influence the function of one member of the stimulus class must influence the function of the others in the same or similar ways (Goldiamond, 1966). For example, breakdowns in civil order as might occur in a disaster area may render red lights, stop signs, and policemen's hand signals ineffective in occasioning stopping in panicked drivers.

Discrimination Defined

The fundamental analytical unit of behavior analysis specifies a relationship involving the behaviors of the organism, antecedent stimuli that occasion those behaviors, and the consequential stimuli that follow them and influence their future probability—the three-term contingency. Applied behavior analysts sometimes refer to it as *ABC* (antecedent–behavior–consequence) analysis. Discrimination is shown by differential behavior with respect to such stimuli. Behavior with respect to antecedent stimuli is emphasized most often in behavior-analytic research. If the organism reliably exhibits one pattern of behavior in relation to Stimulus A and a different pattern in relation to Stimulus B, then one says that discrimination of A versus B has been established.

Less emphasized in behavior analysis but also important for analytical purposes is discrimination of consequential stimuli. In clinical work with children with autism, for example, it is often helpful in assessing preferences among items that could potentially be used as reinforcers in treatment programs. If a given child does exhibit a preference for consequences differing in quality, density, or magnitude compared with others (i.e., behaves differentially with respect to them when given a choice between or among them), then this information is likely to prove helpful in selecting effective reinforcers (Piazza, Fisher, Hagopian, Bowman, & Toole, 1996). By contrast, if the child shows indifference to differences in consequences, particularly schedules that lead to substantially different preferred-consequence densities (consequence delivery vs. extinction in the extreme case) or magnitudes (large vs. small amounts; cf. Dube & McIlvane, 2002), one is led to question whether those consequences will be effective in altering the probability of behavior, either in supporting differentiation of responses or in attending to stimuli that occasion those nominally different consequences.

Discrimination Learning Defined

One can view discrimination learning in at least two ways—as an outcome and as a process, as follows: Before training, one might find that the level of responding to Stimulus A and Stimulus B is virtually identical (no discrimination of A from B). Thereafter, one might apply a differential reinforcement procedure in which a given behavior in the presence of A is followed by effective positive reinforcing consequences, whereas that behavior in the presence of B is not. Very soon, one would expect to find the behavior of interest occurring more often in the presence of A than in the presence of B. Even a reliably demonstrable small difference would indicate discrimination of A from B. Via continued application of these contingencies, however, one might expect to see gradually increasing differences in response to A and B. Ultimately, one might find that the individual virtually always responds to A and virtually never responds to B (virtually perfect discrimination).

How does one characterize this gradual change? In common parlance, one might refer to it as the learning process. However, I characterize these different degrees of discrimination as procedure outcomes, not as a reflection of the learning process per se. Long ago, M. Sidman and Stoddard (1966) showed that stimulus control shaping procedures translated from basic research with nonhumans (e.g., Terrace, 1963a, 1963b) could result in very rapid discrimination learning even in participants who learned slowly if at all under typical discrimination training regimens. Thus, slow discrimination learning was a characteristic of the teaching procedure used, not the discrimination learning process of the participants. Also, appropriate procedures can teach such individuals to learn new discriminations without any special supports for learning (Dube, Iennaco, Rocco, Kledaras, & McIlvane, 1992). If one can guide a learner's attending such that a previous pattern of slow, error-filled discrimination learning is replaced by rapid, accurate learning of comparable material, then attributing previous failures to processes characteristic of a "slow learner" is inappropriate. Characterizing the procedures that resulted in ineffectual learning as "slow teachers" seems more reasonable.

Discrimination in Context

Before going further to expand on and differentiate various types and classifications of discrimination, I think it is important to acknowledge that behavioral discrimination always occurs within a larger context that may or may not be specified formally in behavior analyses. For example, suppose that a researcher observed a pigeon pecking a red key at a very high rate and a green key at a very low rate. In reporting this observation, a behavior analyst would likely emphasize that the reinforcement contingencies signaled by the red and green keys controlled response rates. The behavior analyst would likely report but not emphasize that this red-versus-green discrimination occurred (a) within an experimental space with certain physical characteristics, (b) at a particular time of day, (c) under certain conditions of food deprivation, (d) in a particular geographic location, and so on. Although such contextual characteristics are present in virtually every situation in which discrimination is exhibited and may be important determiners of discriminative behavior, behavior analysts tend to focus their analyses on aspects of the environment and behavior that vary within a given context—if only for efficiency and clarity of communication. I do likewise in the course of this chapter.

SIMPLE AND COMPLEX DISCRIMINATION: FURTHER DEFINITIONS AND ILLUSTRATIVE PROCEDURES

In this section, I provide an overview of procedures that are used to study and potentially teach simple and complex discrimination learning. Readers who are familiar with this area will see my obvious debt to Murray Sidman, whose body of work has provided a systematic consideration of the analytical units of behavior analysis and their various complexities. My objective here is to cover the same basic ground, but with expanded coverage of certain key points, some of which reflect updated information that has become available through empirical studies and conceptual development. Although my perspective may differ from Sidman's in certain respects, I have the same objective: systematic consideration of the analytical units of behavior analysis from the most basic units of discrimination to those that may prove necessary to capture the complexities of complex repertoires that are often associated with cognition in both humans and nonhumans.

Simple Discrimination

When behavior analysts refer to *simple discrimination* in their technical language, they are not making a value judgment concerning task difficulty ("That discrimination is easy"). Rather, the term conveys that the specific stimuli suffice in themselves to occasion behavior differentially. Their discriminative function does not depend on the presence of other stimuli. Recall my earlier example: Competent, law-abiding drivers typically bring their cars to a stop when they encounter a red traffic light and proceed if the traffic light is green. The typical discriminative functions of red and green traffic lights, therefore, are invariant with respect to behavioral differentiation (red = stop, green = go).

Figure 6.1 shows examples of laboratory procedures that may be used to study successive and simultaneous simple discrimination with visual stimuli. Visual stimuli tend to be emphasized in research on the discriminative control of behavior, perhaps because such procedures have historically been fairly easy to instrument. However, appropriate instrumentation allows virtually any stimulus modality to be studied, including but not limited to auditory, olfactory, gustatory, tactile, and interoceptive (i.e., within-the-skin) stimuli.

As the name indicates, the stimuli in successive procedures are typically presented one at a time, and their discriminative functions remain constant over a series of exposures (i.e., trials) unless the procedure is changed. The traffic light discrimination just

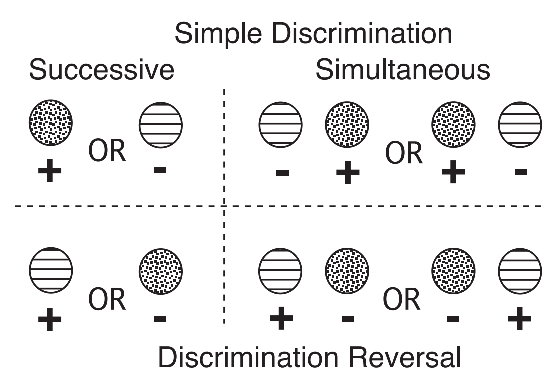

FIGURE 6.1. Examples of successive and simultaneous simple discrimination and simple discrimination reversal procedures showing all possible trial types in one-key and two-key situations, respectively. Positive and negative stimuli are indicated by plus and minus signs, respectively.

mentioned is one real-world example of a successive simple discrimination: Stop signals are red or green—not both, and red always signals "stop," and green always signals "go." In basic and translational research on discrimination learning, however, investigators often use abstract stimuli that have no prior extraexperimental history with the goal of isolating current discrimination learning processes from prior learning about those stimuli. In the illustrative procedure shown in the top left portion of Figure 6.1, the stippled stimulus is always the positive stimulus (S+) and the lined stimulus is always the negative stimulus (S−). The top right portion of Figure 6.1 shows an example of a simultaneous simple discrimination that displays the same stimuli together rather than separately. In this procedure also, the stippled figure is always the S+, regardless of its position in the display, and the line stimulus is always the S−. Although I have used only one positive and one negative stimulus thus far, the number of stimuli to be discriminated does not define a simple discrimination procedure. Although the number of positive stimuli on each trial is typically one, the number of negative stimuli can range from two to a fairly large number (e.g., M. Sidman & Stoddard, 1966, used seven, and de Faria Brino, Assumpção, Campos, de Faria Galvão, & McIlvane, 2010, recently reported a discrimination procedure that used 15 negative stimuli).

The fact that discriminative functions are invariant in simple discrimination procedures does not mean that one cannot change those functions by changing prevailing reinforcement contingencies—often a useful procedure in studies of discrimination learning. The trials below the dashed line in Figure 6.1 show examples of reversals of the simple discrimination functions presented above it. Because these are also simple discrimination procedures, the S+ and S− functions again remain constant over a series of trials, albeit reversed from those shown in Figure 6.1.

Complex Discrimination Defined

Unlike *simple discrimination, complex discrimination* is not a technical term in behavior analysis. Behavior analysts tend to use it to describe a range of situations, some of which may refer to difficulty of discrimination (as when discrimination requires attending to multiple stimulus features, subtle stimulus features, or both) and others of which may refer to the degree of discrimination conditionality (i.e., functions that change in a given procedure). These different aspects of complex discrimination may or may not be acknowledged formally in behavior-analytic writing. I suspect that the sometime lack of clarity may be the result of certain complex technical issues that I consider in this chapter.

On the one hand, simple discriminations may sometimes be referred to as involving complex discrimination when stimuli have many overlapping physical features. One common example is the children's game Where's Waldo? This game requires the player to find a single character in a red-and-white striped shirt, bobble hat, and glasses (Waldo) embedded within a series of progressively more complex visual scenes that include increasing numbers of characters who resemble Waldo. As the visual complexity of scenes increases, discriminating Waldo from the other characters may become more and more difficult. Indeed, even normally capable adults may have difficulty with the most complex scenes. In this sense, one could say that Where's Waldo? implements a series of progressively more complex visual discriminations.

For the purposes of this chapter, however, I limit my definition of complex discrimination to that class of discriminative performances that cannot be accounted for by detection of and response to invariant physical stimulus features (as in simple discrimination). By *invariant stimulus features,* I do not mean only specific features previously established as controlling stimuli (e.g., traffic light colors). Simple discrimination may entail invariant stimulus features, collections of features (as in Where's Waldo?), or other physical properties that may in fact be generalized, as is shown by work on procedures for establishing operant abstraction (or concept formation). Even the lowly pigeon can learn generalized abstractions or concepts, as shown by the classic studies of Herrnstein and colleagues demonstrating that this species could acquire, generalize, and reverse discriminations of scenes that did or did not include many different representations of trees (e.g., Herrnstein, 1979; Herrnstein, Loveland, & Cable 1976).

The typical procedure for establishing abstract or concept learning is to conduct discrimination training with multiple (perhaps many) exemplars, reinforcing responses to stimuli that do contain the exemplar and extinguishing those to stimuli that do not. Herrnstein's (1979) study, for example, used 40 examples containing trees and 40 that did not. There are hard-and-fast rules about neither how many exemplars may be needed to establish any given abstraction nor how many one need give without success to conclude that the learner is not capable of it. Indeed, one largely unresearched (and perhaps unrecognized) question concerns the behavioral processes involved in multiple-exemplar training (i.e., what does such training actually do to the learner's behavior to produce its effects?).

What is clear is that the effects of multiple-exemplar training are not restricted merely to establishing stimulus control by elemental stimulus features or dimensions such as color or form or specific configurations of these features, as in discrimination of Waldo from other characters. For example, if one is taught via multiple-exemplar training to respond to three squares, three diamonds, three stars, and perhaps even to three tones (and not other numbers of these stimuli), simple discrimination would be shown if a learner responded without further training to three parallel lines, three flashing lights, and so on (and not to other numbers of these stimuli). In these cases, "threeness" or, more generally, the "informational equivalence" (cf. Botuck & Turkewitz, 1984) is the physical invariance that defines the basis for simple discrimination—not merely specific stimuli that have occasioned past behavior.

According to the definition I use in this chapter, complex discrimination is conditional discrimination in the sense that behavior occasioned depends on stimulus–stimulus relations involving two or more stimuli. To exemplify conditional discrimination, I consider the matching-to-sample (MTS) procedure that is used widely in basic, translational, and applied research and in research applications such as discrete trial training for children with autism spectrum disorders. In applied work, conditional discriminations typically involve fairly straightforward mapping relations between two (or more) stimuli. For example, in response to a printed word OREO, a child points to a cookie composed of two thin chocolate wafers with a white filling. In response to VANILLA WAFER, by contrast, the child points to a single light brown cookie.

The upper portions of Figure 6.2 show examples of typical MTS procedures used in research. The figure shows two types of procedures—termed simultaneous *identity matching* and *arbitrary* (or *symbolic*) *matching*, respectively. In all of these MTS displays,

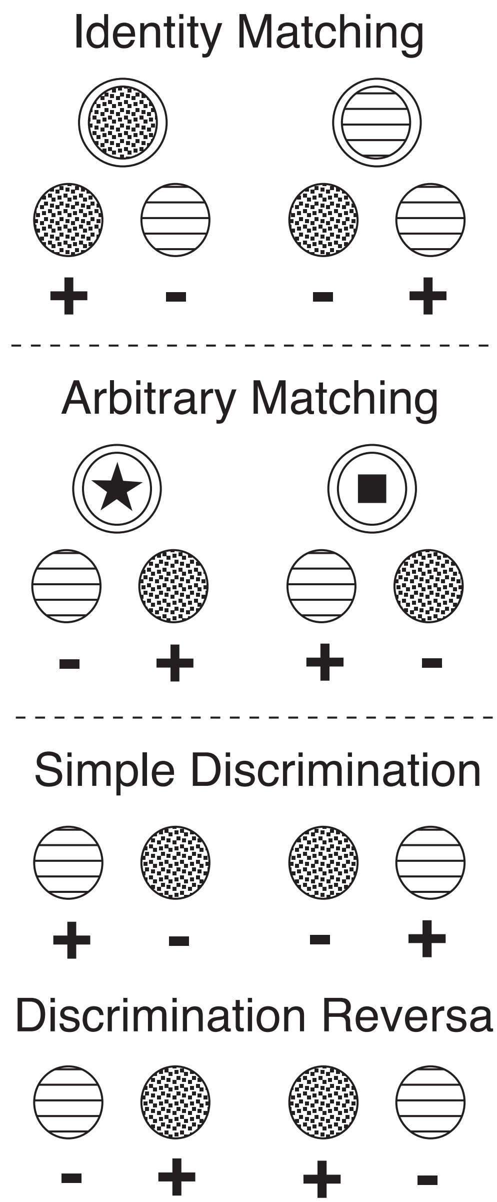

FIGURE 6.2. Illustration and comparison of identity matching, arbitrary matching, and simultaneous simple discrimination procedures. Positive and negative stimuli are indicated by plus and minus signs, respectively.

the stimulus centered at the top serves as the sample stimulus. The two stimuli beneath the sample are the S+ and S− comparison stimuli, respectively. As in other discrimination procedures, the number of negative stimuli can vary, although two or three is the most typical arrangement. There are also MTS variants that use only one comparison (successive MTS; e.g., Frank & Wasserman, 2005) and others that present sample and comparison stimuli in special configurations (e.g., so-called "blank comparison" procedures that I explain subsequently; McIlvane et al., 1987).

On typical identity-matching trials (Figure 6.2, upper portion), the positive comparison is physically identical to the sample and the negative comparison or comparisons differ from it physically. On arbitrary-matching trials (Figure 6.2, middle portion), by contrast, sample and comparison stimuli do not resemble each other physically (i.e., neither the star nor the square resemble their "matching" comparison stimuli). Moreover, on MTS trials of both types, attending to comparison stimuli alone is not sufficient to achieve consistently high matching accuracy scores. Such scores are achievable only if comparison selections are made in relation to (i.e., are conditional on) the sample stimuli.

Controlling Relations in Conditional Discrimination Procedures: Expanded Units of Analysis

As I mentioned previously, the fundamental unit of behavior analysis consists of three terms: antecedent stimulus conditions, defined responses, and consequences. That acknowledged, not all behavior analysts strictly restrict their analyses to three terms. Indeed, when I define conditional discrimination procedures in terms of stimulus–stimulus relations involving two or more stimuli, I implicitly add one (or more) additional term (or terms) to the analytical contingency, implying two (or more) antecedent terms rather than only one. Moreover, when one says that the discrimination of comparison stimuli is conditional on sample stimuli in MTS, one implies that the sample and comparison stimuli may have logically and perhaps empirically separable stimulus functions.

Cumming and Berryman (1965) characterized the comparison stimuli in MTS procedures as the discriminative stimuli and the sample stimuli as selectors of their positive and negative comparison discriminative functions. Their thinking can be seen by comparing the MTS trials in the upper and middle portions of Figure 6.2 with the simple discrimination and discrimination reversal trial types shown in the lower portion. The stippled (identity-matching) and star (arbitrary-matching) samples select the stippled comparison as the S+ and the lined comparison as the S−. By contrast, the striped and square samples set the occasion for the reversal of these discriminative functions. In recalling Cumming and Berryman's characterization, M. Sidman (1986) further characterized conditional discriminations of the general type shown in Figure 6.2 as four-term contingencies to emphasize the distinct selection function of the sample stimuli added to the familiar three-term relation involving discriminative stimuli, responses, and consequences.

M. Sidman (1986) contrasted four-term conditional discriminations with traditionally defined three-term configuration control—the possibility that a participant could meet the contingencies of the identity or arbitrary matching tasks shown in Figure 6.2 by learning the correct response locations for four independent trial displays. Configural control in that sense is suggested in the trial displays shown in Figure 6.3. The upper portion shows a typical interpretation of configural control in which the participant meets the reinforcement contingencies for each of four different three-stimulus configurations by selecting the location in which the positive comparison stimulus for each separate trial type is located (indicated by the S in each trial display). It is possible logically, however, to meet those contingencies in other ways. As suggested by the lower portion of Figure 6.3, one could learn to reject or avoid the location in which the negative comparison stimulus on each trial type is located (indicated by the R in each display). One could also learn to select certain locations on some trial types and to reject certain locations on other types—mixed configural control. Some evidence, in fact, has shown that some research participants do learn to respond to different stimulus displays as independent entities in the manner suggested by the configural control analysis (e.g., Katz, Bodily, & Wright, 2008; M. Sidman, 1992).

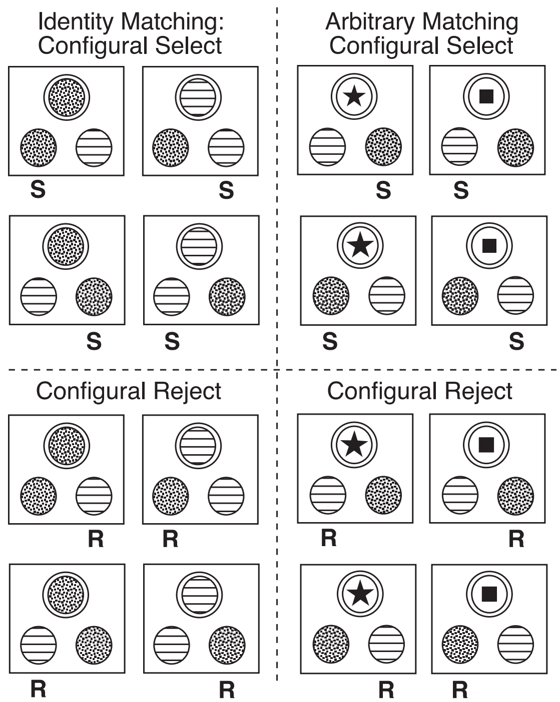

FIGURE 6.3. **Illustration of identity-matching and arbitrary-matching procedures suggesting two types of configuration control, selecting (S) the position in which the positive stimulus is displayed or rejecting or avoiding (R) the position in which the negative stimulus (S−) is displayed. The square frame around each trial type has been added to suggest that the elements of the display constitute a single integrated discriminative stimulus.**

Readers who are not already conversant with this subject matter may have some initial difficulty appreciating the distinction between four-term conditional discriminative control as M. Sidman (1986) described it and the three-term configuration control just mentioned. When M. Sidman and his predecessors referred to configural control, they were describing a simple discrimination outcome occurring in the context of a conditional discrimination procedure. Each of the displays shown in Figure 6.3 was viewed as an integrated, inseparable controlling stimulus involving the configuration of elements or a subset of them (suggested in the figure by surrounding each display with a frame). One way to think about this type of analysis is in relation to identifying faces. If one saw separate displays of the lips or the nose or the eyes of Barack Obama, it would likely be difficult or impossible to identify these elements as uniquely different from those of other African American men. When several of these elements are displayed in their typical spatial position, however, the face of the U.S. president becomes recognizable.

Stimulus Control Topography Analysis

The possibility of different forms of configural stimulus control—as in selecting or rejecting certain locations—provides convenient context for introducing an important issue in the analysis of both simple and conditional discriminative control. How does one differentiate among and account for different forms of stimulus control? Cognitively oriented theories of learning usually use some version of the concepts of attention or representation. In behavior analysis, by contrast, attention is typically referred to in behavioral terms (*attending* instead of *attention*), and thus attention is synonymous with stimulus control (i.e., the stimulus to which one attends). *Representation* is virtually never used in behavior-analytic writing.

Behavior analysts who study stimulus control processes have a problem when they want to talk about different forms of stimulus control, the stimuli to which the individual attends, and other similar efforts to differentiate among controlling stimuli. Such language is awkward and can have unwanted implications (e.g., does stimulus control actually have a form?). McIlvane and Dube (1992) addressed this terminological problem by pointing out that behavior analysts have long differentiated among different topographies of responses within a given response class. For example, a rat might depress a bar in any of several ways (e.g., poking it with the nose; touching it with the left paw, the right paw, both paws). Why not differentiate among different controlling stimuli in the same manner, specifying different topographies of stimulus control within a controlling stimulus class?

McIlvane and Dube (1992) did not invent the term *stimulus control topography* (SCT). Ray (1969) originally used it for a similar purpose, but it was not broadly adopted until fairly recently. In brief, the term refers to the physical features, structural relationships, and controlling properties of stimuli. A major difference between a response topography and an SCT is that any given instance of the former can be directly observed and measured, whereas any given instance of the latter can only be inferred from the results of test procedures (cf. M. Sidman, 1978). That acknowledged, the SCT concept has proven useful to many behavior analysts who study stimulus control processes, and it is increasingly being used in the literature. Notably, the SCT roughly parallels the concept of representation in cognitive psychology, and it can be used as part of a response to criticisms such as those by Rilling (1992), who argued that behavior analysis cannot reach its full potential unless it enriches its concepts of stimulus control.[1] The two terms differ in that *representation* is generally used in an explanatory fashion, whereas *SCT* is used mainly as a description of the stimulus properties that the individual attends to and represents in the course of acquisition of discrimination. That said, cognitively oriented readers are likely to detect that I often use *SCT* as they would use *representation*.

Relational (Stimulus–Stimulus) Control and Multiple-Stimulus Control Topographies

In this section, I consider stimulus–stimulus relations that are entailed in four-term contingency analysis. The upper portion of Figure 6.4 shows the same trial types as those in Figure 6.3, but this time (a) without the frames surrounding the stimuli and (b) with the addition of lowercase *r*s placed between the sample and comparison stimuli. Removal of the frames indicates control by the individual stimuli displayed on the trials and not by a larger, integrated configuration. The *r*s indicate the stimulus–stimulus relations. As in the configural discrimination, two classes of behavioral relations are possible. On any given trial of a conditional discrimination problem, one can meet the requirements of the contingencies by attending to and selecting the positive comparison stimuli (*select* relations), by attending to and rejecting the negative comparison stimuli (cf. Carrigan & Sidman, 1992; Johnson & Sidman, 1993) and thus responding to the positive comparison (*reject* relations), or by a combination of select and reject relations across discrimination trials. The latter is addressed in the lower portion of Figure 6.4. To meet the contingencies of a MTS procedure, one need not learn matching relations between each sample and its corresponding positive comparison stimulus. A mixture of select and reject relations will suffice to permit perfect conditional discrimination (as suggested by the X superimposed on various comparison stimuli).

It may be easiest to consider a mixture of select and reject relations in the case of the arbitrary-matching task. Figure 6.4 (lower right portion) illustrates a case in which the learner has learned a select relation involving the star sample and the stippled comparison and a reject relation involving the

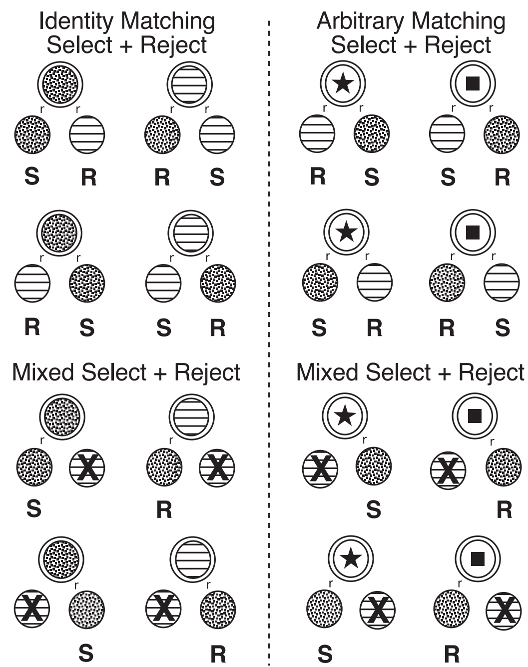

FIGURE 6.4. Upper panel: Trials illustrating select (S) and reject (R) relations (r) in identity and arbitrary matching-to-sample procedures. Lower panel: Trials indicating examples of mixed select and reject controlling relations and minimal relations that must be established to meet high-accuracy criteria in matching-to-sample procedures. The X is intended to suggest that the stimulus in the indicated position is not involved in the controlling relations that permit accurate matching to sample.

[1]Rilling (1992) wrote that "when the stimulus is a complex event (e.g., a color slide of a scene in the real world), the experimenter is forced to confront two problems: perception and representation. . . . A theory of discrimination learning that cannot specify precisely the nature of the event about which [a subject] has learned will be unable to predict the events that control behavior in the future" (pp. 347–348).

square sample and the stippled comparison. In neither case do controlling relations involve the lined comparison and either of the samples (as they do in the upper portion of Figure 6.4). Indeed, the learner need not distinguish any of the physical characteristics of the lined comparison in this illustrative case. Nevertheless, a learner acquiring this combination of select and reject relations would exhibit perfectly accurate matching of the star with the stippled comparison and of the square with the lined comparison.

Notably, an observer watching an individual perform the MTS tasks shown in Figure 6.4 could not accurately infer which of the select or reject SCTs was occurring on any given trial. The overt behavior is identical in all cases. Additional test procedures are needed to measure whether the learner has acquired all possible select and reject relations. Such a test procedure is shown in Figure 6.5.

The top row of Figure 6.5 shows the baseline trial types—two-comparison arbitrary MTS in

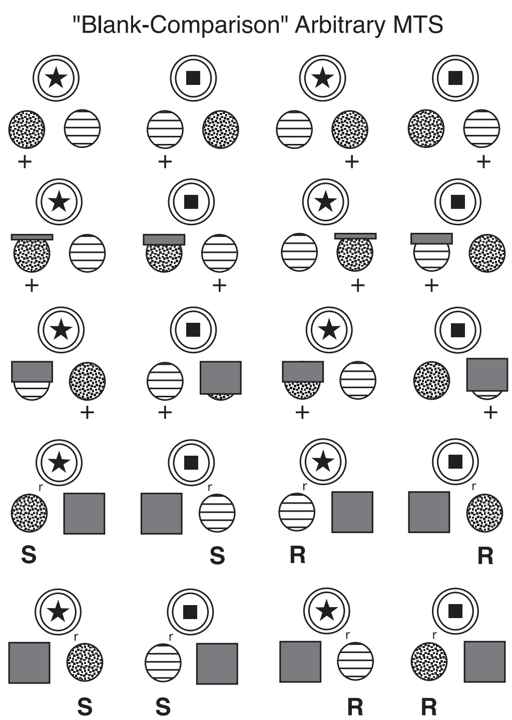

FIGURE 6.5. **Illustrative trials from a procedure designed to establish a blank comparison arbitrary matching-to-sample baseline. The upper three rows show examples of trials used to teach the baseline. The lower two rows show procedures for evaluating select (S) and reject (R) relations (r), respectively.**

this illustration. The next two rows show a nonverbal training procedure in which progressively larger quadrilateral forms are progressively superimposed over one of the comparison stimuli on each trial. Ultimately, the quadrilaterals obscure one of the comparison stimuli completely on every trial (Figure 6.5, fourth and fifth rows). These quadrilateral forms are termed *blank comparison stimuli* because they are uninformative by themselves; they are not consistently related with any sample (or, alternatively, they are related with all samples equally as often). To maintain conditional discrimination that is consistent with the baseline conditional relations on blank comparison trials, the participant must respond to (a) the baseline comparison when it is the positive stimulus in relation to a given sample and (b) the blank comparison when the baseline comparison is the negative comparison stimulus in relation to a given sample. If the participant does these two things, then she or he exhibits both select and reject relations (e.g., Serna, Wilkinson, & McIlvane, 1998).

Does exhibiting select and reject relations after exposure to such a procedure demonstrate that these SCTs were present on the original baseline trials? Not necessarily, because the procedure shown in Figure 6.5 could actually have taught select or reject relations. Once established with one or more conditional discriminations, however, the blank comparison procedure can subsequently be used to assess whether the participant exhibits select and reject relations on other conditional discrimination in his or her baseline—those that have no history with the training procedure shown in Figure 6.5. For example, one could establish the blank comparison baseline with identity-matching trials and then use the procedure to assess select or reject relations with arbitrary-matching trials (McIlvane, Withstandley, & Stoddard, 1984). Another possibility is to establish the baseline in conditional discrimination and then use it to evaluate select or reject relations in simple discriminations and vice versa (see Goulart, Mendonça, Barros, de Faria Galvão, & McIlvane, 2005, for a demonstration of this application of the method).

Higher Order Stimulus–Stimulus Relations

The stimulus–stimulus relations described thus far have been fairly straightforward in nature, mapping onto comparably straightforward situations outside the laboratory (such as the OREO vs. VANILLA WAFER example). Situations in daily life, however, very often have substantially more complex discrimination requirements, especially in the domain of language. Indeed, the information conveyed by many spoken or printed words is determined by context. The words *watch out for the bat,* for example, would likely occasion different behavior on a baseball field than in an attic or cave.

Such higher order conditional relations are modeled in laboratory research using procedures of the general type illustrated in Figure 6.6. The top row shows trials already used to exemplify conditional discrimination. The bottom row shows trials on which (a) the rings surrounding the sample stimuli have become black and (b) the discriminative functions of the comparison stimuli have been reversed from those when the ring color was white. Thus, ring color may serve as a second-order controlling stimulus for the discriminative functions of the sample stimuli (white = original sample-matching contingencies, black = reversal of those contingencies). Applied to the earlier example, the white ring is analogous to the context of the baseball field, and the black ring represents the cave. The same sample stimulus (*bat*) has a different function in the two contexts. Thus, the contextual stimulus is the fifth term in a five-term contingency.

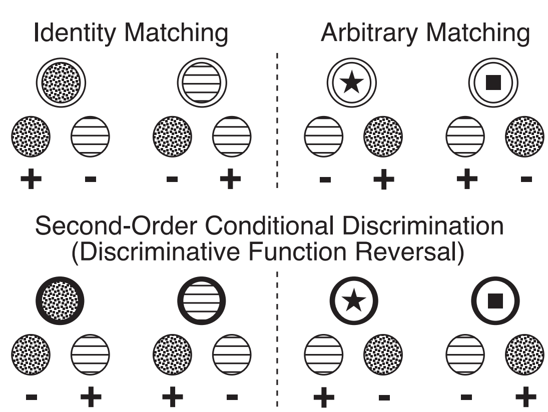

FIGURE 6.6. Procedure diagram showing identity- and arbitrary-matching trial types involved in an illustrative second-order conditional discrimination procedure. The trial types in the first row replicate those used in prior examples. Those in the second row show discrimination function reversal cued by the darkened surround of the sample stimuli. All trial types together constitute a second-order conditional discrimination when they are maintained in the same discriminative baseline.

Differentiating Among Three-, Four-, Five-, and *n*-Term Analytical Relations

My main purpose in the preceding section was to give the reader a conceptual and methodological framework for contingency analysis of simple and complex discrimination. My main purpose in the next section is to explain why it is important to differentiate among behavioral units in the service of analyzing such discrimination. Going forward, I want to reemphasize a key point about the analysis of discrimination. The number of behavioral relations specified in any given analytical unit is the fundamental concern, not the apparent details of procedure used in any given experiment. For example, I have shown that procedures that seem to specify four terms such as MTS do not necessarily require four-term behavioral units (owing to the possibility of configural control on trials on which the participant seems to be sample matching). Similarly, trials that seem to specify five procedural terms (or even more; see Gatch & Osborne, 1989) need not require that many terms in their specification. Logically, the five-term contingency problem could also be solved if the participant learned the correct match for each of (a) four compound stimulus samples (a four-term relation) or (b) four stimulus configurations (a simple three-term relation). Additional tests are needed to evaluate the actual number of stimulus–stimulus relations in behavioral units acquired in the course of acquisition of any particular simple or complex discrimination problem.

ASSESSING CONTROLLING STIMULI AND STIMULUS–STIMULUS RELATIONS

Behavior analysis of stimulus control in discrimination learning virtually always entails some form of stimulus variation to permit the investigator to make accurate inferences about the nature of that control.

The nature of the stimulus variation procedure or procedures implemented depends on the behavioral processes of interest. In some cases, the investigator may be challenged to specify physical properties of individual stimuli that appear to set the occasion for behavior and the limits of those controlling relations. In others, the investigator may be challenged to define functional relations between or among multiple controlling stimuli, some of which may entail complex spatial, temporal, or other physical stimulus properties and others of which are defined arbitrarily by prevailing contingencies of reinforcement.

Regarding translational and applied science implications, the challenges faced by laboratory investigators are also faced by teachers who are trying to translate laboratory procedures into effective methods for teaching children with intellectual disabilities, for example, via discrete trial methods that are common in applied behavior analysis therapy. If a given student is not showing the expected or hoped-for learning and generalization outcomes and if progress is to be made, there may be no effective alternative to introducing contingency measurement procedures of the type to be illustrated. A similar challenge is also faced by behavior therapists trying to understand the subtle environmental determinants of undesirable behavior that persists despite seemingly well-thought-out therapeutic procedures.

My interests in real-world applications may seem at odds with the abstract nature and controlled conditions of the laboratory procedures that I consider in this chapter. They are not. I believe strongly that behavioral scientists, just as those in other branches of the biological sciences, need simplified models of behavioral processes and their interactions to help them analyze their complex subject matter. Moreover, the translational behavioral research enterprise in general is mainly about assessing the degree to which laboratory-based analyses do map on to and inform efforts of clinicians, educators, and other consumers of behavioral science.

Focusing on analyses rather than procedures is a critical distinction here. Although some laboratory procedures do actually find more or less direct applications in the clinic or classroom, what is (or should be) translated from the behavior laboratory is mainly an analytical approach to gathering information about the complex determinants of behavior. As I illustrate procedures for responding to this challenge in simplified model systems in the laboratory, my hope is to convey and periodically exemplify how the analytical approach may find application and extension when one encounters seemingly intractable behavior problems that occur in the world outside it.

CONTROL BY PHYSICAL PROPERTIES OF STIMULI

Behavioral scientists have long been interested in defining those aspects of the physical world that can be discriminated, how reliably they can be discriminated, and the degree to which behavior established under one set of circumstances persists when physical stimulus features are varied (i.e., the amount of primary stimulus generalization[2] or, alternatively, the amount of physical stimulus equivalence that is demonstrable after training). The stimulus variation possibilities are numerous even in a simple simultaneous discrimination with apparently uncomplicated stimuli.

Suppose, for example, that the S+ in a given simple discrimination task is a small triangle and that the S− is a similarly sized circle. After this discrimination is acquired, one can vary the stimuli to explore the limits of the triangle-versus-circle discrimination (or, alternatively, to ascertain which physical stimulus features acquired stimulus control during discrimination training). On a test trial, for

[2]Behavior analysts tend to use the term *generalization* in a variety of contexts as a descriptor for a variety of behavioral processes. For example, applied behavior analysts influenced by Stokes and Baer (1977) tend to conceptualize generalization as an active programming goal referring to diverse phenomena, as in (a) demonstrating a skill acquired in one setting in another setting, (b) exhibiting a skill learned with one set of stimuli with another set of physically dissimilar stimuli, (c) using a given grammatical form with new exemplars, and so on. My preference, however, is to restrict use of the term *generalization* to its original definition, which referred merely to the breadth and limits of current discrimination (Prokasy & Hall, 1963). In this usage, *generalization* can be thought of as the other side of the coin from discrimination, that is, failure to exhibit differential behavior when the properties of a controlling stimulus are varied. When I use *generalization* as a term by itself, I use it in this sense only. When I use the adjective *generalized,* however, I use it in the sense of exhibiting a previously acquired skill with new stimuli, as in generalized identity matching, generalized imitation, generalized sequence reproduction, and so on.

example, one might substitute a small square for the S− (i.e., the circle) to determine whether discrimination accuracy is maintained (i.e., whether the participant continues to select the original S+ reliably). If the participant does continue to select the triangle, then one has a bit of evidence that the participant has attended to physical stimulus features that differentiate triangles from other forms or at least that the participant can differentiate the triangle from a form that has not previously appeared. If discrimination accuracy is not maintained, however, then one has evidence that discrimination depended on some aspect or aspects of the specific triangle-versus-circle stimulus difference. The participant had not learned to select the triangle whenever it was presented with a nontriangular form.

Further tests with other stimulus variations might help to pin down which specific features were likely important in discrimination of the original triangle versus circle stimulus difference. One might substitute, for example, a square for the original positive stimulus. If discrimination accuracy is maintained under these conditions, then one can conclude that the participant attends to some physical feature that is common to the square and the original triangle S+ (e.g., the bottom line), that the participant has learned to reject the circle S−, or both. If discrimination accuracy is not maintained, however, then one knows minimally that prior discrimination training had not established a reject relation in its pure sense (i.e., to reject the circle whenever it was presented with a noncircular form).

As the preceding discussion illustrates, the analysis of the topographies of stimulus control is a nontrivial matter, even in simple discrimination performances. The challenge becomes even more complex when one considers the important issue of what consequences are provided on test trials. When test stimuli are substituted for stimuli that served either as S+ or S− (or both), should one reinforce selections of the stimulus corresponding to the former S+, extinguish selections of the stimulus corresponding to the former S−, or both? The dilemma is that one cannot assume that the consequences that were important to the formation or maintenance of the original discrimination have suddenly become unimportant. How does one know whether any observed performance on the test trials reflects prior learning or new behavior instantiated by the contingency changes?

One approach to this problem is to make a shift in the prevailing contingencies of reinforcement after the original discrimination is reliable, gradually reducing the probability of positive consequences to low levels. If the original discrimination is maintained under these circumstances, then the investigator can present test trials without differential consequences under the defensible assumption that unreinforced selections on such trials will have minimal opportunities for new learning, disruptive effects on the original discrimination, or both. *Defensible* does not mean "certain," however.

At this point, the reader may wonder whether one can ever be truly certain that one has identified the stimuli or stimulus features that have been attended to when a participant acquires any given discrimination of whatever complexity. Perhaps not, but I think that one can achieve reasonable degrees of certainty using carefully designed test procedures. What one cannot do (and what is all too frequently done) is to ignore the complexities of SCT analysis and make assertions on the basis of mere guesswork or incomplete analyses. At minimum, I think that (a) investigators need to admit that statements about the stimuli to which a participant has attended on any given discrimination problem are indeed inferences and (b) the adequacy of such inferences should be judged by the degree to which other possibilities have been excluded. This concern applies even more, perhaps, when one is trying to infer the nature of stimulus–stimulus relations, whether they have their basis in physical properties of the stimuli involved or are purely functional (i.e., arbitrary) relations.

Assessing Relational Stimulus Control Involving Physical Properties

One typical example of relational control involving the physical properties of stimuli would be tests for generality of identity matching to sample (IDMTS), shown by spontaneous matching of physically identical (or similar) stimuli without explicit training on each matching relation. For example, given an established baseline of identity matching of red and green sample stimuli to corresponding red and green comparison stimuli, a limited form of generalized IDMTS is shown by subsequent accurate matching when other stimuli are substituted in the MTS procedure (e.g., yellow, blue).

If a participant is able to exhibit routinely accurate matching of new stimuli within the stimulus dimension of training (e.g., colors), then she or he exhibits identity stimulus–stimulus relations within that dimension. If the participant proves additionally capable of matching stimuli on the basis of other stimulus properties (e.g., form, number, size), then one is especially confident that the participant has learned to match on the basis of generalized sameness versus difference. Even in this case, however, one must be careful to define what has been learned via the IDMTS procedure. If one has learned to match stimuli that differ from one another on gross physical characteristics, one cannot assume that the participant will be able to match stimuli that have physical characteristics that are different or more subtle. For example, if a child has learned to match identical uppercase letters of the alphabet, one should not assume that she or he will immediately be capable of matching lowercase letters, letters in other fonts, and so on.

Generalized Identity Relations

Once an initial baseline of IDMTS has been established, one can evaluate whether the participant will immediately show generality of the identity-matching performance to other stimuli within the training modality or to other modalities. One type of test has been mentioned already—merely to present additional identity-matching problems with new stimuli. Cumming and Berryman (1965) did so in early studies with pigeons. For example, after their subjects had learned to match three different color comparisons to identical color samples (red, green, yellow), they removed one of those and substituted a novel color (blue) to see whether the birds would immediately match the blue comparison with the blue sample. They did not. This and much follow-up research in their laboratory led to the conclusion that pigeons, at least, did not engage in true MTS but rather exhibited rote behavior chains; the content of learning was described as "if red is the sample, then select red," "if green, then green," "if yellow, then yellow," and nothing more beyond these simple if–then rules, each acquired separately via differential reinforcement.

Generalized IDMTS failures should not be surprising. As shown by the examples that I have considered thus far, an IDMTS procedure need not necessarily establish true identity relations among samples and comparison stimuli. One can meet the requirements of the procedure merely by configural control, rote select and reject relations, a mixture of these STCs, and perhaps other subtle forms of stimulus control that are not consistent with identity relations. If the participant does fail to exhibit behavior consistent with identity relations, then the next question logically becomes whether the participant (a) is not capable of displaying generalized identity relations because of neurological insufficiency or species incapacity or (b) is capable of such performance, but the procedures used to establish the identity-matching baseline did not manage the topographies of stimulus control adequately.

A procedurally straightforward method would be multiple-exemplar training—merely training numerous identity-matching performances to criterion and then testing with new ones. *Straightforward,* however, does not necessarily mean "most efficacious" or "most efficient." If one works with children who are nonverbal or who have severe intellectual disabilities, protracted training may be necessary to teach multiple identity matching exemplars (e.g., M. Sidman & Cresson, 1973), and it may not be a surprise if this procedure fails entirely.

Various programming methods for encouraging the development of SCTs that promote acquisition of identity relations may minimize problems of this nature (e.g., Dube, Iennaco, et al., 1992; Dube & Serna, 1998). Briefly, these methods begin by establishing simple simultaneous and successive discrimination performances. The objective of the initial programming is to develop increasingly rapid acquisition of such performances (i.e., learning sets such as "win–stay, lose–shift"; Harlow, 1949) and thus one-trial acquisition of successive and simultaneous discrimination. From these baselines, one can go on to establish identity matching behavioral prerequisites: trial-by-trial acquisition of discriminative control by observing a successively presented sample and discriminative control of reversals of S+ and S− functions of the simultaneously presented comparison stimuli. Such procedures essentially "synthesize" IDMTS from simple discrimination performances. Notably, when identity matching is taught in this programmed way, generalized identity matching can be established even in children with very severe intellectual disabilities (Serna, Dube, & McIlvane, 1997); a similar approach has been used with arbitrary matching (K. J. Saunders & Spradlin, 1989, 1990).

Success in what may be termed *programmed STC management* is not limited only to studies in humans. In the years since Cumming and Berryman's (1965) original search for identity relations, for example, investigators in the animal cognition field have refined their procedures to better manage the SCTs that develop in studies with pigeons. One approach has been to arrange contingencies explicitly such that the desired SCTs are encouraged and undesired ones are discouraged even within a fairly small stimulus set. When such procedures are used, for example, the evidence that pigeons can exhibit generalized identity relations is substantially stronger (e.g., Zentall, Edwards, Moore, & Hogan, 1981). When multiple-exemplar training is used with this species, generalized identity-matching outcomes are perhaps even more convincing (Wright, Cook, Rivera, Sands, & Delius, 1988). Indeed, when animal cognition investigators approach their species as though they were students who require special instruction to perform their best, generalized identity matching can be shown at levels comparable to those of humans with developmental limitations (de Faria Galvão et al., 2005; Kastak & Schusterman, 1994).

Four-Term Relations in Generalized Identity Matching?

The procedures used in the IDMTS procedure have four nominal terms and imply a stimulus–stimulus relation (identity) between the sample and the corresponding comparison. When identity matching is generalized to new stimuli, that outcome seems to be *prima facie* evidence for sample–comparison identity relations rather than merely conditional discriminations acquired by rote and of uncertain status. That conclusion seems to be widespread in current literature, but is it true?

Dube, McIlvane, and Green (1992) presented a somewhat different analysis of generalized identity-matching test procedures that pointed to a possible relationship between virtually instantaneous acquisition of simple discrimination and seeming four-term identity relations. Briefly, they argued that typical test procedures (a) present the sample stimulus alone, (b) require one or more observing responses to it, and (c) follow such responses with the presentation of comparison stimuli to be discriminated. Long ago, Cumming and Berryman (1965) pointed out that presentations of comparison stimuli could serve a conditioned reinforcement function because that presentation was predictive of impending reinforcement (i.e., for correct comparison selections). Might the observing response to the sample followed by the presentation of comparison stimuli be sufficient to establish a simple discriminative (S+) function for the sample stimulus (in the manner mentioned a few paragraphs earlier)? If so, then how does one distinguish between true four-term identity relations and mere chaining of two three-term relations (i.e., acquisition of simple successive discriminative control by the sample and subsequent transfer of that control to simple simultaneous discrimination of the comparisons)?

Dube, McIlvane, and Green (1992) suggested a possible test that used a delayed sample procedure (McIlvane, Dube, Kledaras, Iennaco, & Stoddard, 1990) in which comparison stimuli were presented first. In the place of the observing response, they substituted the requirement that participants make no response for a variable time period (waiting baseline) until a sample was presented. At this point, the participant could select a comparison stimulus. In this procedure, therefore, not only did the sample stimulus function as a potential selector of discriminations in the sense meant by Cumming and Berryman (1965), but it also served as a signal that a comparison stimulus selection could be made—functions clearly different from those of the comparison stimuli. In this case, the four-term nature of the behavior-analytic unit would thus be unambiguous.

ARBITRARILY DEFINED (CONVENTIONAL) STIMULUS–STIMULUS RELATIONS

In analyzing stimulus control relations involving stimuli that share physical features, I was mindful that certain readers might become impatient as they waited for consideration of their main interests: stimulus–stimulus relations involving stimuli that shared no physical features other than the most general ones (e.g., onset). For example, the stimulus–stimulus relations that constitute language repertoires are arbitrarily defined by the verbal community and do not share invariant physical features, as follows: A conventional match for *Snoopy* would be *dog* in Chicago, *chien* in Paris, and *cachorro* in São Paulo. Despite the lack of shared features, the functional analysis approach that I have outlined also applies to the analysis of these and other arbitrary or conventional stimulus–stimulus relations (e.g., stimulus variation may prove necessary to pin down the nature of relational stimulus control). Indeed, the application and extension of behavior-analytic principles and methods developed in studies of relational control by physical stimulus properties to other types of relations led to *Verbal Behavior* (Skinner, 1957) and subsequent efforts to characterize arbitrarily applicable relational responding (Hayes, 1991).

Generalized Arbitrary Relations

On its face, the concept of generalized arbitrary relations may seem like an oxymoron. If relations are defined arbitrarily by contingencies of reinforcement, would they not have to be defined individually on a case-by-case basis? The perhaps surprising answer is no, at least within a certain range of operations. Moreover, that range does not seem to be much different from the circumstances that may lead to generalized identity relations, as follows: To test for generalized arbitrary matching, one must first establish an arbitrary-matching baseline of at least two or three defined sample–comparison relations (more is likely better if the goal is to promote the performance of interest). Thereafter, the participant may be shown an array of two or more comparison stimuli, all but one of which has previously been defined in relation to a sample. If an undefined sample is then presented, the participant is highly likely to select the undefined comparison immediately, even though she or he has never been explicitly trained to do so.

Emergent arbitrary-matching performances of this type have been termed *exclusion* by L. S. Dixon (1977) because her empirical stimulus control analysis suggested that participants selected the undefined comparison in response to the undefined sample stimulus via a reject relation involving the defined comparison stimuli in the displays (i.e., rejecting the already defined comparison as a match for the undefined sample because it had previously been related to another sample—often termed the *process of elimination* in lay language). Wilkinson, Dube, and McIlvane (1998) subsequently suggested the more neutral term *emergent matching* (EM) for performances such as these, which does not imply that such selections were necessarily *reject* relations. Both logically and empirically (M. H. Dixon, Dixon, & Spradlin, 1983; McIlvane, Kledaras, Lowry, & Stoddard, 1992), there are at least two routes to emergent matching, the reject relation proposed by L. S. Dixon (1977) and select relations in which participants may select undefined comparison stimuli in relation to undefined sample stimuli because both stimuli share this property, especially if the stimuli are novel.[3]

Four-Term Relations in Exclusion–EM?

When a participant explicitly rejects already defined comparison stimuli in relation to undefined sample stimuli (as L. S. Dixon, 1977, suggested), this appears to be *prima facie* evidence that the baseline relations were not simple three-term relations. The basis for excluding a defined comparison seems necessarily to be the prior defined relation with another sample stimulus—or else one would predict selection of the previously defined comparison that had

[3]Readers from other behavioral science disciplines may recognize the behavioral phenomena described here as the same as or highly similar to the phenomena termed *fast mapping* by Carey (1978) and *disambiguation* by Merriman and Bowman (1989), used mainly by developmental psychologists. Whatever the terminology, exclusion–EM represents among the most robust, reliable forms of emergent behavior that can be shown. It has attracted the attention of a broad array of behavioral scientists, although the terminological differences across fields may obscure this fact (see Wilkinson, Dube, & McIlvane, 1998, for an overview).

previously been reinforced. If the EM performance has its basis in relating novel samples and comparison stimuli, then it becomes similar to that of generalized identity matching—relating two stimuli on the basis of a common property (novelty or lack of definition) that does not depend on prior direct training with the stimuli involved.

Other Four-Term Relations: Arbitrary Assignment

Notably, generality of arbitrary matching is not restricted only to the case in which defined and undefined comparison stimuli are contrasted. R. R. Saunders, Saunders, Kirby, and Spradlin (1988) have demonstrated a related emergent matching phenomenon termed *arbitrary assignment* or *unreinforced conditional selection* in participants with intellectual disabilities and well-established arbitrary-matching baselines. Arbitrary assignment is shown when participants with such baselines spontaneously show virtually immediate conditional discrimination on entirely novel arbitrary-matching problems. That is, confronted with undefined comparisons X and Y and undefined samples A and B, participants will match, say, X with A and Y with B without any direct training on those relations or differential consequences to support such performances. The arbitrary nature of these relations is shown when other similar participants spontaneously match X with B and Y with A. In neither the former nor the latter case do these participants have a basis for their emergent matching performance in the specific relations established in their MTS histories. What they do have, however, is a previous history of multiple examples of arbitrary-matching relations in general. Thus, it appears that multiple-exemplar relational discrimination training may be sufficient to support emergent arbitrary matching in the exclusion–EM and arbitrary assignment situations.

One question at this point is whether generalized arbitrary matching is seen only in humans and only in those with lengthy histories of MTS performances. The answer appears to be no. McIlvane and Stoddard (1981) demonstrated exclusion–EM in a mute young man with profound disabilities and in follow-up studies with others who had similarly limited verbal skills and little or no MTS experience (e.g., McIlvane & Stoddard, 1985). Also, a growing literature has documented the exclusion–EM potential of nonhumans, including chimpanzees (Beran & Washburn, 2002; Tomanaga, 1993); sea lions (Kastak & Schusterman, 2002); and, perhaps, border collies (Kaminski, Call, & Fischer, 2004).

ASSESSING THE NATURE OF ARBITRARY STIMULUS–STIMULUS RELATIONS

Behavioral phenomena such as exclusion–EM and especially the arbitrary assignment phenomenon address the issue of whether conditional discriminations such as those shown in arbitrary MTS are four-term behavioral units or merely three-term units masquerading as such. When one observes a participant spontaneously matching different comparison stimuli with different samples in an arbitrary-matching procedure with no explicit history of relating those stimuli to each other, clearly something more is going on than rote responses to stimulus configurations or simple chains of three-term relations. The participants have clearly learned something more general about the nature of stimulus–stimulus relations within that procedural context, or, alternately, the procedure is well aligned with fundamental behavioral processes involved in complex discrimination learning. I prefer the latter interpretation for reasons that may become clear in subsequent sections of the chapter.

Four-Term Relations: Arbitrary Stimulus Equivalence

M. Sidman (1986) proposed (or rather noted the implicit fact of) an expansion of the analytical unit beyond the three-term contingency to cover the phenomenon of arbitrary stimulus equivalence (see Chapter 1, this volume, and Volume 1, Chapter 16, this handbook, for more extended consideration of this research area). Figure 6.7 shows a generic diagram of a typical stimulus equivalence procedure with three sets of stimuli (A, B, and C). Solid arrows show arbitrary MTS relations that are established through direct teaching (AB and AC in this example). For example, in one of the three AB trained relations, A1 serves as the sample stimulus, B1 serves

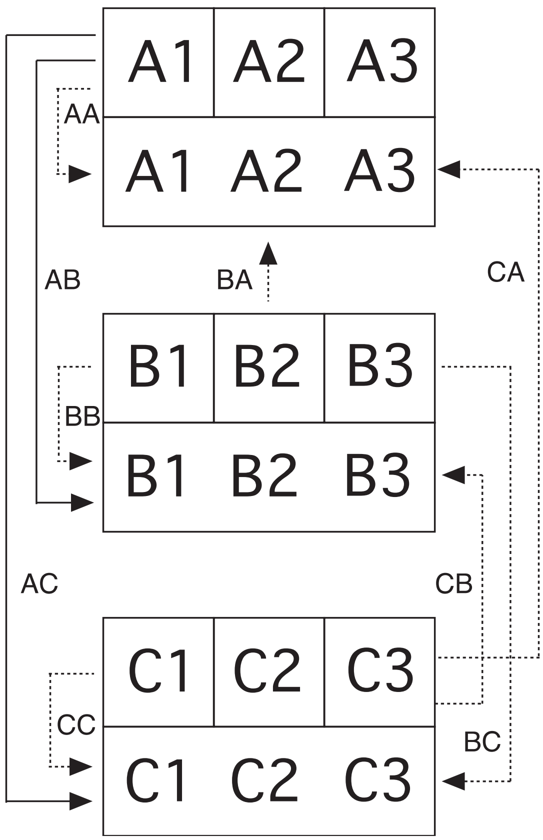

FIGURE 6.7. Diagram of a prototypical arbitrary-matching stimulus equivalence procedure in which sample stimuli are successively presented (suggested by the individual boxes) and comparisons are presented simultaneously (suggested by the rectangular enclosure). Relations AB and AC are established via direct teaching (solid arrows) and the remaining relations AA, BB, CC, BA, BC, CA, and CB (dashed arrows) may emerge without further training.

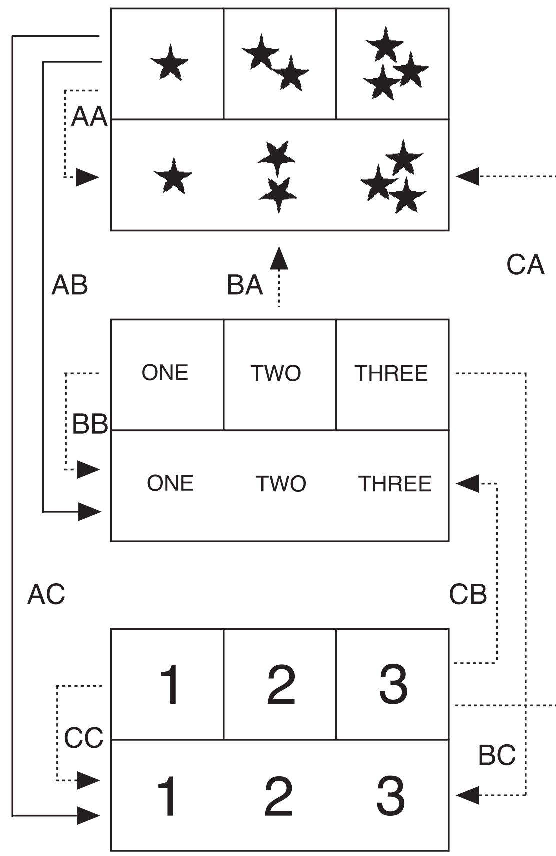

FIGURE 6.8. Diagram of an arbitrary-matching procedure intended to establish equivalence relations among numbers, printed number names, and quantities. Relations AB and AC are established via direct teaching (solid arrows), and the remaining relations AA, BB, CC, BA, BC, CA, and CB (dashed arrows) are intended to emerge without further training.

as the correct comparison stimulus, and B2 and B3 are the incorrect comparison stimuli. Once these two three-term relations are taught, other stimulus–stimulus relations may emerge without further teaching. The dashed arrows show these emergent arbitrary MTS relations (AA, BB, CC, BA, BC, CA, CB). For example, given sample stimuli from Set C, emergence of new stimulus–stimulus relations will be demonstrated if the participant selects the corresponding comparison stimuli from Set A. Figure 6.8 shows an example of a relational discrimination task that might be taught to establish behavioral prerequisites for learning symbols for simple quantities.

Unlike the feature-based equivalence relations mentioned earlier (e.g., triangles of different sizes), arbitrary equivalence relations do not have their basis in physical identity or similarity (i.e., the number *1* does not resemble the printed word *one* or a single star on a page). Thus, emergent arbitrary-matching performance consistent with the training history must be based on the relational properties of the arbitrary-matching relations that were established via direct teaching. Unique in M. Sidman and Tailby's (1982) analysis is the specification of precise criteria for inferring arbitrary equivalence relations, based on mathematical definitions of equivalence, that they mapped onto arbitrary MTS procedures of the type I have considered throughout this chapter. The properties of an equivalence relation are reflexivity, symmetry, and transitivity. In reflexive relations, each stimulus must be shown to relate to itself. If relations AB and AC are taught, then relations AA, BB, and CC must also be evident. Symmetrical relations are bidirectional; having learned AB, symmetry is shown in the emergence of relation BA without further training. Transitive relations must be shown via assessment of relations among three (or more) stimuli that were not simultaneously present during training. For example, teaching relations AB and BC must yield the emergent AC relation. Coincident emergence of the symmetrical counterpart CA relation confirm that AB and BC are in fact equivalence relations (cf. combined test methods; M. Sidman & Tailby, 1982).

Three-Term Relations and Stimulus Equivalence

Studies of stimulus equivalence and other forms of emergent behavior such as the exclusion–EM and arbitrary assignment phenomena show unambiguously that arbitrary MTS in humans can establish true stimulus–stimulus relational learning instead of mere configuration control or rote if–then chains. At one time, it appeared that stimulus equivalence relations might only arise in the context of four-term contingency procedures (M. Sidman, 1986). Subsequently, however, equivalence relations were found to be demonstrable at the three-term level. For example, Vaughan (1988) proposed another definition of stimulus equivalence derived from mathematical set theory: Relations between elements of a set are equivalence relations if they make up a nonintersecting partition of a larger set of elements that make up the universe of elements.

Vaughan (1988) operationalized the partition in simple (i.e., nonconditional) discrimination procedures—three-term contingency relations. The top row of Figure 6.9b shows a successive discrimination procedure of the type used in Vaughan's original work with pigeons, and the bottom row shows simultaneous discrimination procedures of the type that have been used in follow-up studies (e.g., McIlvane et al., 1990; M. Sidman, Wynne, Maguire, & Barnes, 1989). The essence of Vaughan's partitioning method is illustrated in Figure 6.9c: During the original training, the universe of elements is divided into two nonintersecting subsets. Members of one subset are positive stimuli to be selected (i.e., select relations) in a discrimination task, and members of the other subset are negative stimuli to be rejected (i.e., reject relations). When the original discriminations are mastered, the discriminative functions of the subsets are reversed. Originally positive stimuli

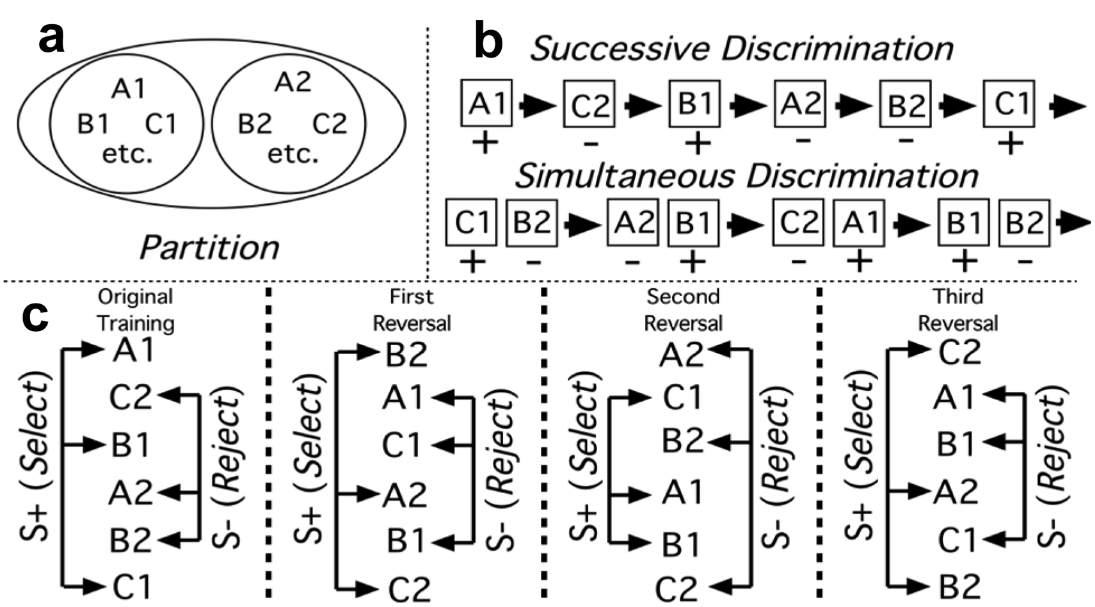

FIGURE 6.9. a: Illustration of the partition as defined in set theory. b: Successive and simultaneous simple discrimination procedures designed to establish the baseline from which the partition derives. c: Repeated reversal procedures that require the participant to initially select members of one set and to reject members of the other set, followed by complete reversal of these relationships.

become negative, and vice versa. When this discrimination reversal problem is mastered, the contingencies are re-reversed, thus reinstating the original discrimination contingencies.

This contingency reversal procedure allows one to ascertain (a) whether participants become more efficient in mastering reversed contingencies as training progresses (often termed *reversal learning set*) and (b) whether spontaneous discrimination function reversals are observed, that is, if experiencing the consequences of the reversed contingencies with some members of a subset leads to spontaneous discriminative function reversals with other members without explicit discrimination training. The second of these outcomes—demonstrated and emphasized in Vaughan's (1988) study—conforms to the notion of a partition and indicates the formation of functional stimulus classes.[4] The contingency reversal procedures have been replicated with verbally able adolescents and adults with intellectual disabilities (Mcllvane et al., 1990; M. Sidman et al., 1989) and with nonverbal children (Lionello-DeNolf, McIlvane, Canovas, de Souza, & Barros, 2008). These findings and others relating to demonstrations of discriminative stimulus–reinforcer equivalence relations (Dube, McIlvane, Mackay, & Stoddard, 1987; Dube, McIlvane, Maguire, Mackay, & Stoddard, 1989) led M. Sidman (2000) to reformulate his account of the nature and origin of arbitrary equivalence relations, suggesting that (a) equivalence relations may be generated directly as a consequence of establishing contingency relationships and (b) all ordered pairs of the components of the constituent analytical units (i.e., stimulus–stimulus, stimulus–response, response–reinforcer, stimulus–reinforcer) might be demonstrable as members of equivalence classes under appropriate testing circumstances.

N-Term Relations Within *N* − 1–Term Contingency Procedures

I have thus far limited discussion of stimulus–stimulus relations to the four-term contingency procedure. However, three-term procedures may also generate performances that must be analyzed as four-term behavioral units. One simple example is the go/no-go procedure shown in Figure 6.10. This procedure displays two (or more) stimuli, usually in fairly close spatial contiguity; the response to these displays is either to respond to it (go) or to do something else (no go). For example, given stimulus displays A1B1, A2B2, A1B2, and A2B1, the contingencies might require the participant to go in the presence of the first two and to do something else in the presence of the second two. In typical go/no-go procedures, positive consequences follow responses on go trials, and responses on no-go trials are followed procedurally by extinction conditions. A variant of the go/no-go procedure may also provide positive consequences if the participant refrains from responding on no-go trials.

Given the previous discussion, it likely comes as no surprise that a participant could master this go/no-go discrimination problem by learning the appropriate response to each of the four stimulus

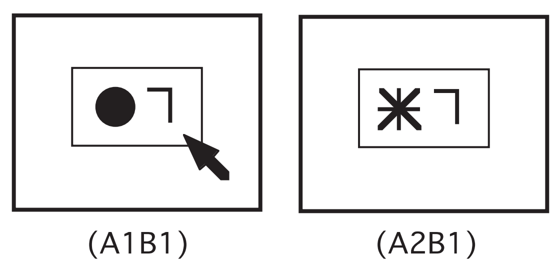

FIGURE 6.10. Illustration of a go/no-go procedure. The trial display on the left is a go trial that is to occasion a response as suggested by the arrow. The display on the right is a no-go trial that is to occasion some other behavior.

[4]This evolved behavior-analytic terminology can be confusing to readers who are not thoroughly conversant with the history of research in stimulus equivalence. The term *stimulus equivalence* is usually (but not exclusively) used to refer to equivalence relations that are shown within four-term contingency procedures. The rationale is that there are two stimulus terms in these contingencies (e.g., sample and comparison stimuli in MTS procedures). When equivalence relations are demonstrated at the three-term level, however, there is only one stimulus term of the contingency. Three-term equivalence relations have their basis in shared discriminative functions (i.e., stimulus–consequence relations) and the name *functional equivalence* has been used to differentiate these from stimulus equivalence at the four-term level. The discriminating reader will note, however, that equivalence at the four-term level also depends on the discriminative functions of the stimuli involved. Sidman (1986) recognized this when he described the function of the fourth (sample) term as to "activate" a given three-term contingency relation. In this sense, therefore, all equivalence relations involve functional equivalence.

configurations in the four trial types—a simple three-term relation. However, this three-term contingency procedure embeds within itself a feature in common with equivalence procedures: Both the A1B1 and the A2B2 displays present two elements that are together jointly discriminative stimuli for the go response, whereas other combinations of these elements are not. Indeed, if these stimuli were displayed in a blank comparison MTS training procedure (Figure 6.5), the combinations A1B1 and A2B2 would be involved in select relations, whereas A1B2 and A2B1 would be involved in reject relations. Viewed in this way, might the procedure establish select stimulus–stimulus relations in the former case and reject relations in the latter?

Debert, Matos, and McIlvane (2007) implicitly asked this question in a study with normally capable participants. Using go/no-go procedures, they followed the logic of typical stimulus equivalence experiments in teaching relations involving three sets of stimuli (Sets A, B, and C). Thus, they taught a larger set of go (A1B1, A2B2, A1C1, A2C2) and no-go (A1B2, A2B1, A1C2, A2C1) arrangements. On probe trials, these stimuli were presented in reversed spatial positions (i.e., B1A1 . . . C1A2), trials that Debert et al. argued were analogous to the reversed spatial positions of sample and comparison stimuli on symmetry trials in typical MTS equivalence procedures. Other test trials presented the stimuli in different combinations—B1C1, C1B1, B2C2, C2B2, B1C2, C2B1, B2C1, and C1B2—that they argued were analogous to transitivity and equivalence probes in typical equivalence experiments. Notably, virtually all participants in this and a related follow-up study (Debert, Huziwara, Faggiani, & McIlvane, 2009) showed emergent behavior consistent with stimulus equivalence relations (similar findings have led others to term contiguous pairing procedures such as these as *respondent-type conditioning procedures*; e.g., Leader, Barnes & Smeets, 1996).

The findings just mentioned have potentially important implications for the classification of stimulus functions within analyses of the type done by Cumming and Berryman (1965) and M. Sidman (1986). When stimulus equivalence is demonstrable in the go/no-go procedure, one has a four-term behavior relation within the context of a three-term contingency procedure. Using Cumming and Berryman's terminology, which stimulus is the selector of discriminative functions and which is the discriminative stimulus? Using M. Sidman's terminology, which stimulus activates a three-term contingency? It seems apparent that the functions identified by these investigators for procedures such as MTS may not apply when one is dealing with four-term contingency relations within the context of a three-term procedure.

Stromer, McIlvane, and Serna (1993) offered the term *separable compound* to distinguish relations of this sort both from the configural compound stimuli discussed in earlier sections and as an alternative to the hierarchical stimulus control functions implied by Cumming and Berryman's (1965) and M. Sidman's (1986) analyses. Although the separable compound is merely descriptive terminology rather than a true explanation, it does occasion certain questions that may take one closer to the latter goal. For example, what are the variables that determine whether a stimulus composed of more than one discrete element is separable or not? How do separable compounds relate to the definitions of equivalence relations offered by M. Sidman and Tailby (1982) and Vaughan (1988) and to extant theories of discrimination learning (discussed later)? Are the hierarchical stimulus functions proposed by Cumming and Berryman and further explicated by M. Sidman not applicable to procedures such as the go–no-go procedures of Debert et al. (2007, 2009), or are they merely masked by their classification as three-term contingency procedures?

Pertinent to the last of these questions, for example, one might argue that a participant responds to the go–no-go procedure by observing the stimuli in sequence, looking first at the stimulus on the left and then at the one on the right or vice versa. Sequenced observing of this sort is in fact required by many four-term contingency procedures (i.e., those that require an initial observing response to a sample stimulus followed by observing and selecting comparison stimuli). Viewed in this way, one could argue that the first stimulus observed serves as the de facto initial (i.e., fourth) term of a four-term contingency and the second as the de facto next (i.e., third) term of that contingency. If the second stimulus observed was a match for the first stimulus observed, then a select relation would hold (a go). If the second stimulus was not a match, however, then a reject relation would hold (a no go). This analysis would hold even if the participant varied his or her observing, initially looking sometimes at the stimulus on the left and sometimes at the stimulus on the right. In such a case, the procedure would occasion behavior that may be directly analogous to that in procedures in which symmetrical relations are explicitly trained to promote the equivalence relations targeted by the experimenter (e.g., Zentall, Clement, & Weaver, 2003).

The analysis just presented seems open to empirical validation and perhaps some new conceptual analyses. For example, one could directly test whether the proposed sequenced observing actually occurs using eye-tracking methodology (e.g., Dube et al., 2006). If sequenced observing of this nature is demonstrated, then Cumming and Berryman's (1965) and M. Sidman's (1986) analyses of four-term contingencies continue to hold even when procedures nominally include only three terms, and one might learn something more about behavioral processes by which separable compounds are separated.

Controlling Relations in Simple and Complex Discrimination: Concluding Comments

In preceding sections, I have considered some of the most important procedures, approaches, and concepts relating the analysis of simple and complex discrimination learning from a behavior-analytic perspective. In particular, I have tried to make it clear that behavior analysts do not treat stimuli as undifferentiated blobs in the tradition (real or perceived) of archaic and mechanistic stimulus–response learning theories of the first half of the last century (e.g., Hull, 1950; Spence, 1937). Responding to the implicit criticism of Rilling (1992), behavior analysis does address the problems of perception and representation, but in a manner that is different from that of cognitive accounts that appeal to intervening variables such as representations, expectancies, and other quasi-neurological entities. Behavior analysts strongly prefer direct observation and measurement of contingency relationships when such procedures are feasible and the accumulation of compelling data to support inferences when inferences are logically or practically necessary. In the next section, I illustrate this point further as I consider some of the pertinent theory that has emerged from behavior analysts interested in simple and complex discrimination learning.

THEORIES OF STIMULUS CONTROL

Given the nature and objectives of this volume and this chapter, extensive consideration of theories of simple and complex discrimination learning would not be appropriate or even possible in the space available. That acknowledged, I think some consideration of basic theory is helpful in further illustrating behavior-analytic approaches to the analysis of discrimination learning processes.

Discrimination Learning: Basic Processes in Acquisition

Dinsmoor (1985) presented one of the most accessible treatments of behavior-analytic theory concerning behavioral processes involved in the acquisition of discrimination via differential reinforcement. He recalled the traditional account of Skinner (1938), in which responses to the positive stimulus (S+) were gradually increased in probability via reinforcement and those to the negative stimulus (S−) were gradually decreased via extinction. Dinsmoor pointed out, however, that this account had certain limitations. For example, he noted that there was usually substantial transfer between the two stimuli of the effects of their respective schedules in the initial stages of discrimination training, quoting Skinner (1933), who wrote, "The reinforcement of S1-R affects the strength of S2-R also, and there is a converse sharing of extinction" (p. 303). Dinsmoor also pointed out a directly related problem: Constant features of the environment are always and often equally predictive of both reinforcement and extinction in discrimination learning procedures. Nevertheless, control by these features obviously does not occur when the research participant responds robustly and reliably to S+ and little or none to S−. He summarized the traditional account and its problems as follows:

> Reinforcement of the response in the presence of S+ increases its strength more in the presence of that stimulus than in the presence of S−; nonreinforcement in the presence of S− reduces the strength more in the presence of that stimulus than in the presence of S+ . . . but such an analysis does not work. . . . [It] deals only with what happens in the presence of each stimulus independently, not with the change in the interaction between them. (Dinsmoor, 1985, p. 366)

Dinsmoor's (1985) solution to this theoretical challenge was to hypothesize that the observing behavior of the participant was drawn to those stimuli (S+) that set the occasion for (a) reinforcement in their presence and (b) no reinforcement in their absence. By *observing,* Dinsmoor clearly meant overt behavior, but he also admitted the possibility of private events, writing, "I think we are obliged to consider analogous processes occurring further along in the sequence of events, presumably in the neural tissue, and commonly known as attention" (p. 365). Positive stimuli, predicting the availability of reinforcement, drew gradually increasing observing and attending, resulting in increases in contact with those stimuli with receptors and associate neural processors. Constant features of the environment, predicting reinforcement and nonreinforcement equally, gradually lost their power to capture observing and attending. The negative stimuli (S−) that predicted consistent nonreinforcement occasioned only observing behavior sufficient to establish that they were not S+ (which was often presented in contiguous locations); they did not sustain observing for the same periods as S+ (e.g., as measured by a class of procedures pioneered by Wyckoff, 1969), thus diminishing their contact with receptors and associated neural processors.

The hypothesized (and sometimes directly measured) differential levels of observing and attending were intended to provide a theoretical mechanism for handling the induction problem with Skinner's (1938) original formulation. They were also informative in providing a plausible account of various behavioral phenomena that could not be handled by theories of gradual stimulus control development such as Skinner's, among them so-called errorless learning (e.g., M. Sidman & Stoddard, 1966; Terrace, 1963a), the feature-positive effect (e.g., Morris, 1977), and differential stimulus control by S+ and S− as measured by generalization gradients (Honig & Urcuioli, 1981).

Discrimination Learning: Steady-State Analyses

Dinsmoor's (1985) account was provided mainly to characterize processes occurring during acquisition within a multiple schedule of reinforcement. Thus, its applicability to the steady state and to other types of situations has yet to be established. Indeed, in recent years, very little theorizing and conceptual analysis has been done about fundamental variables and processes involved in discrimination learning, and the state of the science in this critical area has not developed much beyond the accounts offered by Skinner (1938) and occasionally elaborated by theorists such as Dinsmoor (interested readers should see Volume 1, Chapter 17, this handbook).

One exception to this characterization is contingency discriminability analysis (Davison & Nevin, 1999), which offered a quantitative analysis of responsiveness to discriminative and consequential control of behavior, analogous in certain respects to signal detection theory (Green & Swets, 1966). Briefly, behavioral differentiation was seen as a function of two dimensions of discriminability, one describing antecedent stimuli and the other describing consequential stimuli. Behavioral differentiation is most likely when (a) environmental occasions are easily discriminated and (b) consequences for different behaviors are highly discriminable. Degree of differentiation may be related to values along and across each dimension. McIlvane and Dube (2003) subsequently suggested that the discriminability analysis might profitably be extended to the response dimension of the contingency, a suggestion that is consistent with M. Sidman's (2000) analysis of that dimension in relation to stimulus equivalence class formation.

The contingency discriminability analyses of Davison and Nevin (1999) and their recent elaborations by Nevin, Davison, and Shahan (2005; Nevin et al., 2007) have the advantages of quantitative rigor, empirical support, and far-reaching scope. These models, however, have advanced in part by making certain assumptions concerning the properties of the controlling stimuli. Doing so has allowed them to go forward, bypassing certain theoretical challenges that must ultimately be faced to provide a complete account (e.g., handling the multiple sources of stimulus control that may occur within a discrimination baseline; Ray & Sidman, 1970). Although Davison, Nevin, and their colleagues are clearly making theoretical and conceptual progress, there does not now seem to be an extant theory that manages to encompass all of the necessary elements that will be needed to provide a comprehensive account of the key processes in discrimination learning.

Toward a Comprehensive Theory of Discrimination Learning

Although a comprehensive theory of discrimination learning does not now exist, I think that conceptual and empirical work has established the foundation for developing one. To that end, my colleagues and I have been working over the past 15 years or so to integrate what we have learned into an increasingly formal account that we hope will ultimately advance the analysis of both simple and conditional discrimination learning. We call this effort *SCT coherence theory* (McIlvane & Dube, 2003; McIlvane, Serna, Dube, & Stromer, 2000). In particular, the contingency discriminability analysis of Davis, Nevin, and colleagues has influenced our thinking by leading us to ask whether the sources of behavioral variability in experimental or educational protocols to establish symbolic behavior may be related to issues of contingency discriminability. As noted earlier, *SCT* refers to the physical features, structural relationships, and controlling properties of stimuli. SCT coherence theory suggests that behavioral variability can often be traced to lack of coherence between (a) those aspects of the stimuli that the investigator or teacher intends to gain control of behavior and (b) those that actually gain control (although other sources such as endogenous factors must also be considered; cf. Thompson & Lubinski, 1986).

The most recent version of SCT coherence theory extends coherence concepts to all three terms of the operant contingency, a development that is consistent with M. Sidman's (2000) idea that all elements of the contingency (stimulus, response, consequence) are involved in equivalence relations (see McIlvane & Dube, 2003, for further details). Moreover, the focus on SCT development is consistent with a recent expansion of the contingency discriminability analysis (Nevin et al., 2005, 2007) that adds the concept of the stimulus as "attended to." Indeed, as mentioned earlier, the SCT concept was offered explicitly to come to terms with the stimulus as represented (or attended to).

The coherence nomenclature of SCT coherence theory refers to nothing more than the degree of consistency between the SCTs that the investigator or teacher wants to establish via his or her programmed contingencies and those SCTs that are in fact acquired by the participant or student. *High coherence* means that the SCTs specified by the programmed contingencies (or those perfectly correlated with them; cf. Ray & Sidman, 1970) are those acquired. *Low coherence* means that SCTs acquired are only partially consistent with those specified by the programmed contingencies, for example, in the case in which an investigator or teacher wants to establish select relations but achieves instead mixed select and reject relations that nevertheless meet the contingency requirements (as illustrated in Figure 6.4). No coherence means that none of the SCTs specified by the programmed contingencies are actually established, such as when the investigator or teacher specifies relational learning topographies but establishes instead a mix of nonrelational position control: win–stay, lose–shift (Harlow, 1949). Depending on the nature of the trial sequencing, the latter outcome may result in local or spurious above-chance accuracy scores that suggest incorrectly that some relevant SCTs have been established.

Why is SCT Coherence Sometimes Difficult to Achieve?

The short answer is that programmed reinforcement contingencies are specified insufficiently well to achieve them. In my view, stimulus control researchers and teachers should be guided by a version of

Murphy's law: If programmed reinforcement contingencies allow development of irrelevant SCTs, then they will likely develop, perhaps especially if the participants are nonhumans or humans with developmental limitations. Regarding nonverbal populations, I have argued that SCT coherence is especially difficult to achieve when investigators or teachers and participants or students operate at different levels of neurobehavioral development. For example, humans with developmental limitations often respond to complex stimulus displays by attending to a restricted set of local stimulus elements or features (cf. Dickson, Wang, Lombard, & Dube, 2006). By contrast, investigators or teachers tend to respond to complex stimuli as global, well-integrated percepts; they may tend to program contingencies aimed at establishing such SCTs, and thus there may be a mismatch between the programmed contingencies and the characteristics of the learner.

SCT coherence analyses arose from research findings. For example, in work on discrimination learning of individuals with intellectual disabilities, I and others often encounter stable accuracy scores that are significantly above chance but substantially short of perfection (e.g., 83% correct). Continued training will often not produce improved accuracy. This general phenomenon has been termed a *limitation on the law of effect* by House, Hanley, and Magid (1979). On its face, this finding once seemed to present a substantial theoretical challenge for disability researchers interested in attention processes within contingency learning. When this limitation is characterized in terms of multiple competing SCTs, however, the problem becomes theoretically trivial, and a solution path is indicated—better measurement, better control of observing behavior, and arrangement of environmental contingencies to ensure that desired SCTs are differentially selected by reinforcement, and irrelevant SCTs are selectively extinguished (e.g., McIlvane, Dube, & Callahan, 1996; McIlvane, Kledaras, Callahan, & Dube, 2002).

TRANSLATIONAL STIMULUS CONTROL RESEARCH

Elsewhere, I have tried to differentiate translational behavior analysis from the traditional disciplines of basic and applied behavior analysis (McIlvane, 2009; McIlvane et al., 2011). If translational behavior analysis is indeed an identifiable subfield, as I have argued, then it follows that a component of that subfield should exist that may be identified as translational stimulus control research. To conclude this chapter, I consider two examples of discrimination learning research areas that illustrate translational behavior analysis in action today. In doing so, I also take the opportunity to further illustrate how SCT coherence principles are used in efforts to bypass or overcome learning challenges in both humans and nonhumans.

STIMULUS CONTROL SHAPING

The beginning of translational research in discrimination learning can be traced to Skinner's (1968) objective of developing a technology of teaching, which was intended for broad application in both regular and special education. His objective was to translate procedures and findings of basic research accomplished primarily with nonhumans to improve the human condition. Work in this tradition included extensive development of instructional procedures for establishing educationally relevant discriminations in populations ranging from young children to advanced professional trainees (e.g., Engelmann & Carnine, 1982; Holland, Solomon, Doran, & Frezza, 1976; R. L. Sidman & Sidman, 1965).

Efforts to develop a technology of teaching were also directed at special education populations. At the most basic level, the problem was how to provide effective teaching for children who did not learn readily or at all via usual methods of special education: verbal instruction, drill and practice, and so on. Before the 1960s, many such children were labeled as having severe mental retardation and consigned to institutions. Although these institutions were called schools, they provided little real education to their students; there was no generally effective methodology for teaching such children.

Things began to change, however, when principles developed in basic laboratory research were applied to developing behaviorally based training methods. Several projects showed that children could often be taught communication and self-care skills (e.g., Mackay & Sidman, 1968); however, it also became clear that some children did not respond well to the simple differential reinforcement methods that had been effective with nonhumans under laboratory conditions (Zeaman & House, 1963). Not only were simple reinforcement methods ineffective for teaching new behavior, but the many errors that resulted also interfered with behavior of which the children were clearly capable (e.g., M. Sidman & Stoddard, 1966; M. Stoddard & Sidman, 1967).

Faced with frequent failure of simple reinforcement methods, researchers turned to the "errorless" procedures that were being studied with nonhumans (e.g., Terrace, 1963a). Although these basic studies, such as those inspired by Dinsmoor (1985), were done mainly for theoretical reasons, people interested in teaching children with disabilities were drawn to the errorless methods because they might prove more effective than simple differential reinforcement, especially within the practical limitations of educational environments. Indeed, numerous studies over the years documented the superiority of errorless methods, including stimulus fading (M. Sidman & Stoddard, 1967), delayed prompting (Touchette, 1971), learning by exclusion (Carr & Felce, 2008; McIlvane & Stoddard, 1981), and other related methods that together have come to be known as stimulus control shaping (McIlvane & Dube, 1992).

A prototypical stimulus control shaping program is shown in Figure 6.11. The program was developed by M. Sidman and Stoddard (1966), and their effort remains even today perhaps the best example of empirically validated (*evidence based* in today's parlance) instructional technology for people with severe intellectual disabilities. The purpose of the program was to establish and to test the limits of a circle–ellipse discrimination to evaluate aspects of visual perception in people with little or no functional language—such that they could not be examined by traditionally trained ophthalmologists. The program began with highly salient (i.e., *discriminable,* following Davison & Nevin, 1999) stimulus differences. As shown in the upper-left panel of Figure 6.11, the child was to touch a lit key containing a circle (S+) and not dark keys (S−). On subsequent trials of the program, the initially large stimulus difference was gradually made less distinct (by gradually increasing illumination of the S− keys) and was ultimately eliminated (upper right panel of

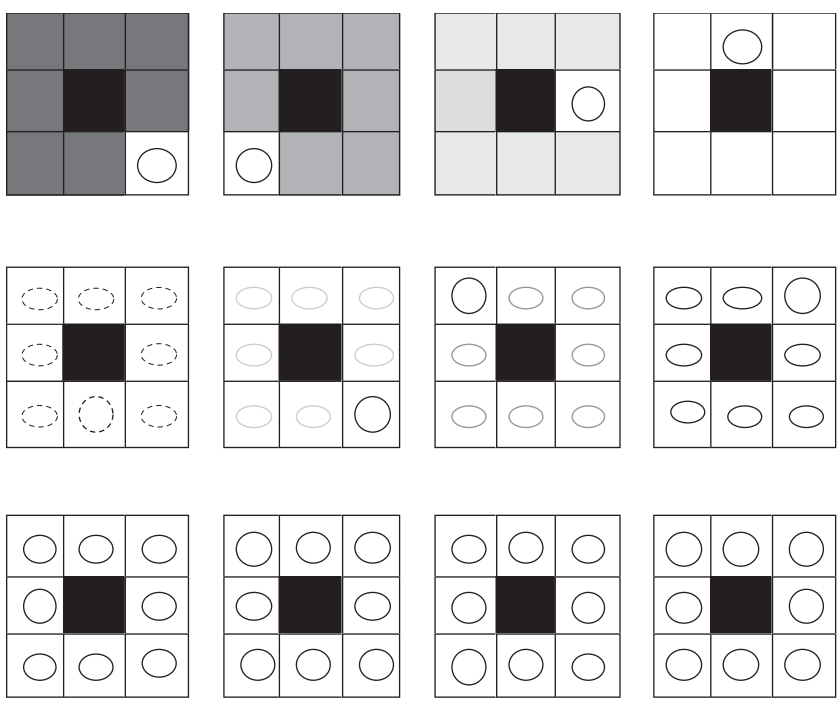

FIGURE 6.11. The circle–ellipse program of Sidman and Stoddard (1966).

Figure 6.11). At this point, the child had to select a lit key with a circle (S+) and not lit keys without one (S−). Thereafter, initially faint ellipses appeared on the S− keys, gradually becoming more distinct over trials (fading in) until both the circle (S+) and the ellipses (S−) were equally as distinct, thus requiring a circle versus ellipse discrimination. In the final stages of the program (lower row of panels in Figure 6.11), the ratio of the major and minor axes of the ellipses was changed gradually such that they became more and more like a circle—allowing the program to evaluate how fine a circle-versus-ellipse difference the child could resolve.

Although many studies of stimulus control shaping have followed the original effort by M. Sidman and Stoddard (1966), few if any have approached their rigor. One sees in action the effort to encourage observing via the initial bright key–dark key stimulus difference, which was also designed to place the ultimate target S+ on the visual receptors and not on S− keys or constant features of the environment (as Dinsmoor, 1985, would likely recommend). With that observing behavior established, the program then introduced progressively more similar distractors (i.e., the ellipses) that might draw observing had they been introduced abruptly, thus likely maintaining the differential observing of S+ throughout. Finally, the circle-versus-ellipse discrimination was refined in much the same manner such that its limits could be established.

Instructive as it is in terms of illustrating theoretical points, I think it may be even more instructive as a case study in translational behavioral science. M. Sidman and Stoddard's (1966) studies of children with severe intellectual disabilities set the stage for much of the follow-up work on instructional programming for children with intellectual disabilities. Although the studies were clearly pointed toward applications, they were just as clearly inspired by Terrace's (1963a, 1963b) basic studies with pigeons. As someone who has worked in the area of discrimination learning for many years, I am concerned that many universities seem to be downplaying or even abandoning basic behavioral research with both humans and nonhumans, and turning their attention to more applied behavior-analytic concerns. However understandable the reasons for doing that may be, I fear that we are on the verge of failing to develop or even recognize the basic–translational–applied science sequences that inspired the translational science of M. Sidman and Stoddard (1966) and those that followed them.

ANALYSIS OF RELATIONAL LEARNING PROCESSES

Earlier in this chapter, I spent much time covering procedures and processes in relational learning, using identity- and arbitrary-matching procedures to illustrate basic questions in stimulus control research. I did not spend much time, however, explaining why these topics have attracted attention from behavioral scientists. Both identity relations and arbitrary stimulus relations have long been considered fundamental components of intelligent behavior. Methods of simple and conditional discrimination originally studied by behavior analysts with basic interests using animal behavior preparations have then been adapted to study relational learning processes in humans.

Identity Relations

Historically, development of generalized IDMTS and its logical obverse, generalized oddity, has been considered an important research topic in its own right. It has been studied extensively in children (e.g., Stevenson, 1973), monkeys (Harlow, 1949), pigeons (Cumming & Berryman, 1965), sea lions (Kastak & Schusterman, 1994), and many other study populations. Stimulus modalities investigated have included visual, auditory, and more recently, olfactory stimuli (Penã, Pitts, & Galizio, 2006).

In humans, generalized IDMTS and oddity were once thought to be beyond the ken of normally capable children younger than ages 4 to 5 and children with disabilities of comparable developmental level (cf. Soraci & Carlin, 1992). That picture began to change around 1990 as various stimulus control prompting and shaping methods emerged. It was found, for example, that generalized identity and oddity relations could be rapidly instantiated in younger children and in people with moderate intellectual disabilities (Mackay, Soraci, & Carlin, 2002; Soraci et al., 1987). The questions then became (a) whether interparticipant variability could be managed such that very young children or those with severe intellectual disabilities could be shown to be reliably capable of displaying generalized identity relations and (b) what were the actual lower limits of intellectual functioning that could support generalized identity relations?

These questions led to a decade-long program of translational behavioral research initiated at the Shriver Center circa 1988 and reinforced by an independent replication at the University of Kansas. The goal was to extend behavioral technology such that children who could master a simple form discrimination, including nonverbal children, could be taught reliable generalized IDMTS. The approach was to (a) carefully task analyze the requirements of the IDMTS task; (b) match those requirements to the best available procedures; (c) rapidly screen out any candidates who could be taught with conventional procedures; (d) further research any apparent holes in either the behavioral analysis or the procedural support, including procedural inefficiency; and (e) conduct a final test with the lowest functioning appropriate candidates to provide the acid test of program efficacy. The summary publications of that program (Dube & Serna, 1998; Serna et al., 1997) reported that virtually all children who could master a simple form discrimination could exhibit generalized identity matching. Notably, nearly all of the methodology used was translated from prior studies that were initiated with nonhuman primates (e.g., Harlow, 1949) and other nonhuman populations. Moreover, in an example of the bidirectionality of translational research (McIlvane, 2009; McIlvane et al., 2011), the findings of this program have also been incorporated in studies that have sought to establish the potential of nonhumans to display true generalized identity relations with similar positive effects (de Faria Galvão et al., 2005).

Arbitrary stimulus equivalence has been of interest not only as a phenomenon of discrimination learning processes but also as a useful model of basic symbolic relations (M. Sidman & Tailby, 1982). In the equivalence analysis, the word *apple* can serve some of the same functions as the object. For instance, hearing the word *apple* may set a hungry listener's stomach to grumbling even if no apple is present. Such substitutability of words for their referents characterizes the relationship fundamental to what is meant in psycholinguistics by a symbol.

Questions in arbitrary equivalence research mirror those in the research on generalized identity relations just described: What individuals or species can display symbolic functions as defined in the equivalence models, and how reliably can they do so (i.e., how reliably can inter- and intraparticipant variability be managed)? In this case especially, concepts from SCT coherence theory find useful application. M. Sidman's (2000) position requires explaining why negative outcomes are reported on equivalence tests. Dube and McIlvane (1996) have argued that such outcomes are not interpretable unless one has also shown that SCTs resulting from the programmed contingencies are consistent with a positive test outcome. That point seems obvious, but it seems to be ignored by many researchers. In what follows, I illustrate the application of basic analyses of discriminative functions to address this critical issue.

As I have considered already, one can meet the requirements of the programmed contingencies by either selecting the S+ or rejecting the S−. Human participants who exhibit stimulus equivalence, even those with mild intellectual disabilities (e.g., McIlvane et al., 1987; Stromer & Osborne, 1982), tend to exhibit both select and reject relations on probe tests. Even less capable individuals may do so, given specialized training regimens (McIlvane et al., 1984). Notably, Tomanaga (1993) reported that (a) a single chimpanzee who had exhibited statistical evidence of symmetry also exhibited both select and reject controlling relations on probes and (b) chimpanzees who failed symmetry tests also did not exhibit select and reject relations. Moreover, *Cebus apella* is also known to not typically exhibit both select and reject relations spontaneously in simple and conditional discrimination learning, but there is good evidence that they can learn to do so (e.g., Goulart et al., 2005).

SCT coherence theory suggests a plausible account of why combined select and reject relations may be strongly positively correlated with positive symmetrical and transitive test outcomes. Briefly, when one verifies both select and reject relations, one demonstrates empirically that one does not have incompatible configural control (i.e., mere three-term units). Rather, one has established true four-term stimulus–stimulus relational control. Moreover, when one verifies both select and reject relations, one excludes the possibility of the mixed, incomplete relational learning illustrated in Figure 6.4, which is also potentially incompatible with positive outcomes on equivalence tests.

SCT coherence principles are also illustrated by studies of the potential deleterious effect of allowing stimulus location to become a source of competing stimulus control. With monkeys, for example, Iversen, Sidman, and Carrigan (1986) showed that the typical invariant sample location may encourage undesired control by sample stimulus–sample location compound stimuli rather than control by experimenter-specified location-independent samples. Iversen (1997) and Lionello and Urcuioli (1998) reported similar findings with rats and pigeons. For many years, in virtually every published equivalence study, experimenters assumed that stimulus location was not part of the participants' SCTs (only relatively recently has the potential SCT coherence problem of stimulus–location compounds been addressed; e.g., Frank & Wasserman, 2005, see also Volume 1, Chapter 16, this handbook). One cannot make this assumption even with humans, however, if they are very young children or have severe intellectual disabilities (McIlvane et al., 2002) or neurological impairments (e.g., McIlvane et al., 1996; M. Sidman, 1969).

How Can Stimulus Control Topography Coherence Be Encouraged?

One first analyzes the SCTs prerequisite for a positive equivalence test outcome. As mentioned, for example, such an outcome may depend on establishing the requisite select and reject relations. Moreover, many potentially competing SCTs can be anticipated, for example, control by position (McIlvane et al., 2002), common physical features (M. Sidman, 1987), novelty (see Zentall, 1996), compound or configural control (Cumming & Berryman, 1965), sample–S− control, and so forth. Given a comprehensive taxonomic analysis, one then uses one or more of a variety of stimulus control management techniques to establish the SCTs of interest.

Some Concluding Comments on Theories of Relational Discrimination

Early in this chapter, I spent considerable time discussing multiple-exemplar training in the context of discrimination learning procedures. Repeating and elaborating a question I asked earlier in a somewhat different context, what does multiple-exemplar training do at the level of behavioral process? For some researchers (Hayes, Barnes-Holmes, & Roche, 2001), multiple-exemplar training gives rise to new behavioral processes that permit behavioral phenomena such as stimulus equivalence, exclusion–EM, and other relational discrimination performances. The jury is still out on whether multiple-exemplar training is always required for such performances or whether they arise spontaneously out of reinforcement contingencies in the manner suggested by M. Sidman (2000). My own opinion is that these issues will not be resolved without refocusing efforts on basic and translational studies of simple and complex discrimination learning processes. Until more is known about how and whether multiple-exemplar training (and experience in general) results in the selection of certain SCTs and the extinction of others, questions such as "Where do equivalence relations come from?" "What are the relational capabilities of [fill in the participant or population]?" and others that have occupied so much time and effort from so many will remain.

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Chapter 7

TRANSLATIONAL APPLICATIONS OF QUANTITATIVE CHOICE MODELS

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Our purpose in this chapter is to foster appreciation of quantitative analyses of behavior for readers whose primary interests are in applied research and practice. We aim to communicate that understanding quantitative models of behavior can inform the development of behavioral applications, thereby improving the practice of behavior analysis. We hope we have done so in a manner that is accessible and will strengthen the likelihood that the interested reader will pursue additional understanding of quantitative analyses.

The goal of a science of behavior is prediction, control, and interpretation of behavior (Skinner, 1953). Quantitative models are precise mathematical descriptions of the relationship between controlling variables and behavior. Understanding quantitative models can reveal order in behavioral relations that is not otherwise readily apparent. We begin our introduction to the topic by presenting two examples of ways in which quantitative models of behavior can bring order to otherwise paradoxical behavioral data.

Differential reinforcement of other behavior is an empirically valid way to decrease the frequency of maladaptive behavior by increasing the rate of reinforcement for an independent response class. The effectiveness of differential reinforcement of other behavior begs the fundamental question of why the rate of the maladaptive behavior would decrease when it is not directly targeted in cases in which the maladaptive behavior is not placed on extinction. Quantitative models of choice provide a conceptual scheme for understanding the interaction between contingencies that maintain separate response classes. The prototypical quantitative model of choice in behavior analysis is the matching law: Proportional response allocation between two or more response alternatives will match the proportional allocation of obtained reinforcement for those alternatives. The effectiveness of differential reinforcement of other behavior–based interventions is easily understood within the conceptual framework provided by the matching law (McDowell, 1988). Increasing reinforcement for other behavior decreases the relative reinforcement rate of the target behavior, thereby decreasing the relative rate of the target behavior.

Consider another example from the area of reinforcer assessment. Imagine a behavior analyst who must design an intervention to foster a client's compliance with an effortful physical therapy routine. The therapist goes through the steps necessary to identify two reinforcers and delivers Reinforcer A after compliance. As the schedule of reinforcement is thinned, however, compliance quickly deteriorates before therapeutic durations are achieved. Out of desperation, the therapist begins to reinforce compliance with another reinforcing consequence that was ranked lower in the initial preference assessment (Reinforcer B). Voila! Compliance is reinstated, and the schedule of reinforcement can be thinned to established performance durations that lead to long-term therapeutic benefits.

At first blush, this pattern of results seems paradoxical—a less preferred reinforcer proved to be more efficacious in maintaining compliance.

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Behavioral economics, however, provides a conceptual approach that allows one to interpret this pattern of results in a sensible and orderly way (see DeLeon, Iwata, Goh, & Worsdell, 1997; Chapter 8, this volume). *Elasticity of demand* for a given reinforcer describes how rapidly consumption of a good (i.e., reinforcer) will decrease in the face of increasing costs. For some goods, demand is relatively inelastic and baseline levels of consumption are maintained in the face of increasing costs (e.g., gasoline), whereas for other goods, demand is relatively elastic and baseline levels of consumption are not well maintained in the face of increasing costs (e.g., bubble gum). In the earlier example, thinning the schedule and requiring longer bouts of physical therapy to access the reinforcer constitutes an increase in the cost of the reinforcer. On one hand, although Reinforcer A may have been preferred when the cost was low (e.g., pointing to it during the preference assessment), demand for that reinforcer was too elastic to maintain compliance in the face of the physical therapy program's increasing demands. On the other hand, although Reinforcer B was not the most preferred reinforcer at low costs, demand for that reinforcer was sufficiently inelastic that it was able to reinforce engaging in the activity for durations that were therapeutically beneficial. Thus, behavioral economics brings order to seemingly disorderly response patterns.

In this chapter, we describe how quantitative models may apply or do apply to complex, socially relevant human behavior. In some cases, direct evaluations of human behavior using quantitative models have occurred in the natural environment or in laboratory contexts. In other cases, the quantitative models provide clear implications for application that have not yet been tested. We focus our discussion primarily on two research areas—the matching law and temporal discounting—that exemplify the utility of using quantitative models to inform understanding of socially significant behavior. We conclude with a brief overview of several other models with promise for or direct implications for application, some of which are considered in more detail in Chapters 5 and 8 of this volume.

MATCHING LAW

In this section we begin our discussion by focusing on Herrnstein's (1961) matching law. First we introduce a variety of quantitative models inspired by the matching law and define the theoretical underpinnings of the parameters of the models. Subsequently, we review applied and translational research that has extended the model to understanding complex human behavior. The section concludes with a discussion of some points of consideration for future research.

Background

One of the historically prominent quantitative models in behavior analysis is Herrnstein's matching law (e.g., Davison & McCarthy, 1988). This model has been used primarily to describe the distribution of responding when behavior is maintained by concurrent variable-interval (VI) reinforcement schedules. In such schedules, two (or more) response options with distinctive cues are available, and the subject may switch between (among) them at any time. Responding to each option produces reinforcers after variable intervals of time, and the schedule for each option is typically varied parametrically during the course of an experiment. According to the matching law, behavior will be distributed across available options such that the proportion of responses directed toward each alternative will equal (or match) the proportion of reinforcement obtained from that alternative.

Herrnstein (1961) quantified the relationship between relative response rate and relative reinforcement rate with this model:

$$\frac{B_1}{B_1+B_2}=\frac{R_1}{R_1+R_2}, \tag{1}$$

where B_1 and B_2 represent the absolute response rates on each of the two alternatives and R_1 and R_2 represent the obtained reinforcement rates on each of the two alternatives.

One of the key theoretical implications inherent in the matching law is that the effect of any contingency of reinforcement on behavior is not absolute; rather, it occurs within a context that includes other behavioral contingencies. Working off of this implication, Herrnstein (1970) recognized that even single schedules of reinforcement operate concurrently with contingencies intrinsic to the experimental environment (e.g., grooming, exploring). Assuming that the estimates of these unmeasured influences on behavior could be derived from the data, Herrnstein extended the matching law to provide a quantitative description of the relationship between absolute response rate and absolute reinforcement rate for behavior maintained by simple VI schedules of reinforcement. Herrnstein's quantitative law of effect is as follows:

$$B = \frac{kR}{R + R_e}, \tag{2}$$

where *B* equals the absolute response rate of the target behavior and *R* equals the absolute reinforcement rate produced by the target response. Theoretically, the free parameters *k* and R_e represent the asymptotic maximal response rate and reinforcement from extraneous sources, respectively.

The model describes a hyperbolic relationship between response rate (*B*) and reinforcement rate (*R*). Figure 7.1 shows three curves drawn with Equation 2. The asymptotic maximal response rate (*k*) is set to 60 responses per minute for all three curves, but the reinforcement from extraneous sources (R_e) is set individually for each curve (R_e = 1, 5, or 10 reinforcer equivalents per minute). Response rate approaches the asymptotic rate (*k*) as a negatively accelerating function of reinforcement rate. Theoretically, the amount of extraneous reinforcement (R_e) for other behavior present in the environment modulates how rapidly response rate approaches the asymptotic rate. If the amount of extraneous reinforcement is low (a lean environment), response rate will approach the asymptotic rate relatively rapidly as reinforcement rate increases. If the amount of extraneous reinforcement is high (a rich environment), response rate will approach the asymptotic rate relatively slowly as reinforcement rate increases. Returning to the matching-based interpretation of differential reinforcement of other behavior–based interventions described earlier, increasing the rate of reinforcement for other behavior amounts to increasing R_e. As the differential reinforcement of other behavior contingency increases R_e, the rate of the maladaptive behavior (*B*) decreases.

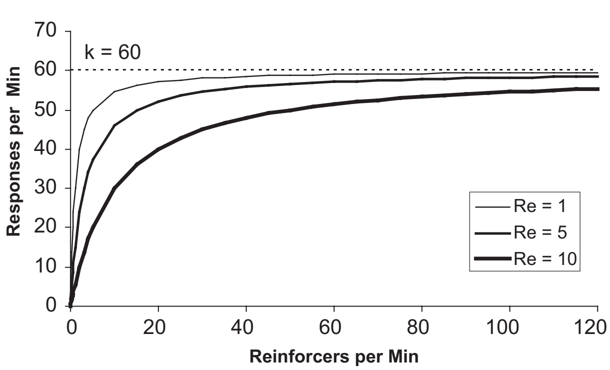

FIGURE 7.1. Response rate as a function of reinforcement rate at three levels of extraneous reinforcement (R_e). *k* = asymptotic maximal response rate.

Empirical studies of concurrent VI–VI schedule performance have shown that systematic deviations from strict matching are typical (Baum 1974, 1979). To accommodate these deviations, Baum (1974) introduced the generalized matching law:

$$\frac{B_1}{B_2} = b\left(\frac{R_1}{R_2}\right)^a, \tag{3}$$

where *b* is a free parameter that adjusts for a constant preference for one alternative that is unrelated to differences in the reinforcer ratio, *a* is a free parameter that adjusts for individual differences in sensitivity to the reinforcer ratio, and the response and reinforcer parameters are as defined for Equation 1.

Note that Equation 3 describes how the ratio of responses matches the ratio of obtained reinforcers, whereas Equation 1 describes how the proportion of responses matches the proportion of obtained reinforcers. The ratio equation is, however, mathematically equivalent to the proportion equation, and the interested reader is referred to McDowell (1989) for details on the relationships between Equations 1 and 3. Shifting from the proportion-based matching equation to the ratio-based equation allows for more intuitive interpretation of graphical representations of data, as explained later. The inclusion of the free parameters gives the model the flexibility to accommodate deviations from perfect matching. The bias parameter, *b,* allows the model to be fit to data for which there is an inherent preference for one response alternative that is unrelated to differences in the reinforcer ratio (e.g., position or color preference). At values of *b* greater than 1.0, preference for Alternative 1 exceeds predictions solely on the basis of sensitivity to the reinforcer ratio. At values of *b* less than 1.0, preference for Alternative 2 exceeds predictions solely on the basis of sensitivity to the reinforcer ratio. The sensitivity parameter, *a*, allows the model to be fit to data that do not vary perfectly with changes in the reinforcer ratio. At values of *a* less than 1.0, undermatching occurs, and the behavior ratio (B_1/B_2) deviates from the predictions of matching in the direction of indifference (i.e., the response ratio is less extreme than predicted by strict matching). At values of *a* greater than 1.0, overmatching occurs, and the behavior ratio deviates from matching in the direction of exclusive preference for the richer alternative (i.e., the response ratio is more extreme than predicted by strict matching).

Figure 7.2 illustrates differences in sensitivity to the reinforcer ratio. The curves in the top panel of the figure were drawn using the proportion-based version of the matching law (Equation 1), and the curves in the bottom panel of the figure were drawn

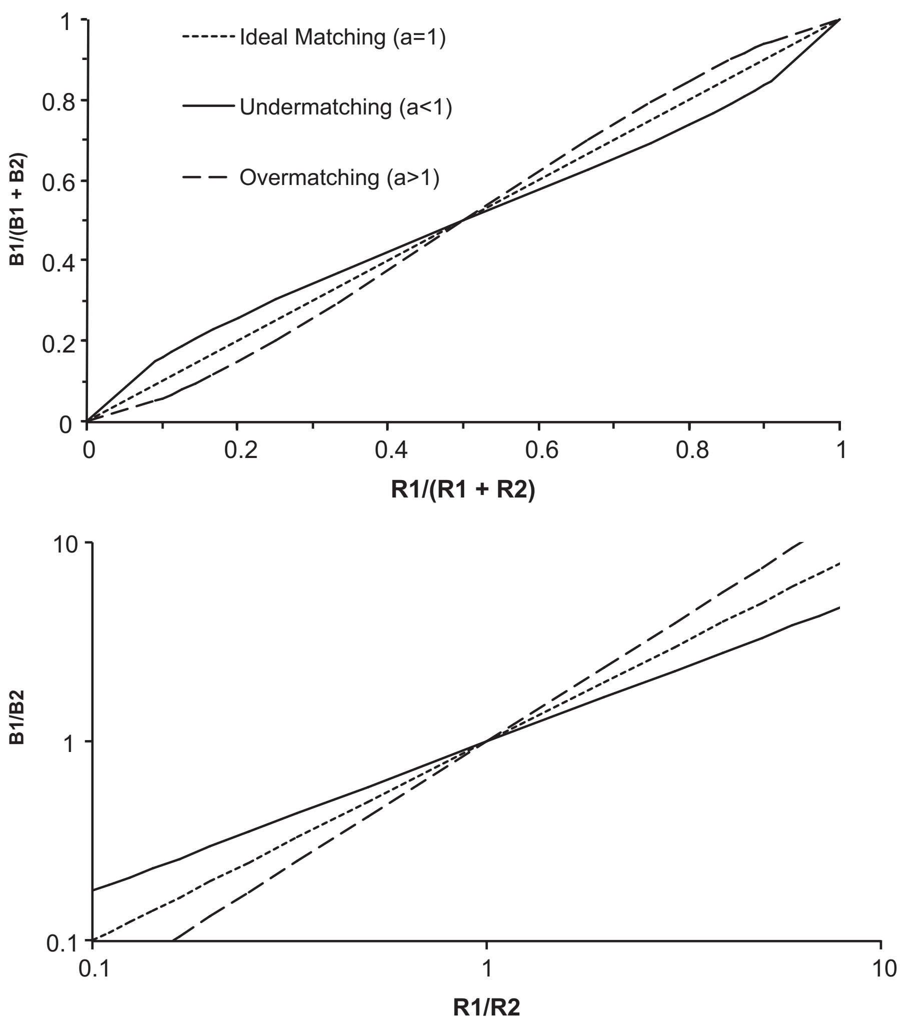

FIGURE 7.2. Matching relations across three reinforcement sensitivities (*a*) with bias (*b*) equal to 1.0. Top: Curves are drawn with the proportion-based version of the matching law (Equation 1). Bottom: Curves are drawn with the ratio-based version of the matching law (Equation 3). Note logarithmic axes. B_1 and B_2 = absolute response rates on each of the two alternatives; R_1 and R_2 = obtained reinforcement rates on each of the two alternatives.

using the ratio-based version of the matching law (Equation 3). In the top panel, departures from ideal matching are evidenced by curved lines. For undermatching, the response ratios are greater than the predictions of ideal matching ($a = 1$) at reinforcer proportions less than 0.50 and less than the predictions of ideal matching at reinforcer proportions greater than 0.50. For overmatching, the response ratios are less than the predictions of ideal matching ($a = 1$) at reinforcer proportions less than 0.50 and are greater than the predictions of ideal matching at reinforcer proportions greater than 0.50.

The interpretive advantages of the ratio-based version of the matching law can be appreciated when one compares the curves in the top panel of Figure 7.2 with those drawn using Equation 3 in the bottom panel. Note that the data in the bottom panel are plotted on logarithmic axes. Generically, Equation 3 is known as a power function—a variable base (R_1/R_2) is raised to a fixed power (a). Plotting a power function in logarithmic coordinates produces plots that are straight lines. Differences in sensitivity to the reinforcer ratio are apparent by differences in the slopes of the lines. Interpreting the degree to which sensitivity to the reinforcer ratio deviates from ideal matching (i.e., $a = 1$) is much more intuitive and easier in the bottom panel than in the top panel.

In lieu of plotting the ratio data in log-log coordinates, one could take the logarithmic transformation of Equation 3 to achieve the same end. Doing so yields one of the more common versions of the generalized matching law:

$$Log\left(\frac{B_1}{B_2}\right) = aLog\left(\frac{R_1}{R_2}\right) + Logb, \tag{4}$$

where all the terms are as defined earlier. Equation 4 takes the general form of an equation for a straight line ($Y = MX + B$), where a, the sensitivity parameter, is the slope and the logarithmic transform of b, the bias parameter, is the Y intercept.

Figure 7.3 illustrates differences in response bias. The curves in the top panel are drawn with the proportion-based version of the matching law (Equation 1), and the curves in the bottom panel have been drawn with the transformed ratio-based version of the matching law (Equation 4). In the top panel, bias is evidenced by curves that are bowed away from the predictions of ideal matching in the direction of the preferred response alternative. In the bottom panel, the curves are straight lines, and bias is evidenced by changes in the Y intercept. That is, the lines are shifted in the axes in the direction of the preferred response option. Again, the ratio-based generalized matching law presents the data in a manner that is more intuitive to interpret.

One additional advantage of using the transformed generalized matching law is that fitting the model to the data requires only linear regression, making it very easy to fit the model to data using widely available spreadsheet applications such as Microsoft Excel. Reed (2009) has provided a step-by-step tutorial on fitting the generalized matching law to data using Excel.

Many response classes of interest to applied researchers do not easily lend themselves to counting of discrete response instances (e.g., lengthy tantrums, studying), and as a result it would be difficult to fit these models to such data. Baum and Rachlin (1969), however, demonstrated that the ratio of time allocated to each concurrently available alternative (as opposed to the ratio of response rates or counts) also approximately matched the ratio of reinforcer frequencies obtained for those alternatives. Thus, in cases for which responses are not easily counted, the following time-based version of the generalized matching law may be useful:

$$\frac{T_1}{T_2} = b\left(\frac{R_1}{R_2}\right)^a, \tag{5}$$

where T_1 and T_2 are the times spent engaging in Alternatives 1 and 2, respectively, during a given observation period. All other parameters are as defined for Equation 3.

The relatively simple environment of the laboratory makes it possible to manipulate relevant controlling variables while holding other variables relatively constant. To study the effects of changing relative reinforcement rate on concurrent schedule performance, for example, the response topographies of the two classes can be made roughly equal (e.g., pecking one of two keys), and identical reinforcers can be used to maintain both responses (e.g., grain).

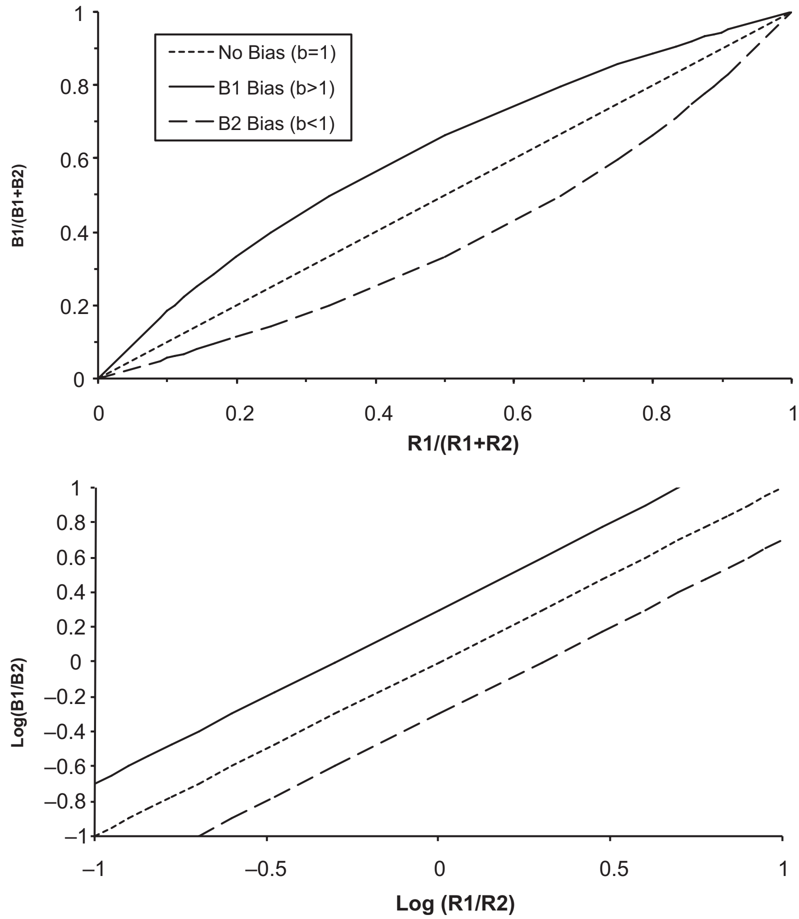

FIGURE 7.3. **Matching relations across three levels of bias (*b*) with sensitivity to reinforcement equal to 1.0. Top: Curves are drawn with the proportion-based version of the matching law (Equation 1) Bottom: Curves are drawn with the transformed ratio-based version of the matching law (Equation 4).**

In applied settings, researchers and practitioners are often faced with situations in which such a level of control is not possible. Thus, studying *in situ* may involve concurrent response classes that differ topographically and functionally, because the competing response classes may be maintained by qualitatively different reinforcers of unequal reinforcing efficacy.

The concatenated matching law was developed to model performances in situations in which choice-affecting variables other than reinforcement frequency vary across response classes (Baum & Rachlin, 1969; Killeen, 1972; see also Davison & McCarthy, 1988, Chapter 4). A generalized form of the model is as follows:

$$\frac{B_1}{B_2} = \frac{T_1}{T_2} = b\left(\frac{R_1}{R_2}\right)^a \left(\frac{Q_1}{Q_2}\right)^c \left(\frac{A_1}{A_2}\right)^d \left(\frac{D_2}{D_1}\right)^e, \quad (6)$$

where Q_1 and Q_2 are estimates of reinforcer quality (e.g., Hollard & Davison, 1971), A_1 and A_2 are the reinforcer amounts, and D_1 and D_2 are the delays to reinforcement for Alternatives 1 and 2, respectively (e.g., Catania, 1963). Note that the ratio of delays is inverted. As delay increases, the reinforcing efficacy of the reinforcer decreases, thereby diminishing the effect of that consequence on the response ratio. The parameters *c, d,* and *e* represent sensitivity to the quality, amount, and delay ratios, respectively. All other parameters are as defined earlier.

With the concatenated matching law, the behavior ratio is assumed to be a function of the product of the ratios of all variables influencing choice (Baum & Rachlin, 1969). Thus, the generalized model is expanded by including a ratio and a sensitivity parameter for each additional variable, and each of those terms is assumed to influence the response ratio in a multiplicative fashion. Holding one or more of these ratios constant while varying the reinforcer frequency ratio should bias the predicted response ratio in a manner similar to *b*. Thus, with respect to assessing the effects of reinforcer frequency across conditions, manipulating these additional reinforcement dimensions can be conceptualized as sources of bias that shift preference toward one response class at all frequency ratios examined.

Implications and Applications

In human environments, choice situations arise naturally. For example, a child who exhibits problem behavior that is reinforced by adult attention might engage in problem behavior that produces some frequency of reinforcement (R_1) or might engage in appropriate attention-getting behavior that is associated with some other frequency of reinforcement (R_2). Similarly, during a play period a student may either play on the monkey bars or read a book. In this case, matching could be assessed in terms of the amount of time spent on academic tasks versus the amount of time spent on everything else (Martens & Houk, 1989).

One could say that all of human operant behavior is reinforced on concurrent schedules, insofar as people are faced with choices at all times. Translational applications of the matching law have involved problem and appropriate behavior exhibited by individuals with disabilities (e.g., St. Peter et al., 2005), collegiate and professional athletic performance (Reed, Critchfield, & Martens, 2006; Vollmer & Bourret, 2000), conversational interactions (e.g., Conger & Killeen, 1974; McDowell & Caron, 2010a, 2010b; Pierce, Epling, & Greer, 1981), academic engagement (e.g., Reed & Martens, 2008), and others. Figure 7.4 depicts the uniformity of the matching effect across diverse topographies of behavior. In all three of the examples, the participants allocated responding that proportionally matched the relative rate of reinforcement for that response. A perfect correlation between such proportions is represented by a dashed line, and it is visually clear that the data points cluster around the dashed lines despite differences in the topography of behavior under study.

In one of the earliest translational applications of the matching law, Conger and Killeen (1974) showed that the conversational behavior of humans was controlled by relative reinforcement in the form of agreement statements by confederates. Five college students participated individually in 30-minute discussion sessions with two confederates. Confederates sitting to the participant's left and right agreed with the participant (e.g., "You're making an interesting point") according to independently

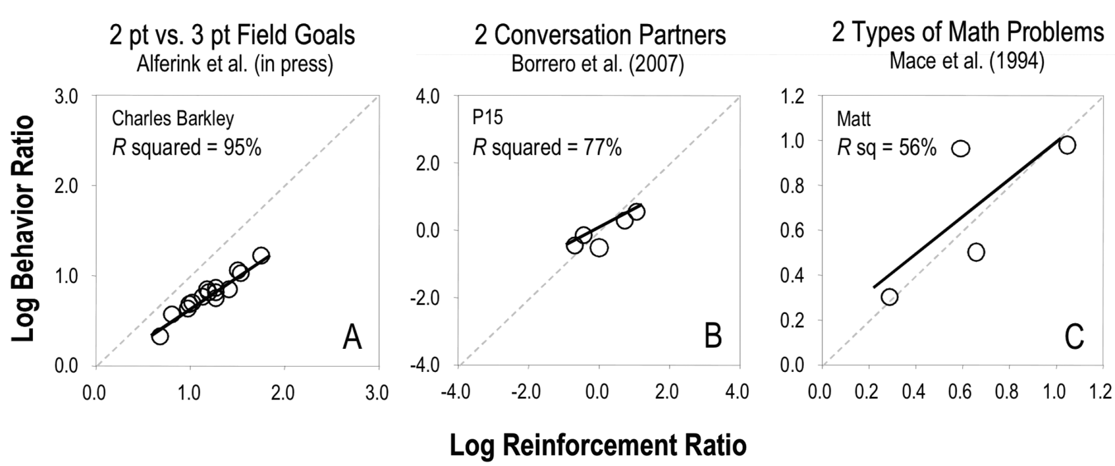

FIGURE 7.4. Results of matching analyses as applied to basketball shot selection (left panel), conversation between two partners (middle panel), and difficulty of math problems (right panel). The dashed line represents perfect matching, and the solid line represents the best-fit line. Original sources for this work appear above each panel. From "What Are We Doing When We Translate From Quantitative Models?" by T. S. Critchfield and D. D. Reed, 2009, *Behavior Analyst, 32,* p. 347. Copyright 2009 by the Association for Behavior Analysis International. Reprinted with permission.

programmed VI schedules. In the final 5 minutes of the session, response allocation adhered closely to allocations predicted by the matching law. Thus, some evidence was garnered that the matching law described naturally occurring human behavior. J. C. Borrero et al. (2007) systematically replicated the Conger and Killeen preparation and found that relative reinforcement rate controlled the relative frequency of vocalizations directed to one confederate or the other, but not the relative duration of these vocalizations.

Neef, Mace, and colleagues conducted an elegant series of translational studies of the matching law with human participants working on academic tasks (Mace, Neef, Shade, & Mauro, 1994, 1996; Neef, Mace, & Shade, 1993; Neef, Mace, Shea, & Shade, 1992). A common feature of the studies was an experimental preparation in which academically delayed students could choose between academic tasks that were equal along all dimensions except for one that was experimentally manipulated. For example, in the Neef et al. (1992) study, the experimenters manipulated the rate of reinforcement such that responding on one stack of worksheets produced a higher rate of reinforcement. The participants allocated their behavior in a manner generally consistent with the matching law (but see Mace et al., 1994, for some constraints on these assertions). In another experiment in that same 1992 article, the experimenters held reinforcement rate constant but altered reinforcer quality (actual coins vs. token reinforcers). Participants allocated responding toward the higher quality reinforcers in a manner that was consistent with the matching law.

Application to socially relevant human behavior. Identifying functional reinforcers is key to applying matching to complex human behavior. Merely noting a high correlation between the rate of behavior and the rate of a particular consequence does not necessarily imply that the consequence is serving a reinforcing function. A parent, for example, may consistently scold a child for engaging in inappropriate behavior, resulting in a high correlation between the child misbehaving and the parent scolding. Although this pattern of results would be well described by the matching law, the behavioral function of scolding remains unknown. Observing a high correlation between the behavior and a consequence is insufficient to identify the function, if any, of that consequence. Scolding could have a reinforcing effect, a punishing effect, or no effect on the child's behavior. Thus, additional analyses are required.

The functional analysis diagnostic technique developed by Iwata, Dorsey, Slifer, Bauman, and Richman (1982/1994) provides a mechanism for evaluating problem behavior from a matching perspective (also see Chapter 14, this volume). In a functional analysis of problem behavior, the reinforcers maintaining problem behavior are identified, and the delivery of those reinforcers in a natural context can then be evaluated. Before the advent of the functional analysis methodology, a degree of guesswork was involved in identifying reinforcers, so matching analyses could not be carried out effectively. Carr and McDowell (1980) had shown that a young boy's self-injurious behavior that was presumed to be solely reinforced by adult attention adhered closely to the matching law insofar as the boy allocated his self-injury proportionally to the rate of attention delivered subsequent to the behavior; however, other sources of potential reinforcement were not ruled out or in. J. C. Borrero and Vollmer (2002) extended that finding by conducting a formal functional analysis to identify reinforcers maintaining problem behavior for three children with developmental disabilities. Next, they evaluated descriptive analysis data, obtained via direct observation without manipulating any variables and collected during observations in the children's natural environment, and found that appropriate behavior (communication) and problem behavior (self-injury, aggression) were almost perfectly allocated in a manner predicted by the matching law. Sy, Borrero, and Borrero (2010) used similar logic to study choices between problem behavior (e.g., aggression) and appropriate behavior (e.g., compliance with instructions) of a young man with autism. A functional analysis had shown that the boy's problem behavior was reinforced by escape from instructional demands and access to preferred tangibles. Descriptive data were then collected on his behavior and his teacher's responses to his behavior.

The descriptive data suggested that the relative amount of time engaged in problem behavior (T_1) and appropriate behavior (T_2) was fairly well described by the relative duration (i.e., amount) of reinforcement associated with each response (A_1/A_2). This was not the case when relative response rates (B_1/B_2) were assessed as a function of relative reinforcement rates (R_1/R_2). Thus, sometimes time allocation is a better representation of reinforcement effects than response rate allocation.

More recently, C. S. W. Borrero et al. (2010) arranged concurrent VI–VI schedules of reinforcement (attention, tangible items, and escape from instructional activity as identified via functional analysis) for problem behavior (e.g., self-injurious behavior, aggression) and appropriate behavior (e.g., communication, compliance) for three individuals with developmental disabilities. In some conditions, the programmed rate of reinforcement was higher when the participants engaged in appropriate behavior, and in other conditions the opposite relation was arranged. The findings generally showed that response allocation was influenced by reinforcer allocation in a manner consistent with the matching law (a = 0.494–1.172).

Athens and Vollmer (2010) extended these findings by holding reinforcement rate constant and equal for problem and appropriate behavior while manipulating variables such as reinforcer delay (D_2/D_1), reinforcer quality (Q_1/Q_2), and reinforcer duration (A_1/A_2). The study was conducted to determine whether response allocation would shift when the reinforcement rate for problem behavior could not be reduced (e.g., when behavior is too dangerous to ignore). In application, it is sometimes the case that problem behavior produces reinforcement regardless of the therapists' intentions (such as when aggression is reinforced by physical attention, but aggression must be blocked). Thus, Athens and Vollmer sought to override the reinforcement for problem behavior by making the reinforcement favor appropriate behavior along one or more dimensions. In seven of seven cases, response allocation shifted toward the favorable schedule insofar as response rates for the problem or appropriate behavior increased or decreased in the direction predicted given changes in reinforcement parameters. In a final experiment, delay, quality, and duration were arranged to favor appropriate behavior simultaneously. The results of the final experiment were most striking: Problem behavior was virtually eliminated despite producing reinforcement at a rate equal to that for appropriate behavior. Collectively, the implication of research on problem behavior and the matching law suggest that if reinforcement schedules in the natural environment can be arranged to favor appropriate behavior (in terms of rate or other dimensions of reinforcement), the matching law can guide treatment decisions to effectively suppress the occurrence of dangerous behavior. That is, behavior is determined not only by its consequences, but by the rate, quality, duration, and immediacy of those consequences relative to some alternative behavior.

Athens and Vollmer (2010) highlighted the importance of translational research considering dimensions of reinforcement other than rate. In basic research, subjects most often produce the same type and amount of reinforcement (e.g., 3-second access to grain for a pigeon) for topographically similar responses (pecks to the left or the right key). As the applied examples described here illustrate, however, concurrent schedules in the natural environment often involve choices between qualitatively different reinforcers (e.g., those produced by playing a computer game vs. those produced by reading a book) and topographically different responses (e.g., self-injurious behavior vs. appropriate communication; McDowell, 1988).

In some cases, bias may result as a function of the effort associated with the response alternatives, and the generalized matching law can be applied to response classes differing in level of effort or difficulty, as demonstrated by Reed and Martens (2008). Reed and Martens examined the effects of response difficulty on children's choices between two sets of math problems by way of the bias (b) parameter of the generalized matching law. In Experiment 1, the two sets of problems (those printed on blue or orange paper) were shown to be easy by way of curriculum-based assessment probes (e.g., two-digit by two-digit addition with sums to 18). Completion of individual problems in each set was reinforced according to different VI schedules (e.g., VI 100 seconds–VI 20 seconds) with tokens that were exchangeable for preferred activities postsession. As shown in the top panel of Figure 7.5, response allocation was well described by the generalized matching law (i.e., sensitivity estimates approximated unity for two of three participants, and there was little or no bias). However, as shown in the lower panel, when one stack of math problems was more difficult (e.g., three-digit by three-digit subtraction with no regrouping), choice was biased toward the less effortful problems ($b = 0.21$–0.70) while still demonstrating sensitivity to the changing relative rates of reinforcement. Equation 6 suggests several manipulations that could offset the bias resulting from the differences in response effort. For example, one could simply deliver a larger amount of tokens for completing the difficult problems ($A_{difficult} > A_{easy}$), or tokens earned for completing difficult problems could be exchanged for a more preferred reinforcer (e.g., extra recess time; $Q_{difficult} > Q_{easy}$). We should note that the effects of these additional variables are thus confounded with the effects of unspecified sources of bias (b). For example, if unbeknown to the teacher, the easy problems were presented in the child's favorite color and the difficult problems in the child's least preferred color, the independent effects of color and difficulty on response bias could not be dissociated without additional analysis. Nonetheless, manipulations of this sort represent a promising area for future research when selection of more effortful responses is in the long-term best interests of the individual.

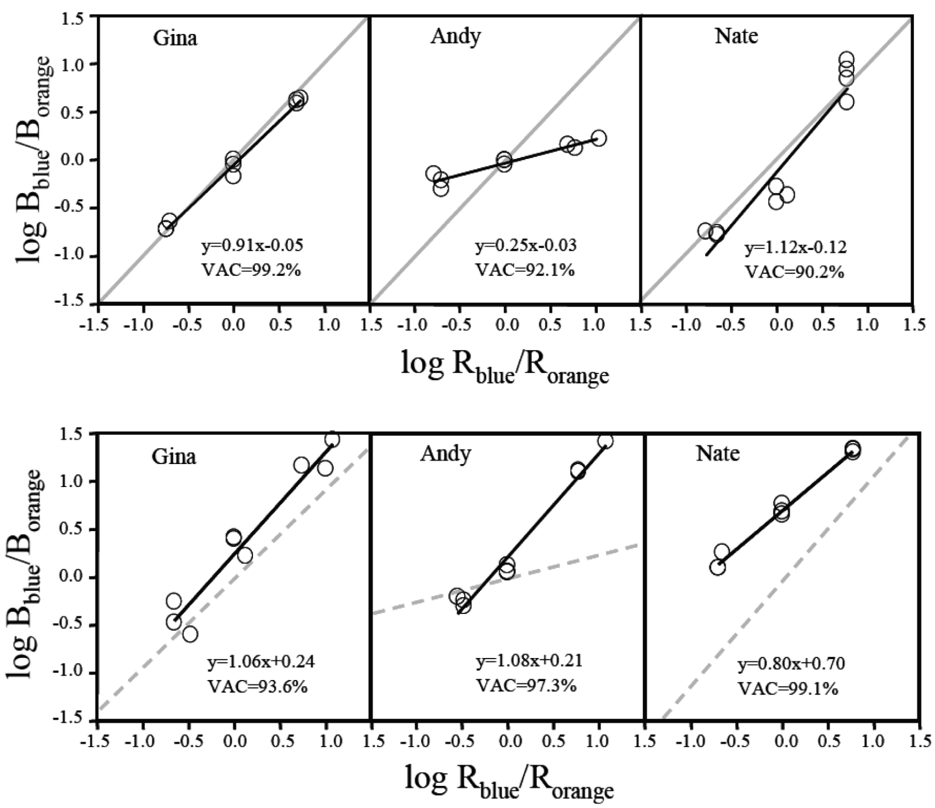

FIGURE 7.5. Results from Reed and Martens (2008). The top panel depicts results of the matching analysis when two sets of math problems of equal difficulty were exposed to concurrent VI VI schedules. The bottom panel depicts results of the matching analysis when the two sets of math problems differed in difficulty (one easy and the other more challenging). *Blue* and *orange* refer to colored paper that distinguished the two sets of math problems. The percentage of variance accounted (VAC) for by the model is included in each panel. From "Sensitivity and Bias Under Conditions of Equal and Unequal Academic Task Difficulty," by D. D. Reed and B. K. Martens, 2008, *Journal of Applied Behavior Analysis, 41*, pp. 45, 48. Copyright 2008 by the Society for the Experimental Analysis of Behavior. Reprinted with permission.

Application to complex human behavior. Another line of translational research related to matching involves analyses of athletic performance. Vollmer and Bourret (2000) used a concatenated matching equation to evaluate response allocation between 2- and 3-point shots among male and female college basketball players. In college and professional basketball, a player can at any time shoot from outside a dividing line (the 3-point line) and, if the shot is successful, earn 3 points. Successful shots attempted inside the 3-point line are awarded 2 points. Thus, $A_1/A_2 = 3/2$, and predicting B_1/B_2 requires a determination of the relative rate of reinforcement for attempting the two shot types (i.e., $B_1/B_2 = [R_1/R_2][3/2]$). Data for male and female college basketball players who attempted 100 or more shots produced sensitivity parameters that approximated unity ($a = 0.913$ for aggregate male performance, and $a = 1.045$ for aggregate female performance). Similar analyses conducted by Romanowich, Bourret, and Vollmer (2007) suggested that professional basketball players' allocation of 2- and 3-point shots was also well described by the matching law.

The studies by Vollmer and Bourret (2000) and Romanowich et al. (2007) focused on the performance of elite basketball players (i.e., those in the top tier of the National Collegiate Athletic Association or those who played professionally for the National Basketball Association). However, Alferink, Critchfield, Hitt, and Higgins (2009) recently showed similar results when assessing the performance of college basketball players who (a) played for successful versus unsuccessful teams, (b) played at differing levels of competition (i.e., Divisions I, II, or III), and (c) were regular starters versus substitute players. An important finding was that the more successful the team or player, the more closely their shot allocation resembled matching. In an analysis of college football, Reed et al. (2006) found similar relations between play calling (i.e., choosing to run or pass; B_1/B_2), and yards gained for each type of play call. Although interest in sports is pervasive in U.S. culture (thus lending a degree of social validity to the line of research), the scientific contribution of these studies was to demonstrate generality of the matching law to highly complex human behavior.

Questions for Further Research

Although applied research on the matching law has demonstrated its generality in a variety of situations, many questions remain unanswered, perhaps because of challenges arising from the complexity of human behavior and human environments. For example, basic research has suggested some constraints on the temporal parameters influencing reinforcement effects (e.g., Chung, 1965); however, little applied research exists on the role of reinforcer delay on reinforcement effects. What variables determine the relation between increasing reinforcer delay and decreasing influence on behavior? That these variables may differ widely among different nonlaboratory settings, populations, and activities seems likely. What is the role of other forms of behavior that occur in the interim between a choice response and subsequent delayed reinforcer?

Response allocation does not occur in a vacuum. In addition, matching is best characterized under concurrent VI–VI schedules with an operative changeover delay (e.g., McDowell & Caron, 2010a, 2010b; Stilling & Critchfield, 2010). A changeover occurs when the organism switches from one defined behavioral alternative to another (e.g., from B_1 to B_2 or vice versa). The changeover delay is arranged such that no response can be reinforced within a predetermined period of time after a changeover. However, in the natural environment, changeover delays are not programmed and may or may not occur. As it applies to severe problem behavior, a child may engage in aggression and an appropriate communicative response, or vice versa, within 1 second of each other. If a reinforcer follows the contiguous emission of two responses in a functional response class, provision of a reinforcer may strengthen the class of behavior (i.e., when I hit my mother and then ask nicely, I get a reinforcer). How long should the mother wait before reinforcing the appropriate behavior? Should she wait at all?

Another consideration for further research concerns reinforcement schedules. Most basic research on matching has been conducted with interval schedules. Human behavior is likely often reinforced according to some blend of interval and ratio schedules (Nevin, 1998). Little is known about the ratio-like features of reinforcement in the natural environment and how they may control response allocation from a matching perspective. For example, basic nonhuman laboratory research has shown that performance under concurrent ratio schedules often results in an exclusive preference for the richer alternative (Herrnstein & Loveland, 1975). By default, exclusive preference for one of two or more concurrently available response alternatives will yield perfect matching (or maximization). Given such findings from the nonhuman laboratory, results obtained from human participants operating in uncontrolled environments should be considered cautiously and should set the occasion for refined data analysis methods that permit for distinctions between operative schedule designations. These represent only a small sample of the challenges faced in translational applications of the matching law.

TEMPORAL DISCOUNTING

We now turn our attention to the temporal discounting literature, which provides a strong example of how the interplay between basic and translational research can inform one's understanding of pervasive socially significant behavioral problems. Following the structure of the previous section, we begin with some background context and introduce a quantitative model of temporal discounting. Then we review some translational and applied research that has been inspired by the basic research findings.

Background

The impact of consequences on behavior diminishes as a function of the delay between the response and the occurrence of those consequences. This basic behavioral process is known as temporal discounting, and it is thought to underlie some behavior problems related to choice and self-control (L. Green & Myerson, 2004; Logue, 1988; Rachlin, 2006). When people speak of impulsivity and self-control, they are often referring to situations involving choices between proximal consequences of trivial or transitory benefit and distal consequences that are in their long-term best interest. The performance is described as impulsive when the smaller–sooner reinforcer (SSR) controls one's behavior and, conversely, as self-controlled when the larger–later reinforcer (LLR) controls one's behavior.

In situations of impulsivity and self-control, behavior often shows a characteristic pattern of preference reversal. When both the SSR and the LLR are far removed in time, organisms express a preference for the LLR. As time passes, however, and availability of the SSR is at hand, preference often reverses, and organisms act impulsively, choosing the SSR in lieu of the LLR. There are many everyday examples of this pattern of preference reversal. Someone, for example, may set an alarm for a preferred waking time, only to later exchange an unhurried morning for a trivial amount of extra sleep by pressing the snooze bar. Likewise, someone may express interest in losing weight, only to later give in to the momentary temptation of a decadent dessert. In addition to these everyday occurrences, socially significant clinical examples of preference reversal abound, as, for example, when someone struggling with substance abuse problems professes a desire for abstinence when the opportunity to use drugs is far removed in time (i.e., during a therapy session or support meeting), only to again use drugs at a later time when the opportunity is immediately available.

Figure 7.6 depicts how preference reversal is a function of delay discounting. The top panel of the figure shows the relative subjective values of two forthcoming consequences as a function of time. Subjective value is an intervening variable that captures how reinforcement efficacy varies as a function of reinforcer magnitude and delay. The bars represent the undiscounted value of the two consequences (a LLR and a SSR), and the curves indicate how the values of those reinforcers decrease as delay increases. The relative placement of the curves indicates the relative subjective value of the consequences. At any given point in time, the outcome with the highest subjective value will be preferred. Note that preference is not static but shifts as the temporal context changes. When both consequences are delayed (Time A), for example, the subjective value of the LLR exceeds that of the SSR, indicating preference for the LLR. However, when delivery of the SSR is imminent (Time B), the subjective value of the SSR now exceeds that of the LLR, indicating preference for the SSR. Thus, as time passes and the delay to both outcomes decreases, preference can reverse.

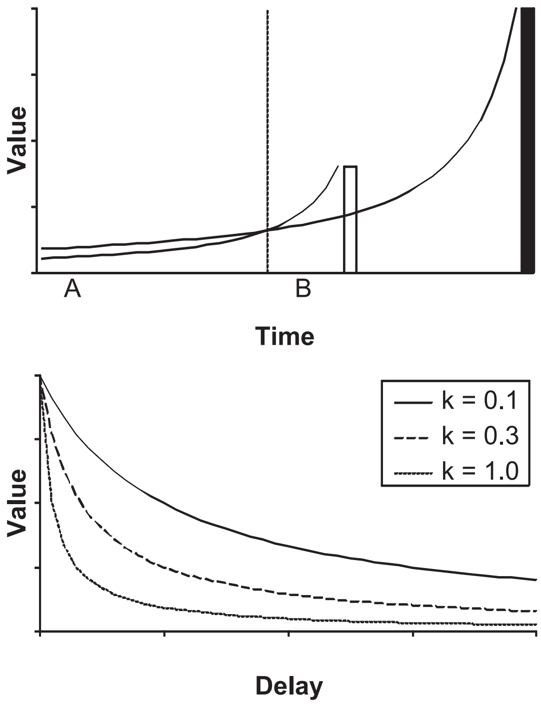

FIGURE 7.6. The top panel depicts the subjective value of SSR (unfilled bar) and LLR (filled bar) as a function of time. The dashed vertical reference line indicates the time at which the discounted value of SSR equals the discounted value of LLR (i.e., the indifference point). The bottom panel depicts delay discounting as a function of *k*.

One way to prevent preference reversals is to commit to a course of action that removes access to the SSR at a point in time (Time A, Figure 7.6, top) when the LLR is the preferred outcome (Rachlin & Green, 1972). The temptation of extra sleep, for example, can be avoided by moving the alarm across the room. The decadent dessert can be avoided by leaving it on the grocer's shelf. Likewise, the drug addict can commit to inpatient therapy.

Returning to Figure 7.6, the dashed reference line highlights the intersection of the value curves and denotes the point in time when the SSR and the LLR are of equal subjective value. By identifying indifference points (different delay–amount combinations of equal value), the relationship between delay and subjective value can be quantified. The curves in the top panel of Figure 7.6 were drawn using a model introduced by Mazur (1987, 1988), who identified indifference points between a SSR and a LLR for pigeons using a titration procedure. The pigeons made repeated choices between short access to grain available after a fixed delay and longer access to grain available after a delay that adjusted as a function of local preference. Without going into great procedural detail, suffice it to say that Mazur exposed the pigeons to contingencies until the adjusting delay reached a steady state. The data were well described by the following hyperbolic model:

$$V = \frac{A}{(1 + kD)}, \tag{7}$$

where V equals the subjective value of an amount (A) of a reinforcer delivered after a delay (D). The constant, k, varies directly with sensitivity to delay. As the value of k increases, discounting of the delayed reward increases.

Other quantitative models of delay discounting have been introduced in which either the delay (D) parameter (L. Green & Myerson, 2004) or the entire denominator (Rachlin, 2006) in Equation 7 is exponentiated. Including the additional free parameter allows those models to fit the data more closely but complicates interpretation of the values of the free parameters. Equation 7 generally fits the data adequately, and the single k parameter provides an index of impulsivity that can be used to compare severity of discounting across conditions or populations. The bottom panel of Figure 7.6 shows a series of indifference curves drawn with different k values. Note that the abscissa has been inverted relative to the top panel. Indifference points are now plotted as a function of delay (as opposed to time until receipt). As k increases, value more rapidly decreases toward asymptotic values.

Area under the curve is another useful measure of severity of discounting (Myerson, Green, & Warusawitharana, 2001). One benefit of using the area under the curve is that the measure is derived directly from the data and does not depend on fitting any particular theoretical model of delay discounting to the data. To calculate the area under the curve, the indifference points must first be expressed as a proportion of the undiscounted value of the reinforcer. Likewise, the delays must be expressed as a proportion of the longest delay. A proportion-based indifference curve is then constructed by plotting the transformed indifference points as a function of the transformed delays. The area of the space subtended by the indifference curve and the axes is then calculated (see Myerson et al., 2001, for details). The area under the curve ranges from 0 to 1.0 and varies inversely with severity of discounting. Thus, a relatively large area implies less severe discounting.

Rachlin, Raineri, and Cross (1991) introduced a method for identifying indifference points with humans using a hypothetical choice task. In a structured interview, participants made repeated hypothetical choices between an amount of money available immediately and a larger amount of money available after a delay (i.e., "Would you prefer $450 now or $1,000 in 3 months?"). The amount of money available immediately was adjusted across choices to identify an indifference point, an amount of immediate money that was of equal subjective value to the participant as a larger amount of delayed money. Across conditions, the delay to the larger amount of money was increased to assess how the subjective value (i.e., the indifference point) decreased as a function of delay. The human choice data are well described by Equation 7.

Recent translational research on impulse control disorders has increased the external validity of framing these disorders as problems of intertemporal choice involving immediate and delayed consequences. Using the hypothetical choice procedure, for example, Madden, Petry, Badger, and Bickel (1997) compared delay discounting of individuals with opioid dependence to that of control participants. Consistent with the hypothesis that drug dependence may be related to relatively poor sensitivity to long-term consequences, the opioid-dependent individuals discounted delayed consequences much more severely (i.e., on average higher *k* values) than control participants. This finding has been replicated with individuals with other impulse control disorders such as dependence on other drugs or pathological gambling (Petry, 2001a, 2001b; Reynolds, 2006). Yoon et al. (2007) have also shown that severity of delay discounting was predictive of postnatal smoking resumption by women who quit smoking during pregnancy. Recent research with nonhumans has also supported the view that drug dependence may be related to excessive temporal discounting. Severity of discounting has been shown to be predictive of drug self-administration in rats (e.g., Diergaarde et al., 2008; Perry, Larson, German, Madden, & Carroll, 2005).

Implications and Applications

When interventions for problem behavior are initially implemented, schedule requirements are often low and reinforcement frequency is high. For interventions to be practical and socially acceptable in the long term (Wolf, 1978), however, response requirements must eventually be increased, and reinforcement frequency will need to be decreased (Stromer, McComas, & Rehfeldt, 2000). Thus, an important consideration in the context of application involves the extent to which a reinforcer will maintain its efficacy when delays are imposed, and basic preparations for the study of temporal discounting may be applied to predict the efficacy of delayed reinforcers in applied contexts.

Much of the temporal discounting research conducted in nonlaboratory settings has been designed for assessment purposes. For example, Reed and Martens (2011) evaluated whether degree of temporal discounting was predictive of the efficacy of delayed reinforcers. First, they assessed the temporal discounting of 26 typically developing sixth graders by having them make choices involving hypothetical monetary outcomes. Next, a classwide intervention was conducted in which on-task behavior resulted in either immediate preferred items or preferred items that were delayed by 24 hours. Analyses were then conducted using the hyperbolic and exponential models as well as the area under the curve. Although the correlation between *k* and on-task behavior varied (.58, .99, and −.5, respectively), results suggested that students who produced steeper discount functions during the hypothetical discounting task (i.e., produced larger *k* values) were generally more likely to engage in less on-task behavior when reinforcers were delayed by 24 hours. Students who produced relatively smaller *k* values were more likely to engage in on-task behavior. These findings represent a possible link between the assessment of temporal discounting, by way of a hypothetical monetary reward assessment, and implications for behavioral interventions in a classroom setting. Specifically, for effective classroom management, reinforcers for students who steeply discount delayed reinforcers should be provided immediately, but reinforcers for other students can be delivered after a significant delay and possibly still remain effective as consequences for academic engagement.

Intervention strategies that incorporate delayed reinforcement are critical for practical implementation. Applied researchers and practitioners will be most interested in the conditions under which (a) sensitivity to delayed reinforcers after appropriate behavior can be diminished and (b) sensitivity to delayed reinforcers after problem behavior can be enhanced. Children tend to more steeply discount delayed rewards than do older adults (e.g., L. Green, Fry, & Myerson, 1994). Likewise, individuals with developmental disabilities (e.g., Vollmer, Borrero, Lalli, & Daniel, 1999), attention deficit/hyperactivity disorder (e.g., Neef et al., 2005), and traumatic brain injury (e.g., Dixon & Tibbetts, 2009) have been shown to favor smaller–sooner outcomes when pitted against larger–later outcomes (indicative of impulsive choice). Despite participants' initial preferences for smaller immediate reinforcers, however, several of these studies have also provided empirical support for strategies that can shift preference from small immediate reinforcers to larger delayed reinforcers. For example, Vollmer et al. (1999) evaluated the impulsive behavior of two 9-year-old boys diagnosed with intellectual disabilities. After a functional analysis, which demonstrated that the aggression of both boys was reinforced by access to food, the researchers taught the boys to make a request that also resulted in access to food. When aggression produced one food item and the request produced more food after a delay, the boys consistently emitted impulsive aggression. However, with the implementation of a signal (e.g., a digital timer that counted down the delay), the behavior of both boys shifted from the alternative associated with the small immediate option (aggression) toward the alternative associated with the larger delayed option (the request).

Thus, signals during delay periods represent one strategy to enhance efficacy of delayed reinforcers for appropriate behavior. Other strategies involve the use of rules and the provision of competing activities during delays to reinforcement. Tiger and Hanley (2005) used rules relating to delayed reinforcement (e.g., children were told that when the experimenter was wearing a blue lei, the experimenter could not attend to them) in the context of a multiple schedule in which reinforcer availability was signaled with one stimulus and the unavailability of reinforcement was signaled with another, with typically developing preschool-age children. The introduction of rules appeared to enhance discriminated responding (i.e., responding was more likely in the presence of the stimulus correlated with reinforcer availability). The classic work of Walter Mischel has also suggested some additional strategies that have been understudied by applied behavior analysts. For example, for young children, provision of a toy during the delay appeared to increase tolerance to a delay when the delay was associated with a larger and more preferred outcome (Mischel, Ebbesen, & Zeiss, 1972). These outcomes have been replicated in behavioral studies involving participants with disabilities who initially displayed impulsive behavior but refrained from impulsivity when given alternative activities during the delay to reinforcement (Dixon, Rehfeldt, & Randich, 2003). Mischel et al. (1972) also showed that the mere presence of the reward during the delay contributed to lower levels of self-control. Thus, to the extent that one can arrange for the absence of the larger (or qualitatively more preferred) outcome at the choice point, self-control may become the more probable response.

Research on temporal discounting also has implications for the design of token systems (Hackenberg, 2009). One of the purported advantages of token systems is that the provision of a token somehow bridges the temporal gap between behavior and terminal reinforcer delivery (e.g., Kazdin & Bootzin, 1972). However, we know of no applied research that has specifically tested this attribute of tokens: If a response requirement is met but produces a reinforcer only after a delay, would this arrangement support less behavior than one in which meeting a response requirement results in an immediate token exchangeable for a backup reinforcer after an identical delay? Although the token reinforcer is immediate, the practicality of the procedure would rest in the fact that backup reinforcers are delayed.

Behavioral contracts represent another type of application designed to overcome temporal discounting. When an individual seeks treatment, say, for weight loss, one approach is to introduce a contract that commits the individual to a large and perhaps harsh contingency. Mann (1972) required participants to sign contracts in which they agreed to turn in highly valued personal possessions. The items, in various conditions, could be earned back or lost contingent on weight loss or lack thereof. The procedure had pronounced effects on weight loss (presumably or at least hopefully influencing dietary habits in some way). Contracts seem to overcome temporal discounting by making the contingency more salient and severe than the ordinary outcome of maladaptive behavior and by introducing an additional set of contingencies for failing to meet predetermined goals. The participants in the Mann study were unaffected by the long-term subtle contingency of weight gain as a function of overeating. However, their behavior was sensitive to a more immediate contingency of regaining or losing personal possessions. Similar applications have been used to compete with substance abuse (Stitzer, Bigelow, Liebson, & Hawthorne, 1982) and smoking (Stitzer, Rand, Bigelow, & Mead, 1986), among other problems of impulse control.

One future application of delay discounting models would involve the use of discounting as an assay for identifying developmental markers and risk for problems associated with impulse control. For example, the efficacy of procedures involving delayed reinforcement might possibly differ as a function of age, disorder, or developmental disability. Indeed, L. Green et al. (1994) have shown that discounting parameters appear to vary systematically across the life span (e.g., degree of discounting has been shown to be greater for sixth-grade students than for college students). As with developmental norms that have been studied for responses such as crawling, walking, and talking, repeated measurement of temporal discounting could be used to establish a general window during which behavior shifts from impulsive to self-controlled. To conduct temporal discounting assessments with young children (those younger than age 12) or individuals with developmental disabilities would probably require some procedural innovations in which choices involve outcomes other than money (however, see Willner, Bailey, Parry, & Dymond, 2010, for one exception). Deviations from typical discounting patterns could be studied as predictors associated with impulse control problems such as attention deficit/hyperactivity disorder (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001) or sensitivity to chronic problem behavior such as pathological gambling (Dixon, Jacobs, & Sanders, 2006). If such predictive utility is identified, it could lead to appropriation of intervention and prevention resources and remediation strategies.

OTHER APPROACHES AND MODELS

In this section, we briefly review some additional quantitative models that may be useful for understanding complex human behavior in applied settings. The purpose of this section is to underscore the breadth of topics that are amenable to quantitative analyses and how cohesive interpretation of complex behavior can be achieved through the application of these models. Our aim is to provide a stepping-off point for an appreciation of the general utility of quantitative descriptions of behavior in framing tractable research questions. For each topic we cite sources that contain more thorough introductions, and we encourage interested readers to consult those sources.

Behavioral Economics

Behavioral economics is an interpretive approach that combines methods from the experimental analysis of behavior with concepts from microeconomics, in particular consumer demand theory and labor supply theory (Madden, 2000). We give the behavioral economics approach only brief treatment here because it is the topic of another chapter in this volume (see Chapter 8). For behavior analysts, behavioral economics offers, among other advantages, a promising way to conceptualize how reinforcement efficacy varies as a function of changes in constraint (i.e., contingency or schedule variables) and to characterize interactions among concurrently available consequences, including qualitatively different reinforcers. A primary dependent measure in demand analyses is overall consumption. In behavior-analytic parlance, consumption is the total amount of a reinforcer produced in a session. Thus, whereas obtained overall reinforcement rate is often construed as a direct or indirect independent variable in behavior analysis, overall consumption is viewed as a performance measure within behavioral economics.

In behavioral economics, the reinforcer's *unit price* refers to the amount of behavior (e.g., number of responses on a ratio schedule) required to produce a specified amount (unit) of reinforcer. According to the law of demand, consumption for most goods (i.e., reinforcers) decreases as a positively decelerating function of price. *Elasticity of demand* refers to how rapidly consumption of a good decreases as a function of unit price (Hursh, 1984). When demand is inelastic, increases in unit price result in less-than-proportional decreases in consumption. When demand is elastic, increases in unit price result in proportionally greater decreases in consumption.

Extensions of behavioral economic principles and procedures to applied contexts have primarily focused on stimulus preference and reinforcer assessment research. Behavior analysts have recognized that increasing response requirements may decrease response output and concomitantly decrease consumption. The nature of schedule thinning is to promote practical interventions in the natural environment (e.g., Roane, Falcomata, & Fisher, 2007). The objective is to ensure increased responding such that the individual maintains a level of reinforcement comparable to that obtained when costs were low. For example, Roane, Lerman, and Vorndran (2001) selected two similarly ranked potential reinforcing stimuli and made access to them contingent on simple arbitrary responses (e.g., button presses) under progressive ratio schedules. Despite the fact that the two stimuli had been equally preferred during the initial preference assessment (when response requirement was minimal), the contingent presentation of one reliably produced more behavior than the other. Thus, demand was greater for one stimulus relative to the other. Roane et al. then tested the differential effectiveness of these stimuli on the reduction of severe problem behavior and found that stimuli associated with greater demand were more effective in suppressing problem behavior when provided noncontingently, contingent on an alternative response, or contingent on the omission of problem behavior.

Basic research has also suggested that random response requirements support more behavior than fixed requirements, under some conditions (e.g., Madden, Dake, Mauel, & Rowe, 2005). At comparatively low unit prices, random and fixed requirements produce similar response output and consumption. As prices increase, however, random arrangements have been shown to support relatively greater response output than that obtained under fixed arrangements. In terms of application, information of this sort might be particularly useful in the design of reinforcement-based systems when larger response requirements must be completed (i.e., when greater response output is socially important or when thinning an artificial reinforcement arrangement).

Behavioral Ecology

Behavioral ecology is the study of behavior–environment interactions in a biological context (Krebs & Davies, 1993). As with behavior analysis, behavioral ecology focuses on functional relations between the behavior of organisms and environmental determinants (Fantino, 1991). Although an established literature has bridged basic behavior analysis with behavioral ecology, behavioral ecology has yet to inform the applied literature. Our inclusion of the topic here is intended to provide another example of the utility of quantitative models in understanding complex patterns of behavior and to inspire translational research driven by this conceptual approach.

At first blush, the relevance of behavioral ecology to applied human research may not be readily apparent. The research questions address such issues as when and how an animal should forage for food, what proximal contingencies account for particular mating strategies, or how predation risk affects other behavioral patterns. The principles of behavioral ecology have, however, also been extended to account for human behavior, primarily to the study of hunter–gatherer societies (e.g., Smith, 1983), and of course the very nature of applied research requires an ecological approach. Applied behavior analysis focuses on socially significant behavior as it occurs *in situ* (Baer, Wolf, & Risley, 1968). Thus, although many questions remain regarding the extent to which ecological models will generalize to human behavior (see Hackenberg, 1998, for a review), behavioral ecology provides an interpretive framework that is as rich as behavioral economics and may be helpful for conducting translational behavior-analytic research.

The quantitative models of behavioral ecology are typically cost–benefit analyses. The key to successful translation will be the identification and quantification of independent variables that are relevant to the particular niche of applied contexts. Some specific problems for which an approach informed by behavioral ecology may be helpful include assessing the effects of resource (i.e., reinforcer) abundance and dispersion on behavior, interpreting the effects of qualitatively different consequences on responding, and understanding social interactions that involve interlocking contingencies of reinforcement.

Optimization is a guiding principle of behavioral ecology and is not thought to be a basic behavioral process or proximate behavioral mechanism per se, but it is assumed to be the outcome of natural selection (see Shettleworth, 1989, and Smith, 1983, for additional discussion). Given limited resources related to inclusive fitness (e.g., food or mating opportunities) and individual variation in ability to compete for those resources, natural selection is assumed to favor individuals who have a relative advantage in exploiting those limited resources, all other factors being equal.

Optimization models have three principal components—a decision set, a currency, and constraints. The *decision set* is the range of response classes available for addressing a particular ecological problem (e.g., to pursue a found prey item or to continue searching for another that may provide greater net caloric gain). The *currency* is an index of the independent variables controlling behavior and is traditionally assumed to be related directly to inclusive fitness (e.g., number of offspring that reach sexual maturity). Extension of foraging models to human behavior in applied contexts may require relaxing this latter assumption. *Constraints* are limitations on the decision set imposed by characteristics of the organism or by the environment. For example, predation risk is an environmental constraint that may dictate whether a forager defends a solitary territory or joins a group at a common resource site. If foraging with a group decreases the risk of predation, the dilution of predation risk may offset a decrease in foraging efficiency that results from increased competition (Bertram, 1980). Metabolic needs provide a good example of an organism-based constraint. If metabolic demands are high, a forager may have to incur risks (e.g., increased predation exposure, foraging at highly variable food sources), if those actions are the only means by which to avoid starvation (Caraco et al., 1990). The optimal brood size for a nesting pair may be determined by a combination of organismic and environmental constraints. The optimal brood size may depend, for example, on the distribution of food resources relative to the nest location and the maximum load that each parent can carry (Houston, 1987; Kacelnik, 1984).

Relative to other interpretive approaches, behavioral ecology may be particularly well suited for conceptualizing how changes in the spatiotemporal arrangement of reinforcers affect behavior. The distribution of resources throughout the environment is a constraint that can have pronounced effects on the behavior that makes up the decision set. Resources can be distributed in an environment along a continuum from randomly dispersed, isolated units to spatiotemporally clumped patches of resources. When the resources are uniformly distributed throughout a foraging territory, the decision set will be characterized by searching for prey and, on encountering a prey item, deciding whether to pursue it. The decision to pursue is driven by additional constraints such as the handling costs of the encountered prey item and the relative abundance of more profitable prey. The optimal diet breadth model is used to predict which prey items should be exploited and which should be rejected (Kaplan & Hill, 1992). Changing from a uniform distribution of resources to a patchy distribution alters the decision set. When resources are arranged in tightly packed clumps and the patches themselves are distributed throughout the foraging territory, the decision set consists of traveling between patches and foraging within a patch. A forager exploiting a depleting patch of resources must decide whether to continue foraging in the current patch in the face of diminishing returns or to give up and travel to a new patch. According to Charnov's (1976) marginal value theorem, a forager should leave a patch of resources when the within-patch rate of gain falls below the average rate of gain for the environment as a whole. Doing so will maximize overall net energy gain.

Compared with other interpretive approaches, behavioral ecology may also be uniquely suited to provide insight on how social dynamics and interlocking contingencies affect behavior. One constraint that affects the behavior of individuals is the presence of other foragers competing for the same resources. The ideal free distribution, for example, refers to how a group of organisms should distribute themselves at multiple resource sites (Fretwell & Lucas, 1969). The ideal free distribution is so named because organisms are assumed to be able to move freely between resource sites and should ideally distribute themselves such that individual resource intake will be maximized. An everyday example of the ideal free distribution is frequently encountered in the checkout lanes of a grocery store. All else being equal (e.g., number of items purchased, cashier competency), individual shoppers will select the shortest line. The end result is an equal number of customers in each lane and the time to check out is minimized for each shopper.

Assuming two resource sites, the distribution of foragers can be modeled with the following equation:

$$\frac{N_1}{N_2} = b\left(\frac{R_1}{R_2}\right)^s, \qquad (8)$$

where N is the number of foragers at the resource site and R is the rate of resource gain at each of two sites, denoted by the subscripts. The parameter s quantifies sensitivity of the group to the ratio of resource input, and b quantifies bias for one resource site over the other that is not related to relative gain (e.g., differences in predation risk). When $s = 1$, the ratio of foragers will match the ratio of resource input at the two sites, and the ideal free distribution will be obtained. At values of $s < 1$, there will be more foragers at the leaner resource site than predicted by the ideal free distribution (i.e., undermatching). At values of $s > 1$, there will be fewer foragers at the leaner resources site than predicted by the ideal free distribution.

Equation 8 provides a good description of data from both laboratory-based and naturalistic studies using a wide range of species (including humans) and contexts (Baum & Kraft, 1998; Madden, Peden, & Tamaguchi, 2002). The ratio of foragers, however, was seldom in quantitative accord with the predictions of the ideal free distribution (i.e., $s \neq 1$). Instead, there were frequently more foragers at the leaner resource site ($s < 1$) than the ideal free distribution would predict. Thus, the aggregate behavior of groups tends to show diminished sensitivity (i.e., undermatching) to the ratio of resource input. Equation 8 is formally similar to the generalized matching law (Baum, 1974; see Equation 3 and accompanying text). One might be tempted to assume that the aggregate data reflected the outcome of less-than-perfect matching by all of the individuals in the group. Baum and Kraft (1998) conducted a laboratory study with pigeons, however, that suggested this was not the case. Although Equation 8 described the aggregate data well, the response patterns of individual birds were not consistent with the matching law, suggesting that the aggregate response pattern was an emergent phenomenon.

This brief introduction is intended to give the reader a sense of how behavioral ecology can help frame questions about organism–environment interaction. Space does not permit us to review the entirety of the field here, and the interested reader is referred to Krebs and Davies (1993) for a thorough introduction to the basics of behavioral ecology. Inclusion of the topic in this chapter is intended to foster research in the area. Behavioral ecology has much to offer translational researchers.

After all, applied behavior analysis, by definition, addresses socially significant behavior occurring in natural settings. As an interpretive approach, behavioral ecology is as rich a patch for translational research as behavioral economics or delay discounting. The challenge for successful translation of these concepts to applied settings will be to identify the relevant decision sets, constraints, and currencies.

Behavioral Momentum: Quantifying Resistance to Change

The success of many behavioral interventions may be related to how resistant the target behavior is to changes in reinforcement contingencies or context. With decelerating procedures such as extinction, response-cost, or differential reinforcement of other behavior, for example, resistance to change may be inversely correlated with the effectiveness of the intervention. If the target behavior is highly resistant to disruption, these operations may be less effective. However, the success of many behavioral programs hinges on the successful generalization of the intervention from training conditions to more naturalistic settings. The degree of behavioral resistance to change may be related to the likelihood that shifts in antecedent conditions and treatment integrity may result in a breakdown of control.

Nevin (1992; Nevin, Mandell, & Atak, 1983) quantified resistance to change within behavioral momentum theory. Translational research in behavioral momentum is examined in detail in Chapter 5 (this volume), and we therefore consider it only briefly here. Behavioral momentum theory relates behavioral persistence to obtained rates of reinforcement within defined contexts. Typical laboratory procedures establish conditions of alternating richer and leaner situations and then assess behavioral persistence by measuring proportional decreases when some disruption is applied equally to both conditions (e.g., sessions of extinction, presession food). Laboratory research has shown that resistance to change is greater in the richer component (reviewed in Nevin & Grace, 2000). Relative resistance can be used to assess differences in resistance to disruption across response classes. For example, when a functional analysis reveals that a maladaptive behavior is multiply controlled (e.g., attention and escape from demands), a subsequent analysis assessing relative resistance to change may reveal important differences in how readily those response classes will be affected by the intervention.

Several studies have demonstrated that the behavioral momentum metaphor is applicable to situations in which the therapist may wish to increase behavioral persistence (e.g., on-task behavior) or decrease it (e.g., stereotypy) for people with intellectual disabilities. As examples of the former, translational research has demonstrated that the resistance of on-task behavior to disruption by distraction is related to reinforcer rates for adults performing a sorting task (Mace et al., 1990) and children with autism performing academic or leisure tasks (Parry-Cruwys et al., 2011); these studies systematically replicated results from the nonhuman laboratory (e.g., Nevin, Tota, Torquato, & Shull, 1990). As an example of the latter, Ahearn, Clark, Gardenier, Chung, and Dube (2003) examined the persistence of automatically reinforced stereotypy (e.g., hand flapping) exhibited by three individuals diagnosed with autism spectrum disorder. Ahearn et al. showed that responding (stereotypy) was more resistant to disruption by the opportunity to engage in an incompatible activity when that opportunity was preceded by noncontingent access to highly preferred foods or activities. In other words, stereotypy occurred more frequently after situations in which overall levels of reinforcement were increased because of noncontingent access to preferred stimuli than after situations in which preferred stimuli were absent. As Ahearn et al. noted, these results suggest that the commonly reported decelerative effects of noncontingent reinforcement (e.g., Vollmer, Iwata, Smith, Zarcone, & Mazaleski, 1993) may not be observed in all cases and may in some cases increase the persistence of undesirable behavior.

Signal Detection Theory

Signal detection tasks ask an observer to report which of two stimulus conditions has occurred—one in which a stimulus is presented (signal plus noise) or one in which the stimulus is omitted (noise alone; D. M. Green & Swets, 1966). Thus, on any given trial there are four possible outcomes—hits, correct rejections, misses, and false alarms. Hits occur when the observer correctly reports the presence of the stimulus, and correct rejections occur when the observer correctly reports the absence of the stimulus. Misses occur when the observer reports that the stimulus did not occur when it was actually presented. False alarms occur when the observer reports that a stimulus was presented when it was not. These contingencies and the possible outcomes describe a classic yes–no detection task and present the simplest detection task in which presence of a target stimulus alternates with its absence. Signal detection analyses permit independent estimates of stimulus discriminability and response bias.

The signal detection task can be readily extended to situations in which the observer must report the occurrence of two different stimuli (e.g., discriminating between two hues) by explicitly adding the second stimulus and the corresponding response. In the nonhuman animal laboratory, for example, left lever presses (B_1) may be reinforced after a tone of a given frequency (S_1), and right lever presses (B_2) may be reinforced after a tone of a different frequency (S_2). Again, there are four possible outcomes—two correct responses ($B_1|S_1$ and $B_2|S_2$) and two error responses ($B_1|S_2$ and $B_2|S_1$).

With respect to application, methods and measures used to characterize decision making in signal detection research are readily exportable to the behavior of data collectors across a range of situations. In the same way that a laboratory animal might be required to identify tones of a particular frequency, human observers in applied settings might be required to identify the occurrence or nonoccurrence of a particular target response (e.g., aggression). Similarly, air traffic controllers may be required to make discriminations about potentially dangerous versus safe traffic patterns (Allendoerfer, Pai, & Friedman-Berg, 2008). The four possible outcomes described previously (hits, correct rejections, misses, and false alarms) also apply to these examples. Lerman et al. (2010) recently applied signal detection theory to the data collection of naive human observers who scored videos of scripted interactions between a teacher and a target student. Results showed that observer responding could be biased by reinforcing the reporting of occurrences of behavior regardless of whether the reports were hits or false alarms. These findings underscore the importance of training observers to accurately use precise operational definitions of the behavior being observed.

Signal detection models have also been extended to the detection of lumps in simulated human breasts. For example, Adams et al. (1976) showed that manual detection of lumps in simulated human breasts was dependent on both the size of the lump and the level of practice in lump detection (i.e., the bigger the lump, the more detection occurs, and the more practice one has, the more likely it is that one will detect both small and large lumps). These findings hold promise for training in the identification of other forms of disease conditions, and extensions could be applied, for example, to the visual detection of malignant versus benign malformations (e.g., melanoma).

Behavioral Detection Models

Nevin (1969), in a review of D. M. Green and Swets's (1966) classic text on signal detection, noted the similarity between the methods of research in psychophysics and those in the experimental analysis of behavior. Specifically, he proposed that detection performances could be analyzed by extension of the matching law. Davison and Tustin (1978) developed such a quantitative model. As with classic signal detection theory, the Davison and Tustin model assumes that stimulus discriminability and biasing reinforcement variables affect performance independently in detection tasks. Thus, when the stimuli to be discriminated are very similar (i.e., difficult to discriminate), performance will approximate matching of the reinforcer ratio (also see Lerman et al., 2010). When the stimuli to be discriminated are very different (i.e., easy to discriminate), performance will deviate from matching and be biased toward correct responding (i.e., a high rate for hits and correct rejections). An approach introduced by Alsop (1991) and Davison (1991) and elucidated by Davison and Nevin (1999) offers an alternative account. The Davison–Nevin–Alsop model assumes that the effects of reinforcement are mediated through stimulus and response generalization. Stimulus and response disparity mediate the extent to which reinforcement generalizes across response and stimulus classes. Thus, reinforcement of correct discrimination of one stimulus is assumed to also affect the tendency to report the other stimulus to the extent that the discriminative stimuli and the response topographies of the two classes are similar. The interested reader is referred to the primary sources for additional details on and explanation of behavioral models of stimulus detection.

SUMMARY

Quantitative choice models provide a useful means of organizing research to improve understanding of socially significant human behavior. To date, the matching law, delay discounting, behavioral economics, and behavioral momentum models have generated a good deal of translational work, as described here and in other chapters in this volume. We have summarized a portion of that work but have also made a case for translational research programs in behavioral ecology and signal detection theory (and its variants). Insofar as the goal of a science of behavior is prediction and control and the goal of the applied science is to address socially meaningful behavior, quantitative choice models are a rich framework, and much more work in these areas is warranted.

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Chapter 8

THE TRANSLATIONAL UTILITY OF BEHAVIORAL ECONOMICS: THE EXPERIMENTAL ANALYSIS OF CONSUMPTION AND CHOICE

Steven R. Hursh, Gregory J. Madden, Ralph Spiga, Iser G. DeLeon, and Monica T. Francisco

> An adequate science of behavior should supply a satisfactory account of the individual behavior which is responsible for the data of economics in general. (Skinner, 1953, p. 400)

More than a decade ago, E. O. Wilson (1998), the founder of sociobiology, an expert in ant societies, and a specialist in evolution, argued that consilience would advance an interdisciplinary and unified science. The term *consilience* was borrowed from the 19th-century historian and philosopher of science William Whewell (1794–1866). Whewell posited that in the rhetoric of scientific discourse, statements of empirical truth are more convincing if three criteria are met: prediction, coherence, and consilience. In this terminology, coherence extends well-established functional relations to other observations without ad hoc modification, and consilience extends scientific propositions about mechanisms and determinants to phenomena and investigative methodologies different from those originally contemplated (Snyder, 2009).

The relatively new field of behavioral economics may represent an example of consilience in which concepts from microeconomic theory are extended to the study of consumption by a range of species in the laboratory and the concepts of operant conditioning are extended to an understanding of demand for economic commodities. The blending of behavioral principles with microeconomic theory has been a fruitful area of research (e.g., Kagel, Battalio, & Green, 1995) and has provided a translational framework for extending principles derived from laboratory studies to an understanding of consumer choice observed in whole communities.

Economics and behavioral psychology have several points of convergence. One is a common interest in the value of goods, defined as reinforcers by the behaviorist and as objects of scarce consumption by economists. A second point of convergence is an interest in the process of choice: for the economist, the allocation of limited resources for the consumption of alternative goods (consumer choice), and for the behaviorist, the division of operant behavior among competing reinforcers. One area of divergence is that behavioral economists in the operant tradition have focused very little on hypothetical economic concepts, such as utility functions, indifference curves, and optimal choices. Instead, research efforts have focused on understanding the environmental factors affecting (a) overall levels of behavior that is instrumental in obtaining or consuming a variety of commodities in closed economic systems (Bickel, DeGrandpre, Higgins, & Hughes, 1990; Bickel, DeGrandpre, Hughes, & Higgins, 1991; Foltin, 1992; Hursh, 1984; Lea, 1978; Lea & Roper, 1977; Rashotte & Henderson, 1988) and (b) the allocation of behavioral resources among available reinforcers (Hursh, 1980, 1984; Hursh & Bauman, 1987; Madden, Smethells, Ewan, & Hursh, 2007a, 2007b).

Behavioral economics, as practiced by students of operant conditioning and behavior analysis, has

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borrowed concepts from microeconomics, especially consumer demand theory and labor supply theory (Allison, 1983; Allison, Miller, & Wozny, 1979; Lea, 1978; Rachlin, Green, Kagel, & Battalio, 1976; Staddon, 1979; see Watson & Holman, 1977, for a review of relevant microeconomic theory). When applied in laboratory experiments, economic concepts are operationalized in special ways that build on more fundamental behavioral processes, such as reinforcement, discrimination, differentiation, and the like. These experiments have directed researchers' attention to new phenomena previously ignored and new functional relations previously unnamed. In this chapter, we apply behavioral economics to the analysis of consumption of various reinforcers and the responding that produces that consumption. We begin the chapter by providing a primer for understanding behavioral economic concepts that may subsequently be applied to understanding a range of behaviors in the laboratory and clinical setting. We provide examples of both present and potential translations of these basic science findings to improving the human condition.

CONSUMER DEMAND

One of the principal areas of economic study is consumer demand; that is, the purchasing activities of the consumer and how they are affected by variables such as price, income, and the variety of goods available in the marketplace. Several basic laboratory researchers have conceptualized the operant behavior of their animal subjects as the behavior of a consumer (e.g., Allison, 1983; Collier, Hirsch, & Hamlin, 1972; Hursh, 1980). When the experimenter manipulates the schedule of reinforcement, he or she is acting as a supplier who sets the price of the commodity and then determines how much of the commodity the consumer will purchase at that price.

The simplest law of economics is the demand law, which states that as the price of a commodity increases, consumption of that commodity will decline. In the operant conditioning laboratory, behavioral economists operationalize price as a cost–benefit ratio; for example, three food pellets (benefit) for every three responses (cost) is a 3:3 ratio = 1. This is referred to as the unit price of the reinforcer, something that is often printed on price displays in U.S. grocery stores (e.g., the unit price of dried pasta may be $0.10 per ounce). The simplest test of the demand law would be to measure consumption when food is available at a low unit price (one pellet per response) and then again at a higher price (e.g., one pellet per 10 responses). Such laboratory tests generally support the demand law when rats are lever pressing for food, water, fat, electronic brain stimulation, and a variety of drugs (e.g., Bickel et al., 1990; Collier et al., 1972). Likewise, increasing the price of the reinforcer generally decreases pigeons' food consumption (e.g., Madden, Dake, Mauel, & Rowe, 2005) and humans' cigarette smoking (e.g., Bickel & Madden, 1999a).

As any grocer will tell you, changing the unit price of a reinforcer may be accomplished by either increasing the cost of obtaining the reinforcer or decreasing the benefits of the reinforcer (e.g., selling an ounce less dried pasta at the same price). In the laboratory, cost is typically quantified by the number of responses the subject must emit per reinforcer, but it could also be quantified as effort expended per reinforcer (e.g., time integral of force; Zarcone, Chen, & Fowler, 2009), time to a reinforcer (e.g., Tsunematsu, 2000), or a commodity loss after each response (e.g., a response–cost contingency), to name just a few cost dimensions. For humans, the cost component may also be specified as the amount of money paid per reinforcer (money being a medium by which past labor is exchanged for present goods and services). The benefit component of unit price refers to the amount of the reinforcer obtained (e.g., grams of food, dose of drug).

Before proceeding much further it is important to note that the demand law applies to total consumption. From a behavioral economic perspective, consumption is a fundamental dependent variable, which contrasts with much operant research that takes response-derived measures (e.g., response rate) as fundamental and procedurally excludes the possibility of meaningfully measuring consumption. In typical studies of operant conditioning, total consumption is determined by the experimenter rather than by the subject. That is, the experimenter caps total consumption in each session, and subjects usually run into this cap. Although this strategy eliminates within- and between-session changes in motivation that may influence response-derived measures, it makes it impossible to study how consumption is affected by price constraints such as those found in the natural environment.

To measure the effects of a broad array of prices on consumption of a reinforcer, one must meaningfully measure consumption of the reinforcer. Hursh (1980, 1984, 1993) proposed that consumption be measured in terms of total daily intake of the reinforcer (e.g., milligrams of food, milliliters of water, or number of injections of a specific dose of a drug). This measure maps well to topics of translational interest such as total calories of food consumed per day among dieters (a seemingly more useful measure than rate of caloric intake during a set period of time). To evaluate the effects of a broad array of price increases on consumption, one must have a baseline measure of consumption when access to the reinforcer is relatively unconstrained. For example, a researcher might place a laboratory rat in an operant chamber with the contingency that a single lever press will deliver one 45-milligram food pellet. Here the price of food is very low: one lever press (cost) for one pellet (benefit), and the unit price equals 1. Setting a low price is important, but one must also not constrain consumption by placing a within-session cap on earnings. To measure unconstrained consumption, the session must be long enough that peak consumption may be achieved (e.g., when satiety halts further consumption within the session). In our experience with rats and pigeons working for food or water reinforcers, peak consumption may be reached by programming 11-hour sessions.

To illustrate the importance of measuring peak consumption, consider a hypothetical study in which consumption is artificially capped by the experimenter at 100 pellets. Had the session continued for 11 hours, peak consumption would have come in at 800 pellets. Thus, the experimenter has seriously underestimated unconstrained consumption. He or she will also be unable to detect the effects of any price increases until the price is sufficiently high that it reduces consumption to less than 100 pellets. For example, if the experimenter increases the unit price of food from one to 20 lever presses and the rat continues to consume 100 pellets, the experimenter will have missed the opportunity to see that in a long-duration session, the unit price increase from one to 20 would have decreased consumption from 800 to 500 pellets. Because consumption of naturally occurring reinforcers is most often not artificially capped by an outside force, conducting long-duration sessions provides a more appropriate model of consumer demand in the natural economy.

Demand Curves

When consumption has been measured across a wide range of prices, the data are plotted as a demand curve with consumption on the *y*-axis and price along the *x*-axis. The demand curve shown in Figure 8.1 is typical of the relation between price and consumption in rats (e.g., Hursh, Raslear, Shurtleff, Bauman, & Simmons, 1988), pigeons (e.g., Madden et al., 2005), monkeys (e.g., Hursh, 1984), and humans (e.g., Bickel & Madden, 1999a). Moreover, the general shape of the demand curve is observed regardless of the reinforcer type (e.g., Madden et al., 2007a, 2007b), including a wide variety of drug reinforcers (Bickel et al., 1990, 1991; Hursh & Silberberg, 2008).

Demand curves are usually graphed on logarithmic axes because it facilitates a visual and quantitative

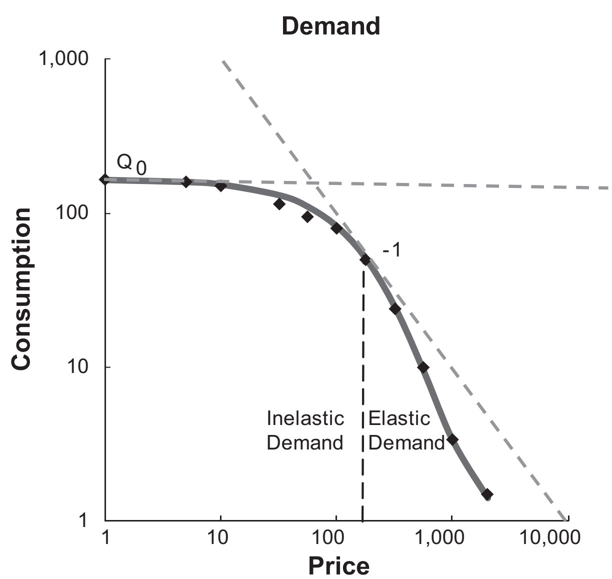


FIGURE 8.1. Diagrammatic demand curve showing the usual shape and increasing elasticity across the demand curve. The vertical line marks the point of unit elasticity (slope = −1), which is the transition from inelastic to elastic demand. The level of demand is denoted as the *y*-intercept or the quantity consumed at zero price—Q_0.

analysis of the proportional relation between changes in consumption and changes in price. A measure of the change in consumption that accompanies a price change is price elasticity of demand. When the decrease in consumption is proportionally less than the increase in price, the slope of the double-logarithmic demand curve is more shallow than −1. Across this range of price increases, demand is described as inelastic. When response output and rate of reinforcement have a direct relation (e.g., on a fixed-ratio [FR] schedule of reinforcement), inelastic demand reflects an increase in response expenditure in the face of the price increase. For example, in the 1970s when the price of gasoline in the United States increased from $0.33 per gallon to more than $1.00 per gallon, consumption decreased by only 10%, whereas average household expenditures on gasoline increased by more than 250%. Such inelastic demand reflects consumers' tendency to defend their consumption of a valuable commodity. Other commodities, such as luxury goods (unnecessary for survival) or goods with many substitutes (e.g., one brand of peanut butter), have more steeply sloping demand curves. When consumption of such goods declines proportionally more than the price of the good increases (slope steeper than −1) demand is described as elastic and consumption is highly sensitive to price. Here, response output (e.g., spending) declines with price increases.

The difference in demand between inelastic and elastic goods is easily demonstrated in a controlled laboratory setting. For example, Figure 8.2 depicts monkeys' average consumption of two reinforcers under conditions of increasing price, each studied in separate experimental sessions (Hursh, 1984, 1993). In one condition, food was available across a range of prices (from 10 to 372 lever presses per food pellet) with saccharin-sweetened water available at a constant low cost of 10 responses. In a similar condition, saccharin-sweetened water was available at the same range of prices and food was available at a constant cost of 10 responses. To ensure that demand for saccharin alone was being measured, an alternative source of unsweetened water was freely available. As may be seen in the left panel of Figure 8.2, demand for saccharin shifted from inelastic (shallow demand curve) to elastic (steep demand curve) at a much lower price than did demand for food. The price at which consumption of each commodity shifts from inelastic to elastic demand is labeled P_{max} and is marked by a dashed vertical line in Figure 8.2. As a corollary to the differences in the demand curves, the number of responses emitted per day in the food reinforcement sessions increased over a broad range of prices whereas responding for

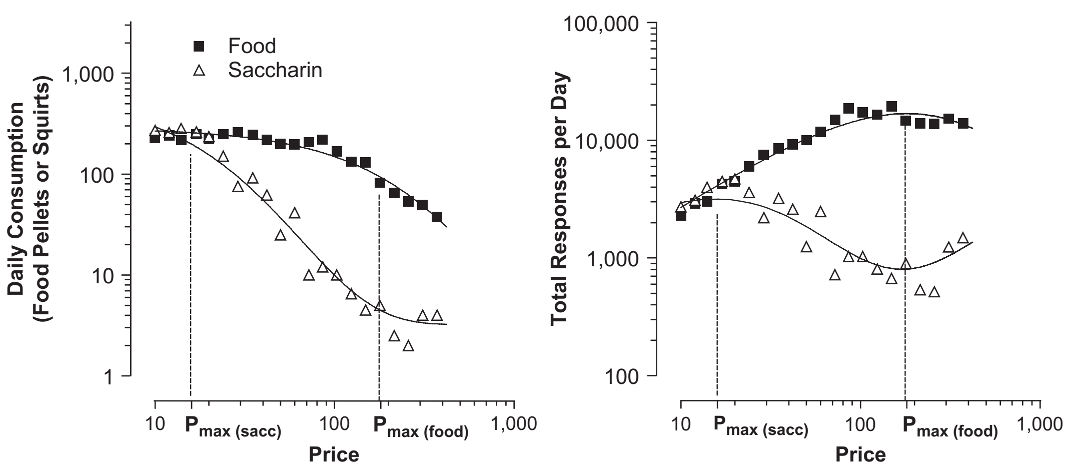


FIGURE 8.2. Left: Two demand curves for rhesus monkeys working for either food or saccharin-sweetened water. The demand functions show the total number of reinforcers consumed each day under a series of fixed-ratio schedules (prices) that ranged from fixed-ratio 10 to fixed-ratio 372. Data from Hursh and Silberberg (2008). Right: Daily output of responding that accompanied the levels of consumption shown in the left panel. The curves were fit with an exponential equation.

saccharin generally decreased over the same range. Note that peak response output per day occurs at P_{max}; at higher prices, spending tends to decline with price increases.

Reinforcer Value

The differences in the demand curves shown in Figure 8.2 might be described heuristically as differences in reinforcer value. Because demand for food was more inelastic than demand for sucrose, it would appear that food was the relatively more valuable of the two reinforcers. Said another way, food appears to be a more effective reinforcer. Measuring differences in reinforcer value or efficacy has practical utility. For example, if one could quantify the value of a range of reinforcers, then one could arrange the most effective reinforcer to be delivered contingent on desired behavior such as drug abstinence (see Chapter 19, this volume) or in the establishment of adaptive behavior designed to replace severe problem behavior (see Chapter 14, this volume). We outline other examples of the practical utility of quantifying reinforcer value later in the chapter.

A common approach to evaluating the reinforcing efficacy of a consequence is to measure the ability of the consequence to maintain behavior under different experimental conditions (e.g., Griffiths, Brady, & Bradford, 1979). Many experimental conditions have been developed for this purpose; prominent among these are choice preparations, progressive-ratio (PR) schedules, and behavioral momentum–based evaluations of resistance to change. If reinforcer X is more valuable than reinforcer Y, then X should be preferred over Y, X should maintain behavior at a high response requirement whereas Y does not, and X-maintained behavior should be less susceptible to disruption than Y-maintained behavior.

However, inconsistencies across different experimental conditions are common. For example, Roane, Lerman, and Vorndran (2001) assessed preference rankings of four individuals with developmental disabilities as they chose between various tangible items. Two equally ranked and highly preferred items were then made available individually according to a PR schedule. Under a PR schedule, the number of operant responses required per reinforcer increases after each obtained reinforcer. Despite equal preference rankings in the choice preparation, under the PR schedule one reinforcer reliably maintained behavior at a high response requirement at which no behavior was maintained by the other reinforcer. Using the behavioral economic language introduced thus far, demand for one reinforcer proved to be more price inelastic than the other despite similar rankings in a preference assessment. Given this, and similar examples of inconsistencies across different experimental conditions (e.g., Bickel & Madden, 1999b; Elsmore, Fletcher, Conrad, & Sodetz, 1980; Jacobs & Bickel, 1999; Johnson & Bickel, 2006; Madden, Bickel, & Jacobs, 2000), several researchers have suggested that one or more properties of the demand curve may prove a useful measure of the value of a reinforcer (Bickel, DeGrandpre, & Higgins, 1993; Bickel & Madden, 1999b; Bickel, Marsch, & Carroll, 2000; Hursh & Winger, 1995; Roane et al., 2001).

The most recent of these suggestions was provided by Hursh and Silberberg (2008). They pointed out three problems with more traditional measures of reinforcer efficacy. First, response rate is an inappropriate measure of reinforcer value because it can easily be affected by contingencies of reinforcement (e.g., differential reinforcement of low or high rates). Second, choice experiments conducted in the tradition of Herrnstein's (1970) matching law have not manipulated directly important economic variables such as income and price and, therefore, have not contacted inconsistencies in preference that would disqualify it as a measure of reinforcer value. Third, a behavioral momentum approach to reinforcer value requires that measures of momentum be independent of baseline rates of behavior; however, some evidence has suggested that this requirement is not met (Nevin, Grace, Holland, & McLean, 2001). To this could be added the critique that behavioral momentum is primarily affected by Pavlovian (stimulus–stimulus) rather than operant (response–consequence) relations and, therefore, is an inappropriate measure of the value of an operant reinforcer.

Arguing in the affirmative, Hursh and Silberberg (2008) suggested that the value of a reinforcer is reflected not only in its beneficial[1] characteristics but in its associated costs. This point was made in an experiment by Madden et al. (2007a) in which rats chose between food pellets and small amounts of a fat solution. At low prices, rats consumed both commodities with a modest preference for food. Thus, when the cost of the two reinforcers was not a factor, they appeared to have comparable benefits. However, when the cost of both reinforcers was increased by substantially raising the FR requirement, food was chosen to the near exclusion of fat. If reinforcer efficacy or value reflects the ability of the consequence to maintain substantial amounts of behavior, then sensitivity to changes in the price of the reinforcer may be a more useful measure of reinforcer value than preference. Accordingly, Hursh and Silberberg argued that the steepness of a demand curve provides a useful metric of reinforcer value: Steeply declining demand curves suggest a weak reinforcer with benefits that do not justify the increasing costs of acquiring it. Shallowly declining demand curves reflect substantial expenditure of resources (e.g., effort, time, money) to obtain the reinforcer when its price increases. This intuitive account of reinforcer value requires a way to quantify the steepness of the demand curve. Price elasticity of demand quantifies steepness at a single point on the demand curve. However, the steepness of the demand curve reflects how these point-price elasticities change. Therefore, Hursh and Silberberg proposed an exponential demand equation with a single free parameter to quantify how steeply the demand curve declines (across the entire demand curve) with increases in price.

QUANTIFYING VALUE FROM DEMAND CURVE DATA

Hursh and Silberberg (2008) argued, and provided considerable empirical data supporting the position, that demand curves may be well fit by an exponential decay function when the logarithm of consumption is plotted as a function of price:

$$\log\ Q = \log\ Q_0 + k\left(e^{-\alpha[Q_0 \cdot c]} - 1\right). \qquad (1)$$

The independent variable in Equation 1 is cost (C), and it is typically measured as the number of responses or units of time spent acquiring each reinforcer. Peak consumption ($\log Q_0$) is obtained empirically by making the reinforcer available at a zero (or minimal) cost. k is a scaling constant that reflects the log-unit range of the consumption data plotted in the demand curve. If k is set to a constant range across reinforcer comparisons, the slope of the demand curve at a given value of C (i.e., the point-price elasticity) is determined by the free parameter, α. Thus α quantifies the rate of change in log consumption with increases in C.

An important characteristic of Equation 1 is that α is unaffected by the scalar properties of a reinforcer (e.g., magnitude, dose). To understand the importance of this for quantifying the value of a reinforcer, consider the results of an experiment conducted by Hursh et al. (1988). Two groups of rats worked for food in a closed economy. For the small-reinforcer group, one food pellet was earned for each lever press, whereas the other group earned two pellets per press. Under these conditions, both groups consumed a little more than 530 pellets per day. However, because of the difference in reinforcer size, Q_0 in the small-reinforcer group was 533 reinforcers, whereas it was 273 in the large-reinforcer group. Obviously, Q_0 does not measure reinforcer value; in this case, it reflects the scalar difference in reinforcers across groups. So that estimates of α in Equation 1 are unaffected by the scalar properties of the reinforcer, Equation 1 uses Q_0 as a multiplier of C (i.e., $Q_0 \cdot C$). In this way, Equation 1 standardizes price ($Q_0 \cdot C$) so that it reflects the cost of achieving peak consumption of the reinforcer. In the remainder of the Hursh et al. study, pellets were earned at FR values ranging from 1 to 360. The resulting demand curves were well fit by Equation 1 ($R^2 > .98$ in both cases), and because of the scalar invariance property of the equation, it provided a single value of α across groups. Hursh and Silberberg (2008) referred to α as a measure of the essential value of a reinforcer because it provides a single quantitative measure of an organism's defense of consumption in the face of constraint.

[1]We use the term *beneficial* to match the term *benefit* in *cost–benefit ratio;* it should not be read as though reinforcers derive their function from benefits. A more scientifically defensible term would be *consequent*.

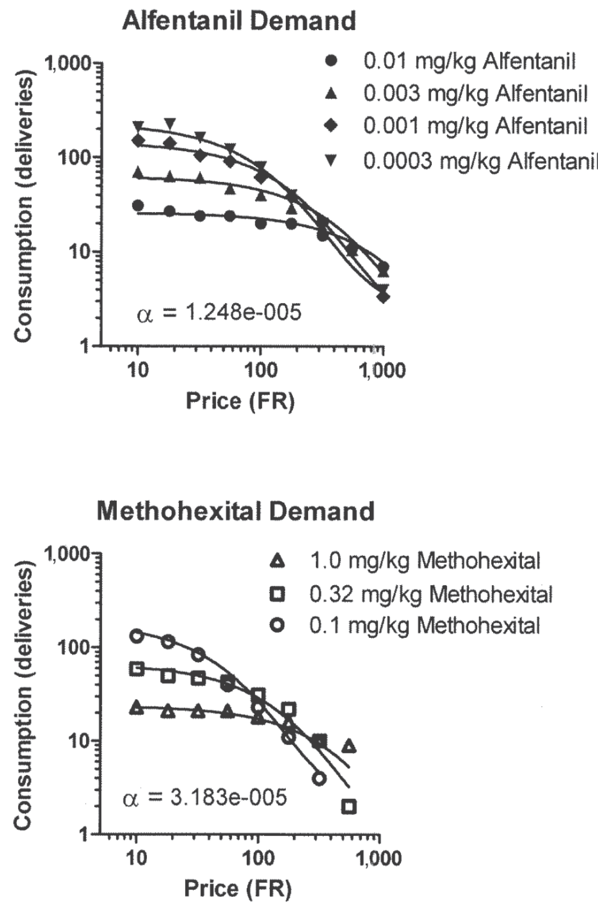
Commodities that are most vociferously defended are the most essential.

Larger values of α reflect steeper demand curves and less essential value, and small α values come from shallow demand curves. Thus, α values are inversely related to value. A perhaps more intuitive measure of essential value, and one that may be derived from α, is P_{max}.[2] P_{max} is inversely proportional to α and can be found using the following approximation:[3]

$$P_{max} = \frac{0.65}{\alpha \cdot Q_0 \cdot k^{1.191}}. \qquad (2)$$

As noted earlier, P_{max} is the price (in units of C) at which the slope of the demand curve (i.e., point-price elasticity) is −1. P_{max} is also the price at which peak responding is achieved; at higher prices, responding declines along the descending limb of the inverted U-shaped response output function. Higher P_{max} values reflect a greater expenditure of resources in defense of consumption.

As an example of how these techniques may be used to compare the value of different reinforcers, we summarize the results of a comparison of two different drug reinforcers (alfentanil, a potent opiate, and methohexital, a short-acting anesthetic) self-administered in different sessions by monkeys (Hursh & Winger, 1995). Figure 8.3 shows the across-subjects average consumption (number of drug deliveries) of each drug at the prices (number of lever presses per injection) shown on the x-axis; the demand curves were fit using Equation 1. The first thing to note is that within-drug doses varied by three orders of magnitude. Because Equation 1 accounts for scalar differences by expressing price as the cost of achieving Q_0, the α value obtained at every dose of the same drug was the same (see the bottom of Figure 8.3). Because scalar differences in drug potency do not affect α, a direct comparison of the essential value of the different drugs could be made. Although methohexital was reinforcing at



	k	α	Pmax (normalized)	R^2
Alfentanil	1.893	1.25E-05	244	0.98
Methohexital	1.893	3.18E-05	96	0.96

FIGURE 8.3. Exponential demand curves fit to average consumption of two drugs self-administered by rhesus monkeys. The drugs were alfentanil and methohexital. Parameters of the demand curves and P_{max} values are shown at the bottom of the figure. The α value for methohexital was 2.5 times greater than the value for alfentanil. P_{max} is shown in normalized units of price, which is the result of Equation 2 multiplied by Q_0 and divided by 100. The α values are constant across doses of each drug, and the k values were constant for all curves. The global R^2 for each drug is also shown. FR = fixed ratio.

unit doses 300 times higher than the lowest dose of alfentanil, its essential value was 2.5 times lower than that of alfentanil (recall the inverse relation

[2]Other potentially useful metrics are consumption at P_{max}, which is found by solving Equation 1 with $C = P_{max}$, and O_{max}, peak response output, which is found by taking the solution of Equation 1 with $C = P_{max}$ and multiplying this level of consumption by P_{max}.

[3]Because Q_0 appears twice in the first derivative of Equation 1, there is no closed form solution for P_{max}, that is, price at which the first derivative of Equation 1 = −1, and exact P_{max} values can only be found using an iterative solver. However, Equation 2 provides a close approximation within a specified range of values of k. The expression approximates P_{max} with a precision that is virtually exact for $k = 5$ and within ±2% for $2 \le k \le 6$, within ±5% for $1.8 \le k \le 8$, and average error of 1.5% for $2 \le k \le 6$.

between α and essential value). These differences were reflected in P_{max} with a larger value for alfentanil. Here, P_{max} is shown in normalized units of price to account for differences in dose that shift Q_0.[4]

VARIABLES AFFECTING VALUE

The term *essential value* may suggest to some readers that the goal is to quantify value as an essential, invariant characteristic of the reinforcer. As any economist who studies consumer demand will tell you, this is not the goal because sensitivity to price manipulations may be affected by several nonprice variables. The word *essential* reflects how necessary the reinforcer is to the organism, and variables that decrease the necessity of obtaining that reinforcer should decrease essential value. One category of these variables is the availability of other reinforcers. Economists have extensively studied interactions between reinforcers that consumers may choose between, and they describe these on a continuum from substitutes to complements. Understanding this continuum will facilitate a discussion of how the availability of other reinforcers affects essential value.

Availability of Substitutes and Complements

The substitute to complement continuum is illustrated categorically in Figure 8.4. To determine the relation between two reinforcers (A and B), A is made available at a constant price and the price of B is increased. If consumption of A increases with the price of B, then one can say that A substitutes for B. If the opposite manipulation is conducted (price of A is increased and price of B is held constant) and consumption of B increases, then one can say that B also substitutes for A. Perfect substitutes demonstrate this reciprocal relation: If the gas station on the north side of the street increases the price of a gallon of gas, then, all else being equal, consumers will purchase more gas at the south-side station. If next week, the south-side station increases prices, then consumers will head to the north side (see Herrnstein & Loveland, 1975, for similar findings with pigeons). Because the gasoline sold at the two stations, and the food obtained by pecking the two keys, are identical, one reinforcer perfectly substitutes for the other.

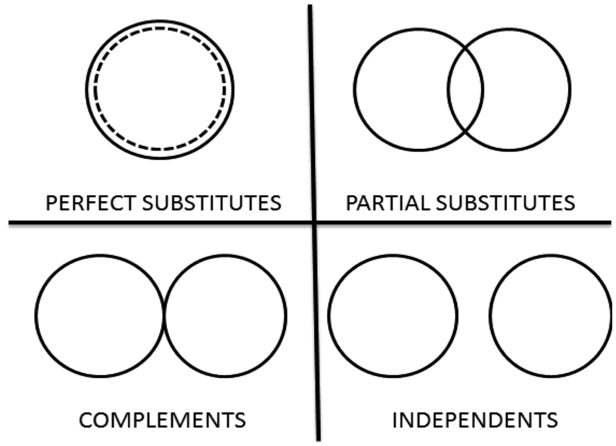


FIGURE 8.4. Diagram of four hypothetical forms of reinforcer interactions. Perfect substitutes serve an identical function, whereas partial substitutes serve a partial function of the other reinforcer. Complements interact, but in a different way than substitutes. Independent reinforcers do not interact. Based on material from *Reframing Health Behavior Change With Behavioral Economics* (p. 38) by W. K. Bickel & R. E. Vuchinich (Eds.), 2000, Mahwah, NJ: Erlbaum. Copyright 2000 by Lawrence Erlbaum Associates. Adapted with permission.

Perfect substitutes are arranged to affect the essential value of a reinforcer in two common ways. First, if a perfect substitute is delivered either for free or at a low cost outside of the experimental session, then food earned during the session is not as essential as it would be if the only source of food were that available at the price prevailing during the session. Hursh (1980) termed these arrangements *open economy* and *closed economy,* respectively. An example is illustrated in Figure 8.5. In this study, Hursh (2000) assessed a monkey's demand for food during 12-hour sessions at a range of prices. In one condition, all of the food consumed was earned during the sessions (closed economy). In the open economy condition, the session ended with the initiation of a 60-minute period in which low-cost food was available: Food was delivered after each response (FR 1). The essential value of food in the open economy was less than in the closed economy (α value 2.5 times greater in the open economy than the closed economy), and the monkey's peak response output was reached at a lower price (P_{max})

[4]Normalized $P_{max} = P_{max}\, Q_0/100 \approx 0.0065/(\alpha\, k^{1.191})$

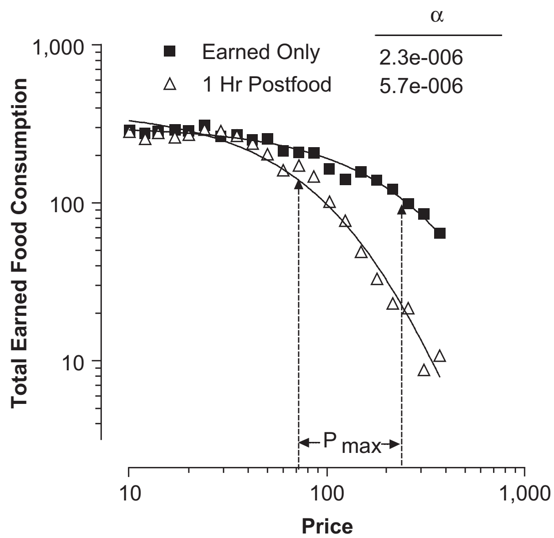


FIGURE 8.5. Two demand curves produced by a rhesus monkey responding for food during a 12- hour work period, either with no other source of food or with a 1-hour period of fixed-ratio (FR) 1 food reinforcement made available immediately after the work period. Consumption is shown as a function of the FR schedule that ranged from FR 10 to FR 372. Alpha values were derived using Equation 1. Data from Hursh (2000).

in the open economy, reflecting reduced defense of within-session consumption that is no longer essential to survival. Similar differences have been documented in several studies comparing demand in open and closed economies (Bauman, 1991; Collier, 1983; Collier, Johnson, Hill, & Kaufman, 1986; Foster, Blackman, & Temple, 1997; Greenwald & Steinmiller, 2009; Hall & Lattal, 1990; Hursh, 1978, 1984, 1993; Hursh & Natelson, 1981; Hursh, Raslear, Bauman, & Black, 1989; Hursh et al., 1988; LaFiette & Fantino, 1988, 1989; Lucas, 1981; Raslear, Bauman, Hursh, Shurtleff, & Simmons, 1988; Roane, Call, & Falcomata, 2005; Zeiler, 1999). The difference in spending (i.e., response output) across open and closed economies underlies consumer protection laws that forbid the formation of monopolies. If only one supplier of an essential commodity exists (closed economy), then consumers will consume less and pay more for the commodity, an outcome that unfairly favors the supplier.

The second procedure for arranging perfect substitutes is to make them available concurrently so that the consumer may choose between vendors. Most studies of choice with animals have arranged for the alternative behaviors to provide the same, perfectly substitutable reinforcer, usually food, which yields a specific kind of environment–behavior interaction in which the amount of behavior allocated to each source of reinforcement roughly matches the relative rate of reinforcement received from the source (the matching law; see Volume 1, Chapter 14, this handbook, or Chapter 7, this volume). These studies do not measure total consumption or essential value; however, the response rate and response allocation data are suggestive of the effects on measures of essential value. For example, as noted earlier, responses allocated to obtaining Reinforcer A decline when a perfect substitute, B, is available at a lower price (e.g., Green & Rachlin, 1991). Likewise, periodically providing free access to a perfect substitute will decreases instrumental responding for food (e.g., Rachlin & Baum, 1972). Bickel, Madden, and DeGrandpre (1997) reported that periodically providing free cigarette puffs during a session in which puffs were earned decreased consumption and generally increased price elasticity of demand for earned puffs. Many choices made in the natural economy are between commodities that are not perfect substitutes but fall into one of the other interactions depicted in Figure 8.4.

In their everyday lives, people rarely choose between perfect substitutes. Instead, they choose to allocate their resources between different reinforcers that share some, but not all, characteristics. For example, Kagel et al. (1995) examined rats' consumption of equally priced root beer and Tom Collins mix and found that rats consumed about 3 times as much root beer. In a subsequent condition, the price of root beer was increased, and the price of Tom Collins mix decreased. If the latter functioned as a perfect substitute for the former, then, all else being equal, Tom Collins mix (the lower priced commodity) should have been exclusively consumed. Instead, root beer consumption fell by about 40%, and Tom Collins mix consumption more than tripled. This reveals an important characteristic of imperfect substitutes: The consumer will not trade one unit of A for one unit of B if B only partially substitutes for A. Reinforcer B typically lacks some quality possessed by A. For example, a bus ride functions as a partial substitute for driving a private vehicle to work. The bus will get you to work on time, but it lacks the comfort of a private vehicle.

The effect of partial substitutes on essential value is illustrated in Figure 8.6. In one condition, humans could obtain doses of methadone (0.4 milligrams per delivery) by pressing a lever under an increasing series of FRs (methadone alone). During a second condition, methadone and a different opiate, hydromorphone (0.15 milligrams per delivery), were concurrently available, but hydromorphone was available at a constant price (FR 32). At the lowest price of methadone (FR 32), very little hydromorphone was consumed. As the price of methadone increased and methadone consumption decreased, consumption of hydromorphone increased, revealing a substitute relation between these two drugs. This is called a *cross-price change* in demand for hydromorphone, because consumption changed in response to the price of another good (discussed in more detail later). Of further note is the change in elasticity of methadone (α) when hydromorphone was available as a substitute. Sensitivity to methadone price more than doubled when hydromorphone was available and peak consumption (Q_0) was reduced by a third (80 vs. 120). Similar findings

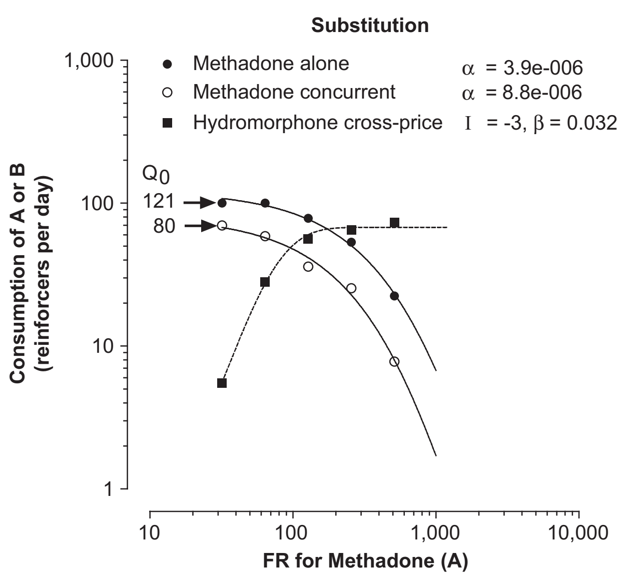


FIGURE 8.6. Mean daily consumption by human subjects of methadone and hydromorphone as a function of the price (fixed-ratio [FR] schedule) of methadone, in log-log coordinates. Data from Spiga (2006).

have been reported when the partial substitute was a nondrug reinforcer (Greenwald & Steinmiller, 2009) and when both the target and partial substitutes were nondrug reinforcers (Tustin, 1994).

A final reinforcer interaction is a complementary relation. Reinforcers are described as complements when they tend to be consumed at a constant ratio (e.g., one tortilla chip to 5 grams guacamole, one left shoe to one right shoe). A complementary relation between reinforcers is demonstrated if the price of one reinforcer increases (e.g., the price of guacamole doubles) and consumption of both reinforcers (chips and guacamole) decreases, despite no increase in the price of chips. Such a decrease reveals the tendency of the two commodities to be consumed in a constant ratio.

A complementary relation is illustrated in Figure 8.7. In this study conducted by Spiga, Wilson, and Martinetti (2011), humans smoked cigarettes and drank ethanol-containing beverages available at a range of prices. In the left panel, cigarette consumption was measured across a wide range of cigarettes prices (FR 10–512). In one condition, cigarettes were the only commodity available for purchase (closed circles), whereas in a separate condition cigarettes (open circles) could be purchased at this range of prices, and ethanol (closed diamonds) was concurrently available at a fixed price (FR 32). Two interesting effects were observed. First, when cigarette prices increased, consumption of cigarettes and ethanol decreased. The latter decrease, despite no change in the price of ethanol, reveals a complementary relation between cigarettes and ethanol. Second, making a complement (ethanol) available increased cigarette consumption and increased the essential value of cigarettes (i.e., lower value of α). A similar relation is shown in the right panel of Figure 7. When the price of ethanol increased, ethanol and cigarette consumption both declined, and the essential value of ethanol increased when cigarettes were concurrently available.

Reinforcer interactions from substitutes to complements may be quantified using cross-price elasticity of demand—the slope of the demand function relating consumption of a fixed-price reinforcer to the changes in price of an alternative commodity. As noted earlier, if this function has a positive slope,

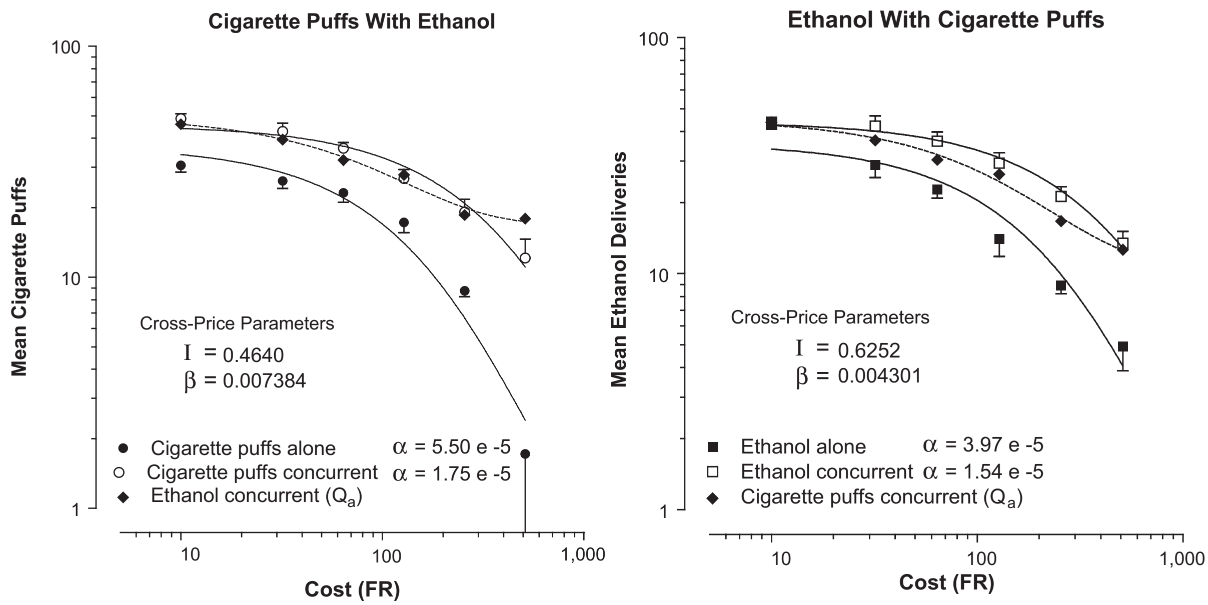


FIGURE 8.7. For human subjects, consumption of cigarette puffs or ethanol drinks. Left: The price of cigarettes was manipulated with and without ethanol concurrently available at a fixed price. Right: The price of ethanol was changed with and without cigarettes concurrently available at a fixed price. FR = fixed ratio.

then the second commodity is a substitute for the first (Figure 8.6); if the slope is negative, then the second commodity is a complement of the first (Figure 8.7); if the slope is zero, they are independent (i.e., no interaction between the reinforcers).

An extension of exponential demand was used to fit the cross-price demand curves in Figure 8.6 for hydromorpone (substitute for methadone) and in Figure 8.7 for ethanol and cigarettes (complements to each other):

$$Q = \log\left(Q_{\text{alone}}\right) + Ie^{-\beta \cdot C}, \tag{3}$$

where Q_{alone} is peak consumption of the fixed-price reinforcer at the lowest price of the other reinforcer, I is the interaction constant, β is sensitivity of consumption of the fixed-price reinforcer to changes in the price of the other reinforcer, and C is the cost of the variable-price reinforcer. In Figure 8.6, the interaction term I was negative (−3), indicating a reciprocal or substitute relation between consumptions of the two commodities; in Figure 8.7, the interaction terms I were positive (0.5 for ethanol and 0.6 for cigarettes), indicating a parallel or complementary relation between consumptions of ethanol and cigarettes.[5]

To summarize, essential value may be dramatically affected by the availability of alternative reinforcers. When substitutes are available, the essential value of a reinforcer declines relative to when no other source of reinforcement is available. Low-priced concurrently available perfect substitutes produce large decreases in essential value, with imperfect substitutes (Kagel et al., 1995) and delayed alternatives (e.g., Roane et al., 2005) producing more modest declines in essential value. At the other end of the continuum, concurrently available complements increase the essential value of a reinforcer. These reinforcer interactions are not traditionally incorporated into prominent models of decision making such as Herrnstein's (1970) matching law, although interested readers should see Green and Rachlin (1991) or Herrnstein and Prelec (1991).

Essential Value and Cost Variables

An untested assumption of the exponential demand equation is that estimates of essential value are general to other cost manipulations. That is, Equation 1

[5]If the prices of both Commodity B and Commodity A are changing, then Equation 3 can be expanded by replacing the $\log(Q_{\text{alone}})$ term for Commodity B consumption at a fixed own-price with Equation 1 that specifies how consumption of Commodity B varies with a variable own-price. This expanded form provides an economic foundation for determining choice ratios as the ratio of several such expanded demand equations, a topic beyond the scope of this chapter.

does not specify how costs are operationalized, and therefore, the assumption is that measures of essential value such as α will be unaffected by the variety of ways in which costs may be arranged. To date, tests of Equation 1 have been limited to studies in which costs are operationalized as FR values.

As an initial test of the generality of essential value estimates, we used Equation 1 to fit the demand curves shown in Figure 8.8. In this closed economy study conducted by Madden et al. (2005), pigeons pecked a key to obtained three 45-milligram food pellet reinforcers in two separate conditions. In one condition, the cost of food was set by an FR schedule, whereas in the other condition, costs were programmed according to a random-ratio (RR) schedule (each response has a constant probability of leading to reinforcer). Because the reinforcer was identical across conditions, the essential value of food should be unaffected by how cost was operationalized. Despite the effort costs being identical across conditions (e.g., 48 pecks per reinforcer or an average of 48 pecks per reinforcer), demand for food proved to be substantially more elastic when the FR schedule controlled the delivery of food. This difference is reflected in the α values shown in Figure 8.8.

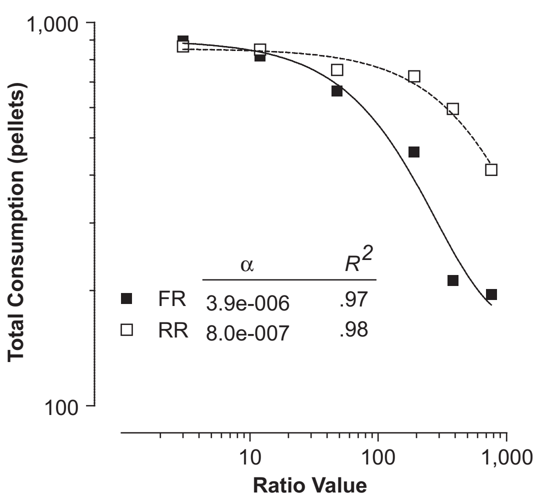


FIGURE 8.8. Pigeons' averaged food consumption under fixed-ratio (FR) and random-ratio (RR) schedules. The R^2 values suggest the data are well fit by Equation 1, but the different α values reveal that essential value is affected by schedule of reinforcement type. Data from Madden et al. (2005).

These data are consistent with Hursh and Silberberg's (2008) position that the value of a reinforcer is determined not only by its benefits but also by its costs. However, Equation 1 does not incorporate a parameter for how costs are operationalized. A general solution to this problem may be scalar transformations of different cost manipulations (e.g., expressing RR values as harmonic rather than arithmetic means; see Killeen, 1968). Such transformations may prove useful if one's goal is to precisely quantify the essential value of a reinforcer across many different cost manipulations. However, if one's goal is merely to rank order the essential value of a variety of reinforcers, then Equation 1 may prove adequate. Evaluating this possibility will require experiments in which several different reinforcers are rank ordered on the basis of their essential values obtained under one cost manipulation (e.g., delay to reinforcer delivery) and then these rankings are redetermined under a different cost manipulation (e.g., effort expended). Such a study would evaluate the ordinal generalizability of essential value.

DISCOUNTING THE VALUE OF DELAYED OUTCOMES

A few studies have examined the effects of reinforcer delay as a cost factor affecting consumer demand (e.g., Bauman, 1991; Tsunematsu, 2000). Those studies that have been conducted have reported that when delay costs are increased, demand for the reinforcer follows a positively decelerating demand function comparable with those in the preceding figures in this chapter. To our knowledge, no studies have yet used Equation 1 to estimate reinforcer value when delay is the cost variable. Instead, the bulk of the behavioral economic research on the effects of delay on reinforcer value has been conducted in the delay discounting literature. These studies have used psychophysical procedures to estimate the value of delayed reinforcers. One widely used and illustrative procedure asks human or animal subjects to make repeated choices between a smaller–sooner reinforcer (SSR) and a larger–later reinforcer (LLR). Depending on the choice made on Trial x, the amount of the SSR arranged on Trial x + 1 is either increased (the subject chose the LLR) or decreased (the subject chose the SSR). This choice-dependent adjustment process is repeated until the subject is indifferent between the reinforcers. At this indifference point, the value of the LLR is given by the amount of the SSR. This process is repeated at a range of delays to delivery of the LLR, and the resulting indifference points are plotted as a function of their delay. The resulting delay-discounting function is shown as the solid curve in the top panel of Figure 8.9. This finding is remarkably consistent across species and reinforcer types (see Madden & Bickel, 2010, for a review).

Across species, the hyperbolic discounting equation (Mazur, 1987) well describes steady-state choices:

$$V = \frac{A}{(1+kD)}. \tag{4}$$

In Equation 4, A is the amount of the LLR, D is the delay to its delivery, and k is a free parameter that varies with the steepness of the discounting function. When humans make prospect choices between immediate and delayed rewards, their pattern of choices conforms to the same hyperbola describing animal choices involving real delays and real reinforcers (e.g., Green, Fry, & Myerson, 1994; Kirby, 1997; Rachlin, Raineri, & Cross, 1991; although see Green & Myerson, 2004, for evidence that for humans the curve may deviate slightly from a strict hyperbola).

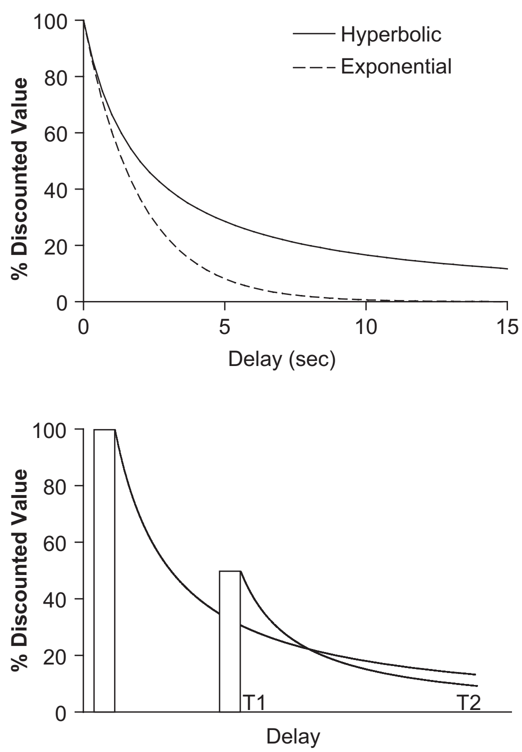


FIGURE 8.9. Top: Illustrative hyperbolic and exponential delay discounting functions. Bottom: Irrational preference reversals predicted by the hyperbolic shape of human and nonhuman discounting functions. T1 = Time 1; T2 = Time 2.

This finding has been of great interest to behavioral economists because the hyperbolic shape of the delay discounting curve is not predicted by normative economic theory. The latter holds that the value of a delayed outcome should decline exponentially, as shown by the dashed curve in the top panel of Figure 8.9 (e.g., Samuelson, 1937). An exponential decay function is the outcome of devaluing a reinforcer at a constant rate over time. For example, in Figure 8.9 the delayed reward loses 39% of its value when delayed by 1 second (discounted value = 61%). At a 2-second delay, the reward is discounted by an additional 39% (discounted value is 37% = 61 − [61 × 0.39]), and so on.

Given the considerable body of empirical evidence that human and nonhuman choice reflects a hyperbolic rather than an exponential discounting process, several behavioral economists have hypothesized that hyperbolic discounting may be the product of two exponential discounting processes (e.g., McClure, Laibson, Lowenstein, & Cohen, 2004). One process is controlled by limbic brain structures that discount delayed rewards according to a steep exponential decay function when an immediate reward is available. The other process is controlled by frontal cortex structures and discounts rewards in the upper range of delays according to a more shallow exponential curve. The temporal proximity of the reward is presumed to control the degree to which these two processes are engaged, with more immediate rewards uniquely able to control limbic function. This model of discounting has not been universally embraced (e.g., Ainslie, 2010), and empirical challenges exist (e.g., Peters, 2011). However, as discussed later in the chapter, the model has inspired a new executive function training approach to improving delay tolerance in drug-using populations (Bickel, Yi, Landes, Hill, & Baxter, 2011).

Regardless of whether hyperbolic discounting ultimately proves to be fundamental or the product of two exponential decay processes, hyperbolic delay discounting may help to make sense of some forms of irrational behavior that make little sense from a normative economic perspective. For example, exponential delay discounting predicts that organisms should be rational decision makers in the sense that choice should not waver over time. A rational cigarette smoker who decides to quit smoking on Monday would not waver from this decision on Tuesday, not even when faced with an immediate temptation such as the offer of a free cigarette. Likewise, other people, having committed to pursuing a healthy diet, exercise, and debt repayment would walk the straight and narrow until their goal was achieved. People's everyday experience, however, tells them that they are not rational decision makers.

Choice inconsistencies such as drug relapse, breaking a diet, and incurring more debt are predicted by the shape of the hyperbolic discounting function. To illustrate, the bottom panel of Figure 8.9 shows two vertical bars corresponding to the LLR and SSR. When choices are made at Time 1, the SSR (e.g., a high-calorie, high-fat hamburger) is immediately available, whereas the LLR is delayed (e.g., staying with your diet and later experiencing health benefits, weight loss, etc.). At Time 2, both reinforcers are delayed, with the difference in delivery time at Time 2 being the same as at Time 1. Also shown are two hyperbolic discounting curves, both using the same rate of discounting (i.e., *k* value). Assuming that choice favors the reinforcer with the greater discounted value (i.e., the higher of the two curves) at Time 2, the individual chooses the LLR. Thus, after an overindulgent meal, one resolves to eat better next time. Unfortunately, something dreadful happens as the next meal gets closer—one travels from Time 2 to Time 1. Along this path, the discounted values of the reinforcers are switching positions as an immediate temptation (SSR) gets nearer. At Time 1, with menu in hand, the value of the hamburger now outweighs the delayed benefits of pursuing a healthy diet. Although this irrational choice is not predicted by the economist's exponential discounting process (exponential discounting curves do not cross), it is by hyperbolic delay discounting.

The interspecies generality of hyperbolic delay discounting would appear to suggest that people are doomed by their phylogenetic heritage to make irrational intertemporal choices. According to the ecological rationality hypothesis, choosing immediate over delayed reinforcers may have offered organisms a selective advantage in a natural environment filled with predators, competition, unpredictable food supplies, and scarce mating opportunities (e.g., Stevens & Stephens, 2010). These tendencies, well honed by natural selection, are not well suited to the unnatural context in which consumer choices are frequently made: A context in which consumables never imagined by people's foraging ancestors are now readily available if they are just willing to sacrifice their long-term health or wealth to consume them.

Individuals who very steeply discount the value of delayed rewards would be expected to be most susceptible to the draw of immediate temptations. A steeply discounted delayed reward retains almost none of its value and therefore cannot compete with an immediate reward. Conversely, those whose choices produce a shallow discounting curve would be expected to eschew SSR temptations because they cannot compete with the nominally discounted value of the LLR.

Consistent with this prediction, a substantial body of research conducted over the past decade or so has revealed that individuals diagnosed with a substance use disorder (MacKillop et al., 2011; Yi, Mitchell, & Bickel, 2010), pathological gambling (Petry & Madden, 2010), or obesity (Davis, Patte, Curtis, & Reid, 2010; Rasmussen, Lawyer, & Reilly, 2010) more steeply discount delayed rewards. Data suggesting that delay discounting may play a role in the initiation, continuation, or relapse to one of these addictions come from two sources. First, animal experiments in which delay discounting is assessed first and rats are then given the opportunity to self-administer cocaine have suggested that steep delay discounting of food rewards predicts the acquisition of sustained cocaine self-administration (see review by Carroll, Anker, Mach, Newman, & Perry, 2010). The same has not been observed of nicotine self-administration (Diergaarde et al., 2008), perhaps owing to the substantial training necessary to produce nicotine self-administration in rats. However, Diergaarde et al. (2008) found that when the price of nicotine was increased by increasing the FR requirement, demand for nicotine proved to be more inelastic among the rats that most steeply discounted delayed food rewards (i.e., the essential value of nicotine was higher for the impulsive rats). These rats were also more likely to press the nicotine lever after an extinction phase when nicotine reinforcer cues were presented.

Second, human studies have suggested that the steepness of the delay discounting curve is predictive of (a) the initiation and escalation of cigarette smoking (Audrain-McGovern et al., 2009), (b) success in substance abuse treatment (e.g., MacKillop & Kahler, 2009), and (c) relapse after treatment (Yoon et al., 2007). Thus, steep delay discounting is correlated with the propensity to engage in a variety of drug-related activities. Stronger statements of the role that steep delay discounting may play in drug taking and other addictive behavior must await the result of studies that experimentally manipulate the steepness of the discounting curve. Assuming that discounting is not a trait (Odum, 2011), an experimental manipulation of delay discounting will allow us to determine whether steep discounting is causally related to addiction.

The latter experimental approach characterizes studies evaluating the effects of acute and chronic drug exposure on delay discounting. Acute dosing in animals has produced a large but very mixed literature, with some studies showing an effect in one direction and others showing the opposite or no effect. When the effects of a drug are consistent (e.g., nicotine), the number of studies conducted to date is very small (see review by de Wit & Mitchell, 2010). Among humans, acute doses have produced almost no effect on delay discounting (de Wit & Mitchell, 2010), which may be a product of using hypothetical rewards and delays (see Reynolds, Richards, & de Wit, 2006). By contrast, chronic exposure to cocaine, either provided by the experimenter or self-administered, appears to increase the degree to which delayed rewards are discounted (see review by Mendez et al., 2010). This does not appear to be true of all drugs of abuse, because chronic amphetamine exposure produces no effect on delay discounting (e.g., Floresco & Whelan, 2009).

In sum, the direction-of-causation arrow is not consistently pointing in a single direction. Individuals who steeply discount the value of delayed rewards may be more likely to initiate and escalate cocaine use, whereas neuroadaptations to chronic cocaine would appear to produce greater intolerance of delays (i.e., steeper delay discounting curves; Setlow, Mendez, Mitchell, & Simon, 2009). Considerably more research is needed to explore the generality of these findings across drugs, species, and procedures and to determine whether drug self-administration is affected by experimental manipulations of delayed reward discounting.

TRANSLATING BEHAVIORAL ECONOMICS

The translational utility of these concepts, methods, and analyses are many. For example, quantifying the value of drug reinforcers under identical contextual circumstances (e.g., monkeys self-administering drugs at a range of FR requirements in a closed economy) may prove useful in evaluating the abuse liability of newly developed analgesic medications; those that produce high P_{max} values would be released with warning labels and instructions to physicians about the abuse potential of prescribing the drug. As noted earlier, the extent to which these P_{max} values, or perhaps the rank ordering of these values, prove to be applicable to a wide variety of cost manipulations is an area for future research. In this section, we consider a few of the translational directions that have begun to be explored in behavioral economics and those that may show promise in future research. Much of this translational research (and research potential) falls under the rubric of addictions, but a handful of applied behavior analysts have begun to profitably use behavioral economic concepts to suggest new interventions in the treatment of severe problem behavior in individuals with intellectual and developmental disabilities. We consider these translations in turn.

Measuring Addiction and Treatment Efficacy

Several economic theories have been forwarded to explain the development of an addiction—an increasingly strong tendency to seek and consume a specific commodity (e.g., Becker & Murphy, 1988). The present application of the demand law offers a systematic, hypothesis-free means by which to describe the neurobehavioral longitudinal changes that are described as addition. Such measures may prove useful in informing present and future theorizing about the origins and progression of addiction.

For example, a growing literature has indicated that for some commodities, extended exposure to the reinforcing properties of that commodity leads to progressive changes in demand (see escalation, e.g., Ahmed & Koob, 1998). In a recent experiment with rodents as subjects (Christensen, Silberberg, Hursh, Huntsberry, & Riley, 2008), demand curves for infusions of cocaine were determined after a brief familiarization with the drug and then after a 2-week history of infusions. Figure 8.10 illustrates the effect of the extended history of consuming cocaine. So as to focus on changes in elasticity, we used an exponential demand equation that sets Q_0 of both demand curves to 100% (see Hursh & Winger, 1995). The 2-week history of self-administering cocaine rendered drug demand more inelastic when

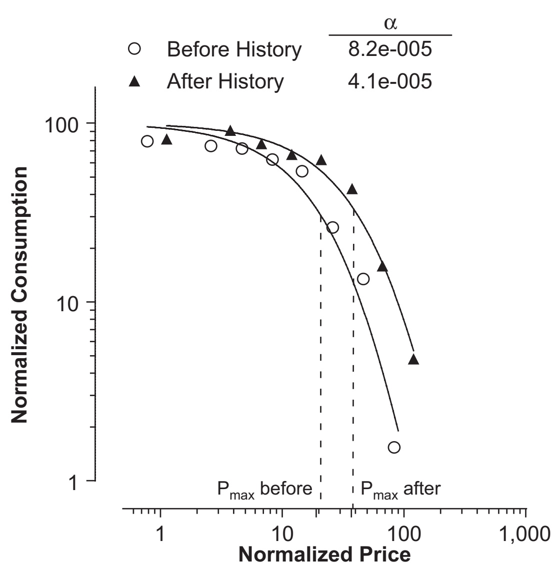


FIGURE 8.10. For the mean of a group of rodents, consumption of cocaine infusions as a function of increasing fixed-ratio schedules before and after a 2-week history of exposure to cocaine, in log–log coordinates. The shift in P_{max} is shown as the two vertical dashed lines. Data from Christensen, Silberberg, Hursh, Huntsberry, and Riley (2008).

compared with postacquisition demand (50% reduction in α; P_{max} increase from 19 to 37; for similar findings, see Wade-Galuska, Galuska, & Winger, 2011). There may be utility in conceptualizing addiction as a longitudinal experience-dependent shift in the essential value of a reinforcer, pursued to the relative exclusion of other commodities—a process that may be quantified using the procedures outlined earlier.

Building on these assumptions, some researchers have begun to ask whether characteristics of demand curves are correlated with intensity of drug dependence, affected by relapse cues, and whether these characteristics have predictive utility in determining responsivity to treatment, relapse, and so forth. Several first steps have been taken in this emerging literature. Murphy, MacKillop, Tidey, Brazil, and Colby (2011), for example, used a simulated cigarette purchase task to quantify elasticity of demand for cigarettes among adolescent smokers. The adolescents were asked to report how many cigarettes they would purchase per day if cigarette prices varied across a wide range. So as to quantify demand in a simulated closed economy, participants were asked to imagine that no other source of cheaper cigarettes was available. Equation 1 provided good fits of individual participants' simulated demand functions, with O_{max} (i.e., peak spending) most consistently correlated with participants' level of nicotine dependence. A very similar methodology was used by Madden and Kalman (2010), who reported that therapy-related changes in essential value of cigarettes (α) were predictive of smoking cessation at 2-month follow-up. The simulated purchase task also proved useful in quantifying increases in the essential value of alcohol when heavy drinkers were exposed to the smell of their preferred alcoholic beverage (MacKillop et al., 2010). Procedures such as these hold the promise of integrating more ambiguously defined concepts like "craving" into a quantifiable behavioral economic model of factors affecting drug use and relapse.

A second translational application of the demand curve procedures outlined earlier is in evaluating the efficacy and mechanisms of action of medications designed to reduce drug use. One category of medications, agonists, has been discussed briefly in the context of Figure 8.6, and we expand on it here. Agonists are drugs that at least partially substitute for the drug of abuse. For example, methadone is an imperfect substitute for heroin; it is an opiate agonist and has many of the psychoactive properties of heroin and morphine. Methadone is explicitly formulated so that an oral dose will prevent opiate withdrawal but will not produce a pronounced euphoria or high. Given this imperfect substitute interaction, it is not surprising that even when heroin is considerably more expensive than methadone, some heroin is still purchased from illicit sources (see Stitzer, Grabowski, & Henningfield, 1984). In addition, heroin is often consumed socially, and these social events appear to serve as complements to the primary reinforcing consequences of the drug. To the extent that methadone must be consumed in a clinical, nonsocial environment, its value in a no-complement context will be diminished in the same way that the value of cigarettes was diminished when its complement, ethanol, was not available, as shown in the left panel of Figure 8.7 (see Hunt, Lipton, Goldsmith, & Strug, 1984).

Figure 8.11 illustrates how the efficacy of an opioid agonist medication, in this case methadone, may be usefully quantified by measuring its effect on Q_0, α, or other components of a drug demand curve. A methadone-maintained participant could press a button on a FR 10, 32, 64, 128, 256, or 512 to earn 0.40 milligrams per delivery of methadone, with consumption capped at 40 milligrams (half of their daily methadone maintenance dose). Sessions were conducted between 9:00 and 10:30 a.m., and the unconsumed dose from the session and the remaining portion were provided at either 11:00 a.m. (30 minutes postsession), 2:30 p.m. (4 hours postsession), or 4:30 p.m. (6 hours postsession). Demand for methadone was most elastic when a free source of methadone was available 30 minutes later and was increasingly inelastic as the delay to this substitute increased.

A second class of medications, antagonists, seeks to decrease the reinforcing value of the illicit drug. An antagonist medication binds to the neurochemical receptor and blocks the action of the illicit drug without itself producing a psychoactive effect (see Volume 1, Chapter 23, this handbook). A common

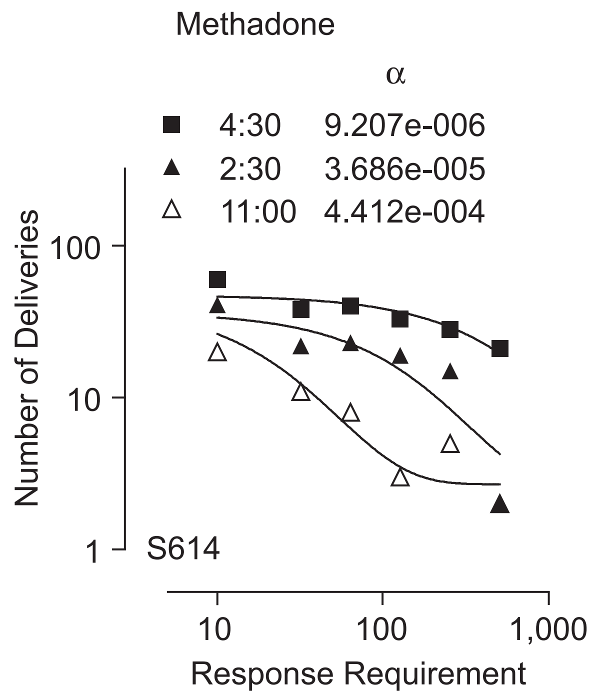


FIGURE 8.11. Consumption of methadone assessed in a human subject under increasing fixed-ratio schedules in the morning at 9:00 a.m. Additional methadone was available later for free, and the delay to the additional methadone varied from 11:00 a.m. (open triangle) to 2:30 p.m. (closed triangle) to 4:30 p.m. (closed square). The sensitivity to price (α) is shown in the legend and decreased with increases in time to the additional methadone. Data from Spiga (2006).

antagonist for opiate drugs is naltrexone or naloxone; it is used in emergency rooms to rapidly block the action of opiates in patients who have taken an overdose. As a therapy, the antagonist partially or completely blocks the action of the target drug and presumably would reduce demand.

This presumption was tested in a study reported by Harrigan and Downs (1978). Monkeys worked for morphine under a series of increasing unit prices, arranged by decreasing the morphine dose per reinforcer. Morphine self-administration was studied either alone or when combined with two doses of continuous naltrexone infusions. As seen in Figure 8.12, at the lowest common unit price, naltrexone dose dependently increased consumption of morphine. However, when the price of morphine was increased, naltrexone produced dose-dependent larger decreases in demand for morphine. This apparently complicated effect of naltrexone can be

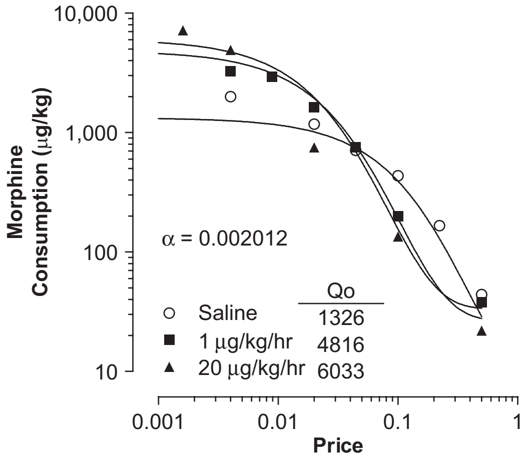


FIGURE 8.12. Effects of two doses of naltrexone on morphine consumption across a range of morphine prices. The value of α was not significantly different across conditions, but Q_0 increased across conditions. Data from Harrigan and Downs (1978).

resolved by examining the exponential demand curves for morphine alone (saline) and in combination with naltrexone shown in Figure 8.12. The dose-dependent increase in morphine consumption at the lowest common unit price is reflected in the upward shift in Q_0. However, naltrexone dose did not affect α (the common value of α is shown in the figure), suggesting that naltrexone did not change the essential value of morphine, it simply lowered the potency of each morphine infusion and raised the effective price of the drug.

As should be clear from examining Figure 8.12, and to the extent that these data are generally characteristic of antagonists, the utility of an antagonist medication depends on the prevailing price of the illicit drug and the price-increasing effect of the medication. When little constraint is placed on acquisition of the illicit drug, drug consumption increases (so as to overwhelm the effect of the antagonist). Such an increase raises at least three problems. First, some of the drug-seeking activity associated with illicit drug purchases involves illegal acts. Second, greater drug consumption translates to larger profits for drug dealers, a situation that may help to recruit more people to jobs in the illicit drug trade. Third, greater consumption of intravenous drugs may increase the use of dirty needles and the risk of needle-transmitted diseases such as HIV/AIDS.

For an antagonist medication to produce a net benefit to the illicit drug user and society, the postantagonist price must shift consumption to the elastic portion of the demand curve. There drug consumption and drug-seeking activities both decline.

Assuming that an antagonist medication could produce such a price shift, it raises the challenge of inducing users to voluntarily administer a medication that increases the functional cost of their preferred drug. This might be feasible on a limited scale with court-ordered depot injections of time-released antagonists, but other, less coercive strategies might prove more acceptable. Some antagonist medications produce desirable effects that may increase their acceptability. For example, bupropion is a nicotine receptor antagonist with atypical antidepressant effects (e.g., Dwoskin, Rauhut, King-Pospisil, & Bardo, 2006; Miller, Sumithran & Dwoskin, 2002). In a recent study of the effects of bupropion on simulated demand for cigarettes, Madden and Kalman (2010) reported no change in either Q_0 or the essential value of cigarettes after 1 week of bupropion use. This outcome suggests that the mechanism by which bupropion increases smoking cessation is unrelated to changes in the essential value of nicotine as a reinforcer. These studies have demonstrated the potential utility of quantifying the effects of a variety of medication classes on peak consumption and reinforcer value.

Economic Concepts for the Treatment of Addiction

A third area of translational potential is in treatments for addictive behavior. The difference between inpatient and outpatient treatment for addictive behavior, for example, is an obvious parallel to the distinction between closed and open economies, respectively. In the inpatient setting, the benefits of drug abstinence are "consumed" in a monopolistic setting—no substitute drug reinforcers are available to compete in the inpatient marketplace. When the economy is opened after a person is released from inpatient drug detoxification, drug-abstinence reinforcers must compete with drug reinforcers, a competition that often leads to drug relapse (Wikler, 1977). It is safe to say that detoxification does not cure addiction. This may in part be due to long-lasting Pavlovian conditioning: Cues in the client's everyday environment that elicit conditioned drug effects (craving) appear to increase the essential value of the drug reinforcer (MacKillop et al., 2010; see Podlesnik & Shahan, 2010, for a complementary account). Detoxification presumably does not affect the essential value of the drug reinforcer, so when drug cues are encountered, drug-seeking behavior is easily reinstated.

Beyond the contribution of drug cues to reinstate behavior maintained by the essential value of illicit drugs, relapse is an important (if not fundamental) reflection of the economic conditions that skew preference toward the illicit commodity. Consider the simple price difference between illicit drugs and nondrug reinforcers. In terms of a cost–benefit ratio, for those using drugs regularly, drugs are typically available at a lower price than nondrug reinforcers. For example, the heroin-dependent individual meets his or her life's goal every day when another bag of heroin is obtained and the drug is injected. The benefits of drug consumption (e.g., euphoria and escape from opiate withdrawal) are enormous relative to the procurement costs of obtaining a dose of heroin (a cost that may be met in a single day with a modicum of effort). Once obtained, the benefits of the injected drug are immediate (undiscounted) and may be accompanied by complementary social reinforcers. By comparison, the costs of a nondrug reinforcer that could compete with the benefits of drug use are much higher and substantially delayed. Acquiring the skills necessary to obtain a job that yields a salary enabling the purchase of goods and services with comparable benefits is years away, as are the benefits of beginning the hard work of repairing or replacing a dysfunctional social network.

Given this imbalance in the price of drug and nondrug reinforcers, a sustained pattern of drug use should surprise no one because to choose to walk the path of abstinence requires a substantial and sustained decrease in the summed value of reinforcers obtained per day (see Herrnstein & Prelec, 1992). That is, one must give up drug reinforcers and contact with drug-using friends and must live for some time without effective substitutes. Individuals addicted to a variety of drugs discount the value of these delayed substitutes more than do comparable individuals with no history of addiction (Yi et al., 2010); thus, these delayed imperfect substitutes cannot compete with the immediate undiscounted value of drug reinforcers. Given this imbalance, it is not surprising that drug users tend to seek drug treatment when they hit rock bottom (e.g., Cunningham, Sobell, Sobell, & Gaskin, 1994); that is, when the price of continuing to use drugs is drastically increased (e.g., loss of drug supply, loss of health, significantly deteriorated social relationships). At this time, treatment seeking represents an increase (or at least a sideways step) in the summed value of reinforcers obtained per day.

Outpatient treatment is a necessary step in the treatment or rehabilitation process; successful progress has been realized by recognizing that such treatment occurs in an open economy in which the benefits of treatment are economic goods evaluated in a competitive market. This is true of a range of outpatient programs beyond those for drug and alcohol abuse (e.g., for obesity). Innovations that increase the immediate benefits and reduce the proximal costs of therapy will serve to swing more clients toward treatment seeking and compliance with the outpatient protocol.

One approach to accomplishing this is to consider the effects of substitutes and complements on demand for the addictive good. As already discussed, making available a low-price substitute will decrease demand for a reinforcer. Carroll and Rodefer (1993) demonstrated this in the lab when monkeys' consumption of PCP decreased (larger values of α and smaller values of P_{max}) when a sweet saccharin solution was introduced to the drug self-administration sessions. This substitution effect was more prominent in a separate study when the saccharin solution was made available while rats were initiating cocaine use (Carroll & Lac, 1993). Nonetheless, these substitute effects rarely produced drug abstinence; especially among those animals already consuming drugs on a regular basis (e.g., Comer, Hunt, & Carroll, 1994). One reason is that a saccharin solution is not a perfect substitute for the drug reinforcer; if it were, the subject would exclusively prefer whichever reinforcer was available at a lower price (Herrnstein & Loveland, 1975). A second reason that abstinence was not achieved is that the contingencies were such that the nondrug reinforcer was available even if the subject was consuming the drug. This is analogous to opening a gymnasium at night to deter drug use and then allowing intoxicated youths to enter the gym.

Achieving abstinence requires that access to the substitute be contingent on drug abstinence (Higgins, 1999). This substitute reinforcer strategy has been successfully used in contingency management of substance abuse (see Chapter 19, this volume). Here, drug abstinence is reinforced with escalating-magnitude tangible rewards designed to partially substitute for the drug of abuse. As abstinence continues, the magnitude of the tangible reward increases, which increases its ability to function as an effective substitute for drugs that may increase in value with physical and psychological withdrawal (Roll & Higgins, 2000). Thus, unlike the animals self-administering drugs in the Comer et al. (1994) study, if a contingency management patient relapses to drug use the tangible reward is not presented, and the patient pays an opportunity cost when the reward magnitude is reset to the initial value.

The consideration of complementary relations between drug and nondrug reinforcers has been limited in the treatment of substance use disorders. Thus, a novel behavioral economic approach to reducing a problem behavior is to search for reinforcers that complement the reinforcer maintaining the problem behavior. If consumption of the latter may be constrained, then consumption of the former will be reduced.

Polydrug abuse. Understanding the substitute-to-complement continuum and how these reinforcer interactions affect demand may help to understand polydrug abuse (see Petry & Bickel, 1998). *Polydrug abuse* is the concurrent or sequential consumption of more than one drug of abuse. It is frequently observed in the clinical population and has been identified as a distinct and common pattern of drug use (Chan, 1991; Petry, 2001). According to the economics of consumer choice, the drug user may be thought of as a consumer making choices in an illicit market offering multiple drugs at competing prices. The level of consumption of a single drug is strictly determined not by its own utility and market price but also by the utility and price of available alternatives. Changes in patterns of abuse can only be understood if this context of competing goods is understood.

The administration of clinically prescribed medications, such as methadone, adds another dimension to what, in many cases, is already a complicated picture of multiple drug use. The result of such medications and compliance with medication schedules will depend, in part, on the various elasticities of demand in the entire polydrug marketplace. Ironically, interventions that inhibit reinforcement by one drug (e.g., antagonists) and reduce demand (e.g., price increases) may, at the same time, increase consumption of other drugs that serve as substitutes. Other drugs may also serve a complementary function such that the essential value of Drug A is increased by the availability of a low-priced source of Drug B. Figure 8.13 illustrates these effects in human subjects (Spiga, 2006). In the left panel, the price of methadone was manipulated in two separate conditions, one in which valium was concurrently available at a fixed price (FR 32) and a second in which methadone was the only drug available. In the right panel, the conditions were reversed. Two interesting effects were observed. First, when the price of the target drug increased, consumption of the other drug increased, suggesting a substitute relation. Second, the essential value of the target drug was enhanced by the presence of the alternative (i.e., lower α values), suggesting a complementary relation. The translational implication for methadone patients is that although providing methadone in clinical settings somewhat decreases valium consumption at low prices (lower Q_0 in the right panel of Figure 8.13), it also serves to sustain valium consumption in the face of price increases. Furthermore, decreasing availability of methadone (e.g., by raising the street price of the drug or increasing the travel distance to a methadone clinic) only makes matters worse as valium consumption increases (see left panel of Figure 8.13).

Translating delay discounting. Individuals who compulsively use psychoactive drugs, gamble, or overeat on average discount delayed rewards more steeply than do demographically matched non–drug

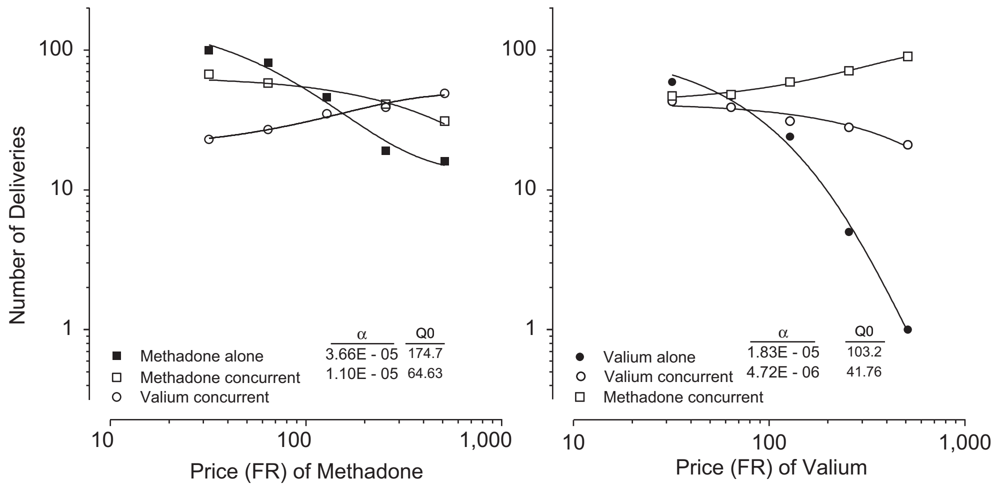


FIGURE 8.13. Mean daily consumption by human subjects of methadone and valium as a function of the price (fixed-ratio [FR] schedule) of methadone (left panel) or valium (right panel). The cross-price changes in consumption of valium are shown on the left at a fixed price of 32; the cross-price changes in consumption of methadone are shown on the right at a fixed price of 32. Data from Spiga (2006).

users, nongamblers, and those who do not eat excessively (Madden & Bickel, 2010). As noted earlier, some evidence has suggested that steep discounting of delayed rewards precedes and predicts drug taking (Carroll et al., 2010) and is predictive of failure in drug treatment trials (e.g., MacKillop & Kahler, 2009). The finding that individual differences in delay discounting among rats are predictive of drug taking is presumably a function of biological differences because rats were treated identically in these studies.

A second source of individual differences in delay discounting is the environment in which an individual lives, makes choices, and experiences consequences of those choices. This class of variables has received considerably less attention in the delay discounting literature, which is somewhat surprising because experimentally produced differences in delay discounting offer an opportunity to investigate whether steep delay discounting is causally related to subsequent addictive behavior. If so, then procedures that render discounting curves more shallow may hold promise for preventing the development of addictions.

Applied researchers may not want to wait for current basic research to investigate whether experimentally altering the degree to which an animal discounts delayed outcomes affects subsequent addiction-related behavior. There are compelling reasons to believe that steeply discounting delayed behavioral outcomes plays a role in the decision to live for the moment and ignore delayed aversive side effects of present-oriented hedonism. These arguments have been well laid out for substance use (e.g., Bickel & Marsch, 2001) and pathological gambling (Madden, Francisco, Brewer, & Stein, 2011; Rachlin, 1990), and components of these arguments could be applied to a host of disorders including obesity (Rasmussen et al., 2010), attention-deficit/hyperactivity disorder (see Chapter 15, this volume), and failure to self-manage tic disorders and obsessive–compulsive disorder (both of which involve a preference for immediate negative reinforcement over delayed improvements in quality of life). In the sections that follow, we explore the effects of three systematic environmental contingencies that have been arranged in the basic research laboratory and have proven effective in decreasing delayed reward discounting.

Teaching delay tolerance. Mazur and Logue (1978) taught pigeons to better tolerate delays to a larger–later reward (see Logue, Rodriguez, Peña-Correal, & Mauro, 1984, for similar findings). In their study, pigeons first chose between large and small food reinforcers, both delayed by 6 seconds. When the birds strongly preferred the larger reinforcer, the delay to the smaller one was gradually decreased over a period of about 1 year, all the while maintaining preference for the LLR. As noted, at the end of this training pigeons more often chose a LLR over a SSR when compared with control pigeons that did not receive this delay tolerance training. Similar interventions have successfully been used with preschool children described by their teachers as being impulsive (Schweitzer & Sulzer-Azaroff, 1988), children diagnosed with attention-deficit/hyperactivity disorder (Binder, Dixon, & Ghezzi, 2000), and adolescents with traumatic brain injury (Dixon & Tibbets, 2009). The latter demonstrations have been somewhat limited in that no data were reported on how long the effects of training lasted and to what extent choices made outside of the training setting were affected by this training. Thus, these studies may be regarded as proof of concept, with much work remaining to be done to evaluate and ensure the effects of training will last and will generalize to a wide variety of choice contexts.

Reward bundling. In their text *Midbrain Mutiny: The Picoeconomics and Neuroeconomics of Disordered Gambling,* Ross, Sharp, Vuchinich, and Spurrett (2008) described reward bundling as the most important strategy that an individual can learn in the avoidance of addictions such as substance abuse or pathological gambling (see also Ainslie, 1992). Bundling rewards means considering not just the consequences of the present choice but the consequences of repeatedly receiving the same outcome and repeatedly not receiving the outcome forgone well into the future.

The top panel of Figure 8.14 illustrates decision making without use of the reward bundling strategy—that is, the individual at Time 1 considers the SSR and LLR as though this were the only choice ever made and these were the only consequences ever experienced. Considered as single outcomes, the steep discounter shown makes the impulsive choice because the discounted value of the LLR falls below the undiscounted value of the SSR.

The middle panel of Figure 8.14 illustrates two reward bundles that a decision maker, situated in time at Time 1, might choose between. The first bundle is composed of three SSRs (SSR bundle);

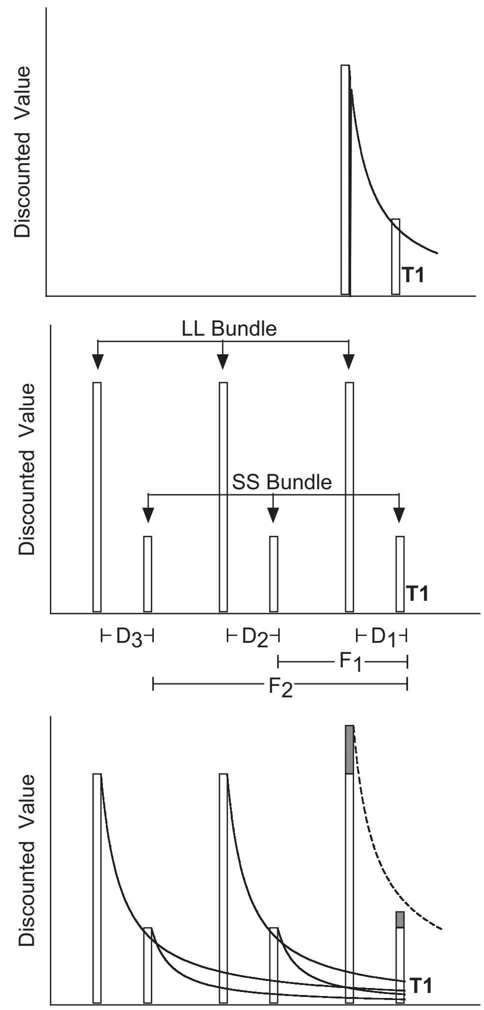


FIGURE 8.14. Delayed reward bundling. The top panel shows the discounted value of larger–later reinforcer (LLR) relative to immediately available smaller–sooner reinforcer (SSR). The middle panel illustrates that three rewards will be bundled; choosing the SSR results in the organism obtaining the SSR on the present trial and the next two trials (i.e., following future intervals F1 and F2). Likewise, choosing the LLR bundle results in three LLRs across three trials, the first following the programmed delay (D1), the second after F1 and D2, and the third after F2 and D3. The bottom panel shows the discounted values of the two bundles. The value of the three SSRs is given by the height of the SSR bar with the discounted values of the next two SSRs added in the shaded area. The discounted value of the LLR bundle is given by the dashed discounting curve. T1 = Time 1.

one delivered now (at Time 1) and the others in the future (after delays F_1 and F_2). When the individual chooses the SSR bundle, he or she enjoys the immediate benefits of the SSR and is committed to receiving the remaining two smaller rewards in the future (and not receiving any of the LLRs). The second reward bundle is composed of three LLRs, one delivered after the delay (D_1) and the others in the future ($F_1 + D_2$ and $F_2 + D_3$).

When the three separate LLRs are combined into a single bundle, the value of the LLR bundle is determined by the sum of the discounted values of all rewards in the bundle. This is illustrated in the bottom panel of Figure 8.14. Consider first the value of the SSR bundle. The value of this bundle is the value of the immediate reward (the open portion of the SSR proximal to Time 1) plus the sum of the discounted values of the next two small rewards in the bundle. We summed these two discounted values and added this to the height of the SSR bar nearest Time 1 (the filled portion of this bar).

The benefit of reward bundling occurs when the discounted values of the three LLRs are summed. The dashed curve in the bottom panel of Figure 8.14 shows the summed discounted value of the three bundled LLRs. Now the discounted value of the LLR bundle exceeds the value of the SSR bundle, and the impulsive choice is avoided. Experiments with both humans (Kirby & Guastello, 2001) and rats (Ainslie & Monterosso, 2003) have illustrated that when rewards are bundled, impulsive decision making is decreased. To our knowledge, no attempts have been made to evaluate the effects of reward bundling on human decision making in an applied setting.

Engaging executive functioning. A good deal of evidence has supported the hypothesis that hyperactivation of limbic structures and hypoactivation of frontal cortex structures underlay addiction (e.g., Baler & Volkow, 2006). Limbic structures such as the amygdala and ventral striatum (which includes the nucleus accumbens) are activated by positive surprises and stimuli signaling these better than expected events (e.g., Schultz, 2002). These limbic structures are hypersensitive to drug rewards and drug cues in addicted populations (e.g., Bechara, 2005). Limbic structures appear to be more active when humans make impulsive choices in a delay discounting experimental preparation (e.g., McClure et al., 2004). By contrast, greater relative activation in the prefrontal and parietal cortex is observed when humans select LLRs (McClure et al., 2004). The latter structures are associated with executive functioning (i.e., cognitive activities that facilitate control of present behavior by anticipated future consequences; Barkley, 1997) and appear to be hypoactive in drug-dependent populations (e.g., Hester & Garavan, 2004).

Bickel et al. (2011) suggested that steep delay discounting is the product of executive system dysfunction, which may owe its origin to atrophy resulting from lack of use. In their experiment, Bickel et al. assessed delay discounting in stimulant users before and after they came to the lab and extensively practiced executive functioning tasks that targeted attention and memory. Participants in the executive function training group were paid on the basis of their performance on the attention and memory tasks, and training continued until their performance reached asymptote. A control group was paid a yoked amount for completing a structurally similar task that did not engage attention or memory skills. After training, the executive function group demonstrated significantly more shallow delay discounting than did the control group. This improvement was, interestingly, constrained to delay discounting, because no effects of executive function training were detected on six other nondiscounting measures. This finding is an intriguing one that will need to be systematically replicated in other labs and with other populations.

Clearly, more basic research is needed on the reliability, duration, and generalization of these three methods for experimentally decreasing the degree to which delayed rewards are discounted. The results of these studies should inform clinical work that targets for change the wide varieties of impulsive decision making. However, applied researchers have already begun to teach delay tolerance as a means of affecting socially important behavior (e.g., Hanley, Heal, Tiger, & Ingvarsson, 2007; Chapter 15, this volume). We applaud these efforts and look forward to continued cross-pollination between applied and basic laboratories.

TRANSLATING BEHAVIORAL ECONOMIC PRINCIPLES TO OTHER APPLIED SETTINGS

As the breadth of this volume demonstrates, behavior analysts work in a broad array of settings in which behavior is an obstacle to personal and societal well-being. Thus, the behavioral economic principles discussed here apply beyond the study and treatment of addiction, although addiction is clearly the area in which these principles have most often been used. A second area in which behavioral economic principles have begun to be translated is in the treatment of behavior problems among individuals diagnosed with autism or intellectual or developmental disabilities. In the sections that follow, we outline some of the translations that have been undertaken with this population, and we hope that these examples will occasion new translational research by our readers.

Evaluating and Enhancing Value

Applied behavior analysts who work with individuals with autism and intellectual or developmental disabilities have developed techniques designed to determine the relative efficacy of therapeutic reinforcers (e.g., Fisher et al., 1992). These repeated-choice techniques, often referred to as *preference assessments,* were developed to determine quickly the most effective reinforcer that may be arranged in an operant contingency with adaptive, prosocial behavior (Poling, 2010). However, several studies have suggested that the results of these preference assessments may not predict responding when access to the reinforcer is increasingly constrained (e.g., DeLeon, Iwata, Goh, & Worsdell, 1997; Francisco, Borrero, & Sy, 2008), for example, when the schedule of reinforcement is thinned, and the reinforcer is gradually faded from use.

The results of a preference assessment do not parallel anything on a behavioral economic demand curve. Although the price of each reinforcer is very low in a preference assessment (e.g., simply pointing to the preferred item results in its delivery), the results of this assessment do not correspond to peak consumption (Q_0) because the participant is not given relatively unconstrained long-duration access to the reinforcer. If the participant was (e.g., the participant was placed in a room with all of the potential reinforcers and the time spent with each before the participant elects to leave the room was measured), then peak consumption would be assessed; however, as noted earlier, peak consumption is not predictive of essential value.

Valid assessments of essential value in applied settings may be impractical. Multiple long-duration sessions in which consumption of a single reinforcer is increasingly constrained would be time spent not addressing the individual's behavioral deficits. Moreover, little is known about the stability of the essential value of nonessential, nonaddictive reinforcers such as access to a particular toy or a specific snack. Thus, it is possible that after spending weeks assessing a complete demand curve for a cheese puff, the participant will no longer work for cheese puffs, but will work for a chocolate cookie. Thus, the demand-analysis methods outlined earlier in the chapter may have little utility in applied settings.

Addressing this concern, Roane (2008) suggested that PR schedules may hold promise for assessing something akin to essential value because they allow a rapid assessment of the highest price an individual will pay to obtain the next reinforcer. PR schedules are most often arranged so that the number of responses required for the next reinforcer increases between reinforcers. The last response requirement completed before the participant stops responding for a criterion period is the PR breakpoint, or the highest price that will be paid to consume the next reinforcer. Several human studies that have assessed both have suggested that PR breakpoints and P_{max} values are positively correlated (Bickel & Madden, 1999b; Jacobs & Bickel, 1999; Johnson & Bickel, 2006); however, two animal studies in which rats' PR breakpoints and P_{max} values were assessed with food, water, and a fat solution revealed a significant positive correlation in only one of four assessments (Madden et al., 2007a, 2007b). Furthermore, caution is warranted in using PR schedules among individuals who engage in maladaptive behavior maintained by escape (e.g., escape from the caregiver's demands to comply with instructions, engage in academic tasks, etc.; see Poling, 2010). For example, DeLeon, Williams, Gregory, and Hagopian (2005) found that signaled transitions from low to high reinforcer prices resulted in punctuated increases in maladaptive behavior.

Random-Ratio Schedules

A different tactic for arranging effective reinforcers is to focus less on determining the value of the reinforcer and more on arranging a schedule of reinforcement that yields inelastic demand for a preferred reinforcer (as identified by a preference assessment). Recall the results of the Madden et al. (2005) pigeon study in which demand for food under RR schedules was significantly more inelastic than was demand for the same type of food arranged according to equivalent FR schedules (Figure 8.8). If Madden et al.'s findings may be generalized to humans in applied settings, then arranging a RR schedule will meet the goal of identifying a contingency that better maintains behavior when access to the reinforcer is constrained. Suggestive evidence was reported by De Luca and Holbourn (1992) who arranged a variable-ratio schedule of reinforcement for obese children to pedal a stationary bike. When pedaling rates were compared with those of a different group of obese boys from a prior study under FR schedules (De Luca & Holbourn, 1990), peak rates were found to be higher under variable ratio than FR. Indeed, as reinforcer price was increased by increasing the variable-ratio schedule value, the obese boys' pedaling rates approximated those of nonobese boys. Notably, these peak rates were maintained over long periods of many sessions with the outcome that the obese children lost weight and improved their fitness.

Administering a RR schedule in an applied setting can be as simple as the participant's rolling a die or pulling a poker chip from a bag; if the criterion number or color is revealed, then the reinforcer is delivered. A potential additional benefit of the RR schedule is that it may decrease the probability of problem behavior associated with transitions from preferred to nonpreferred activities (e.g., McCord, Thomson, & Iwata, 2001). When pigeons transition from signaled low to high prices under a FR schedule, they pause for inordinate periods of time before beginning work on the FR (Perone & Courtney, 1992); these pauses can be accompanied by aggressive behavior in pigeons (e.g., Kupfer, Allen, & Malagodi, 2008). However, a recently completed study revealed that scheduling food reinforcers according to a RR schedule ameliorated these maladaptive pauses (Brewer, Williams, Madden, & Saunders, 2012). The translational value of these findings will await empirical evaluation with humans in applied settings.

Applied Implications of Substitutes and Complements

In our earlier discussion of open and closed economies, we noted that the essential value of a reinforcer is diminished when a perfect or partial substitute reinforcer is available either concurrently or after the experimental session. This has important implications in applied settings in which behavior occurs in a context of choice in which substitute reinforcers are either concurrently available or will soon be available. At least one applied study enrolling individuals with intellectual or developmental disabilities has reported results consistent with laboratory studies of open and closed economies (Roane et al., 2005): When a perfect substitute was available after sessions in which reinforcers were obtained according to a PR schedule (open economy), within-session consumption was lower than when these reinforcers were unavailable (closed economy). The implications of this are obvious: If therapeutic reinforcers are to establish and maintain adaptive behavior, they will be more effective if access to perfect substitute reinforcers is strictly contingent on engaging in the adaptive behavior.

Similarly, when substitutes are available concurrently, the marketplace is opened, and therapeutic reinforcers must compete with those that maintain problem behavior. Shore, Iwata, DeLeon, Kahng, and Smith (1997) turned this analysis on its head, reasoning that the reinforcer maintaining problem behavior would be less effective if it was placed into a competitive marketplace in which substitute reinforcers were concurrently available (see McDowell, 1988, for an identical suggestion derived from Herrnstein's 1970 matching law). This technique is particularly useful when the therapist does not control the reinforcer maintaining the problem behavior. In the Shore et al. study, three children with intellectual or developmental disabilities engaged in self-injurious behavior that was maintained by the stimulation produced by the injurious act. Beyond preventing self-injury through restraint, the therapist cannot control this consequence. Thus, Shore et al. made available a low-price reinforcer (an item identified by a preference assessment) hypothesized to function as a substitute. In all three cases, self-injurious behavior was substantially reduced when the substitute item was available. In a subsequent condition, the price of the substitute was increased by increasing the effort expended to physically manipulate the substitute item. Consistent with the demand law, these price increases reduced consumption of the substitute item and, suggestive of a bidirectional substitute relation, increased self-injurious behavior.

Other investigators have examined functional similarity as a characteristic of reinforcers that interact as substitutes (DeLeon et al., 1997; Tustin, 1994) in people with intellectual or developmental disabilities. DeLeon et al. (1997) constructed demand functions for two individuals with intellectual or developmental disabilities in which the price of two concurrently available reinforcers increased progressively and identically across phases of the analysis. At low prices (FR 1–FR 1), the participants consumed each of the available reinforcers about equally. However, as prices increased (FR 2–FR 2, FR 5–FR 5, etc.), a clear preference sometimes emerged for one of the stimuli over the other. This preference emerged only when the two available commodities were functionally similar (e.g., cookie and cracker), not when they were functionally dissimilar (e.g., cookie and 30-second access to a mechanical toy). These investigators concluded that the simultaneous price increases magnified small differences in preference that remained undetected when costs were low and that demand for the lesser preferred similar stimuli was more elastic than that for the lesser preferred dissimilar stimuli because physically similar commodities, sharing functional properties, are more substitutable. That is, when two commodities are functionally similar, the individual can exclusively consume the more preferred item without suffering deprivation for the shared form of stimulation. When the reinforcers are functionally dissimilar, however, exclusive consumption of one deprives the person of the form of stimulation provided by the other (i.e., exclusively choosing the toy deprives the individual of any appetitive reinforcers).

Two points can be made by integrating the findings of the Shore et al. (1997) and DeLeon et al. (1997) studies. For simplicity, we refer to the reinforcer that maintains the problem behavior as R_{prob} and the reinforcer that substitutes for $R_{prob,}$ and reinforces an appropriate, alternative response, as R_{sub}. When demand for R_{sub} is elastic, and assuming that R_{prob} substitutes for R_{sub}, then we would expect problem behavior to reemerge when the price of R_{sub} is minimally increased (as it did in the Shore et al. study). The reemergence of problem behavior will also happen when demand for R_{sub} is inelastic, but it will not happen until the price of R_{sub} is increased more substantially. The elasticity of R_{sub} is important because in applied settings it is often impractical to deliver R_{sub} after every appropriate alternative response. Thus, progressively intermittent use of R_{sub} is common in these settings, and one should be prepared for R_{prob} to substitute for R_{sub} when the price of R_{sub} is increased. Second, if R_{prob} is functionally similar to R_{sub}, then this will render more elastic demand for R_{sub} (DeLeon et al., 1997) which, as noted in our first point, will further increase the probability of problem behavior reemerging when minimal constraint is placed on consumption of R_{sub}. Taken together, for some individuals the optimal substitute for R_{prob} may be one that has a high essential value but is functionally dissimilar from R_{prob}.

Consistent with this analysis, in the treatment of escape-maintained problem behavior some researchers have arranged to reinforce compliance with a reinforcer that does not share any apparent functional qualities with escape, that is, a reinforcer that would be expected to function as an economic independent. For example, some researchers have successfully reinforced compliance with an edible reinforcer and have reported that edibles more effectively reinforce compliance than escape (DeLeon, Neidert, Anders, & Rodriguez-Catter, 2001; Lalli et al., 1999; Piazza et al., 1997). A question of interest in the current discussion concerns the frequency of escape-maintained problem behavior when the price of the edible reinforcer is increased, for example, when schedule thinning is implemented to make the intervention more practical. Because escape presumably does not substitute for the edible, one might expect demand for the edible to be more price inelastic than if compliance were reinforced with escape. One would also expect to see problem behavior reemerge at lower prices when the therapeutic reinforcer is escape than when it is an edible. Said less technically, and from the client's perspective, "If the therapeutic reinforcer is escape, why would I comply with several task requests to earn a break? I can get the same thing by engaging in problem behavior." When the therapeutic reinforcer is an edible for which there are no available substitutes, then engaging in problem behavior is not a viable alternative.

This hypothesis was tested in an unpublished study by DeLeon et al. (2009). The study compared three treatments of escape-maintained problem behavior in five individuals with intellectual disabilities. Across all three treatments, problem behavior produced a 30-second escape from task demands, whereas task completion resulted in access to (a) a substitute for escape (i.e., a 30-second break), (b) a small edible but no break, or (c) a choice between (a) and (b). A PR schedule increased the price of the therapeutic reinforcer until problem behavior increased to at least 50% of baseline. In four of the five participants, arranging a nonsubstitutable therapeutic reinforcer yielded less problem behavior as the price of that reinforcer increased.

The applied utility of complementary relations between reinforcers is largely untapped. The two general strategies are as follows. First, identify the reinforcer maintaining the problem behavior (functional analysis), and then attempt to identify consequences that may function as complements to that reinforcer. For example, if problem behavior is maintained by escape, then one might look for complementary conditions that increase the value of escape. That is, in applied settings escape involves escape from a nonpreferred setting followed by a transition to another setting. What is that other setting? Is it enhancing the value of escape? Can it be eliminated?

The second general strategy is used when one is attempting to enhance the value of a therapeutic reinforcer. Is it possible to make available a noncontingent complementary good that will increase the essential value of the therapeutic reinforcer? For example, if chips are the reinforcer, will the noncontingent availability of chip dip increase the ability of chips to maintain behavior? If attention is the reinforcer, will noncontingent access to social activities (e.g., playing a game) enhance the essential value of attention?

CONCLUSION

The application of microeconomic theory to conceptualizing and understanding operant behavior as consumer choice has brought new measures (e.g., total consumption) and variables (e.g., substitute and complementary reinforcer relations) to the science of behavior analysis. Most of these investigations have been conducted in laboratory settings, but the topics studied in these settings (e.g., drug seeking and drug taking) have always been less than a half-step away from application. The potential of behavioral economic principles to influence behavior in applied settings in important ways should be clear from this chapter and the beginnings of work being done in these settings today. As the basic laboratory continues to reveal new functional relations, we look forward to the continued translation of these relations to bettering the human condition.

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Chapter 9

ENVIRONMENTAL HEALTH AND BEHAVIOR ANALYSIS: CONTRIBUTIONS AND INTERACTIONS

M. Christopher Newland

The heightened public awareness that environmental contaminants can act on the nervous system and have effects that appear in behavior presents a major challenge to behavioral scientists in all areas. They are being asked to conduct both hazard assessment (are there neurobehavioral effects of some chemical at any dose?) and risk assessment (what is the risk to a population at a specific level of exposure?) for behavioral effects that are not always well understood. The heavy metal lead provides an excellent example. Concern over lead poisoning lies in claims that it lowers scores on IQ tests, retards academic performance, and results in disruptive and even criminal behavior. The problems posed are daunting: How easy is it to detect a 5-point drop in scores on IQ tests? Can scientists predict these effects from experimental models using laboratory animals? Can they identify behavioral and neural mechanisms that account for these effects? What economic costs are incurred if the average IQ drops a few points, and how does this cost compare with that of reducing lead in the environment?

These concerns are reflected in policymaking. Federal legislation and regulation of toxic substances specifically include behavior, including schedule-controlled operant behavior, as a regulatory endpoint (Tilson, 1990). The inclusion of nervous system damage in general, and its behavioral manifestations in particular, represents a sea change in public concern over unintended exposure to chemicals. Where cancer has been (and still is) a significant concern, the recognition that adverse behavioral effects follow certain types of chemical exposure is increasing. These effects carry over into a large number of domains. Environmental contaminants, even at very low exposure levels, contribute to disorders across the life span, including developmental disabilities and the hastening of age-related impairments. Behavioral scientists' understanding of how this happens not only has public policy implications but can also inform them about the behavior and neurobiology surrounding these disorders.

WHAT IS NEUROTOXICOLOGY, AND WHY BEHAVIORAL TOXICOLOGY?

The term *environmental neurotoxicity* refers

> broadly to adverse neural responses to exposures to all external, extragenetic factors [including] occupational exposures, lifestyle factors, and exposures to pharmaceuticals, foods, and radiation. . . . It does *not* [italics added] refer merely to the toxic effects of chemicals that are present in the environments of air, water, and soil. (National Research Council, 1992, p. 9)

Although it is true that much of the work done under the term *neurotoxicology* concerns chemical exposure, this definition noted that it need not be limited to chemicals. Other events with behavioral

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consequences could fall under this definition, including closed head injuries, significant stressors or other traumas, or drug exposures. Behavioral scientists' knowledge of how to examine environmental neurotoxicants could certainly be applied usefully in these other areas.

Why *behavioral* toxicology? Just as "nothing in the nervous system makes sense except in light of behavior" (Shepard, 1994, p. 9), one can argue that nothing in neurotoxicology matters until behavioral consequences occur. Tiny changes in the processes of neurotransmission or the course of development do not raise concern until they are manifested in behavior. The important role played by behavior is seen not only in neurotoxicology but also in the neurosciences. Psychology, including the study of behavior, has been listed as one of the pillars of neuroscience, along with anatomy, physiology, pharmacology, and embryology (Kandel, 1991).

Behavioral toxicology, then, is the study of the behavioral expression of neurotoxic events. The core assumptions are that behavior is orderly and can be brought into the laboratory for study and that what occurs in the laboratory corresponds to what is seen in people. Insofar as neurotoxic effects become important when seen in behavior, behavior can be viewed as the way to answer the so-what questions that are inevitably posed about subtle changes reported by other disciplines.

The presence of psychological, neural, and public health sciences is part of what makes neurotoxicology so interesting. This area exemplifies an arena in which behavior analysis participates in an interdisciplinary attempt to understand the many determinants of behavior. Clues about neural and behavioral mechanisms of action derive from observations that, for example, a compound results in perseveration in behavior, disrupts dopamine in selected regions of the nervous system, and damages laminated structures like the frontal cortex and cerebellum, as does methylmercury (described in the Mechanisms and Interventions section later in this chapter).

Behavior analysts can benefit from this participation by learning more about influences on behavior or, as described later in the Human Testing section, links between conditioning principles and the sorts of behavior tapped by neuropsychological testing.

Another tactic that behavior analysts might learn is the extrapolation from small-scale studies to broader conclusions about public health. Many in behavior analysis are quite accustomed to small-*N* experimental design, but many discoveries in behavior analysis must be confirmed or applied on a much larger scale. The ability to scale up investigations will be key to the long-term impact of behavior analysis, and some ideas for doing so can be drawn from environmental neurobehavioral toxicology (see the Assessment of Risk section).

SCOPE OF THE PROBLEM

In 1984, the National Research Council estimated that more than 65,000 chemicals were in production. Barely any information was available on the overwhelming majority of these chemicals, even those whose structure suggested significant potential for toxicity and that were high priority, that is, used in commerce at a rate exceeding 1 million pounds (500 tons) per year. About 12 years later, the Environmental Protection Agency concluded that there were about 15,000 new chemicals but, as noted by the Environmental Defense Fund, the understanding of them has not improved (Roe, Pease, Florini, & Silbergeld, 1997). Even among high-priority chemicals, the problem of toxic ignorance is severe. Of these chemicals, only 33% have undergone any neurotoxicity testing, and 10% have undergone testing for developmental neurotoxicity (Roe et al., 1997).

How many are neurotoxic? How many accelerate aging or disrupt development? We do not know, but we do know what kinds of problems these chemicals might cause. About 10% of boys in the U.S. population are estimated to have attention-deficit/hyperactivity disorder, and many of these cases can be linked to environmental contaminants (Visser & Lesesne, 2005). Between 3% and 25% of cases of attention-deficit/hyperactivity disorder have been attributed to environmental contaminants alone or in combination with parenting, drug use, or other lifestyle factors (Landrigan, Kimmel, Correa, & Eskenazi, 2004). (When gasoline was leaded, this number would have been much higher.) The costs of these effects are difficult to estimate, but they are certainly large (Koger, Schettler, & Weiss, 2005). The economic benefits of attending to environmental causes of behavioral deficits can be seen in recent estimates of the impact of removing lead from gasoline. This single act has been estimated to have resulted in a halving of violent crime (Reyes, 2007) and of the number of individuals eligible for a diagnosis of mental retardation (Nevin, 2009), and many have argued that further action may have even greater benefits (Gilbert & Weiss, 2006). The addition of lead to gasoline in the 1930s imposed a massive societal cost, one that was difficult to detect in comparison with chemicals that cause functional deformities or cancer.

THE CHALLENGE

Behavioral toxicology has sometimes been viewed, somewhat derisively, as "high-dose pharmacology." In fact, the opposite is true, at least with respect to environmental neurotoxicants, which is why the design of behavioral procedures that are sensitive and informative is both challenging and important. Figure 9.1, from a symposium on the future of neurotoxicology (Weiss et al., 2008), illustrates the issue of dose. The top panel shows an idealized quantal dose–response relationship that might arise from a laboratory study. Two effects are shown: a subtle effect (e.g., the proportion of animals whose lever-press rates declined) and a more severe effect (e.g., severe, overt effects or even death).

Sensitivity varies across individuals, with a portion of the sample showing effects at a dose of 20 units (e.g., 20 micrograms per kilogram per day) and others showing no effect until the dose exceeds 80 units. Subtle effects occur at lower doses than severe effects, but in this example at least, the right end of the curve showing subtle effects overlaps with the left end of the curve that shows overt pathology or death: A dose of 100 or so is barely effective for some, but highly toxic for others.

Now consider the experimental design problem in determining the leftmost open data point, a dose that affects 5% of the sample population. Following a rule of thumb that at least five cases are required to detect such a data point, one would need 5/.05 = 100 subjects to detect effects in these sensitive individuals. Rarely, however, will one know when designing a study which combination of variables (e.g., dose, gender, age, strain) will contribute to individual susceptibility. Detecting such a level can lead to very large and complex study designs, as illustrated in the ED01 study, designed to detect the dose that caused cancer in 1% of the experimental group and that required many thousands of subjects to do so (Gaylor, 1980).

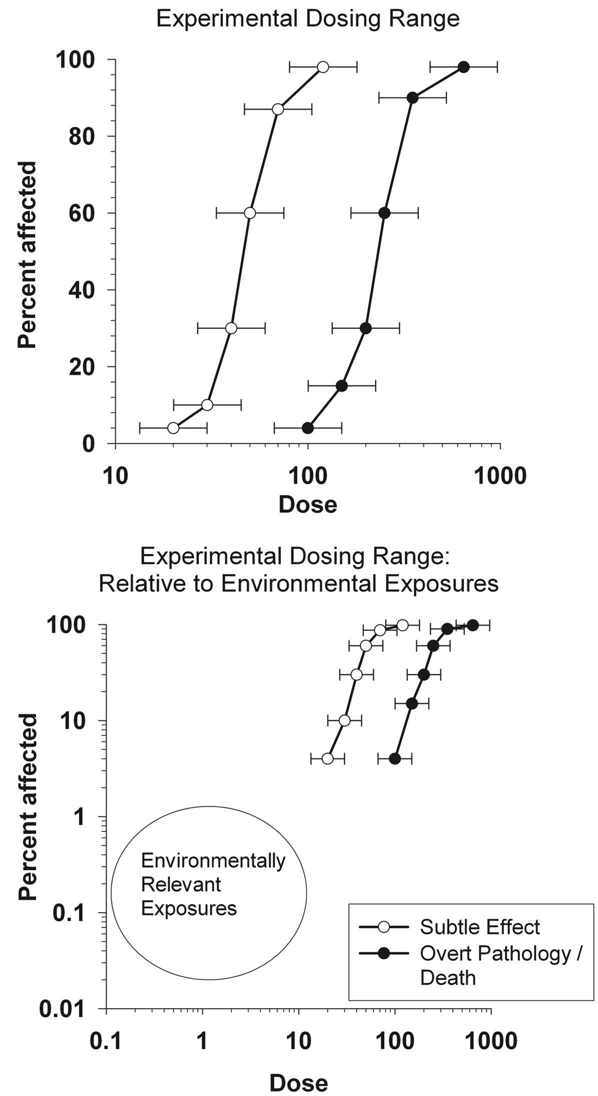

FIGURE 9.1. A dose–response relationship showing percentage of the population affected on the vertical axis, seen from a laboratory (top) or an environmental (bottom) perspective. From "The New Tapestry of Risk Assessment," by B. Weiss, D. Cory-Slechta, S. G. Gilbert, D. Mergler, E. Miller, C. Miller, . . . T. Schettler, 2008, *NeuroToxicology*, *29*, p. 889. Copyright 2008 by Elsevier. Adapted with permission from Elseiver.

However, a dose that causes a large effect in 5% of the population could be a national disaster.

Environmental exposures are typically well below those used in the laboratory, as illustrated in the bottom panel, in which the top dose–response relationships are replotted against what may be environmentally relevant exposures that lie to the left of those usually studied in the laboratory.

The best solution is to use behavioral measures that are sensitive and that reflect effects seen in exposed populations. That is where behavior analysis has played an important role. By exploiting the law of effect, behavior analysts can gain control over variability across subjects and within subjects and design sensitive preparations and measures that reflect either integrated nervous system activity or specific neural processes. This control enhances experimental and statistical power to detect important effects.

A second solution, implemented in tandem with the development of sensitive measures, is low-dose extrapolation, in which a structured estimate (i.e., an educated guess) is generated to estimate what occurs at environmentally relevant exposures. Biostatistics, using data from experimental models and epidemiological investigations, plays a large role here (described in the Assessment of Risk section). A third, untenable solution is to give up and say that scientists cannot deal with such low exposure levels because they lead them too far from the data. This approach, which ignores valuable quantitative information that is available, has led to such "solutions" as the Delaney clause (a 1958 amendment to the Food, Drug, and Cosmetic Act of 1938) that forbade any chemical that caused cancer at any dose from entering the marketplace. Such an approach would be a nightmare if applied to neurotoxicity because some doses will often have a behavioral effect. This approach has been criticized because it imposes large barriers to the development of safer chemicals, such as pesticides, while leaving older, unsafe ones "grandfathered" into approved use (O'Donoghue, 1994).

CONDITIONED AND UNCONDITIONED BEHAVIOR

One question that sometimes arises is, "What do we mean by *behavior*?" A useful definition can be difficult to come by, but a functional classification of behavior is helpful. One approach is to distinguish between conditioned and unconditioned behavior. *Conditioned behavior* typically refers to responding that has been brought under the control of Pavlovian or operant conditioning. This approach takes time but also refines behavior, reduces variability, and helps to identify important influences. *Unconditioned behavior* might be viewed as anything else and can include spontaneous locomotor activity or even elementary forms of learning such as habituation. Because observations of unconditioned behavior can be accomplished quickly, such behavior can be helpful in the early stages of an investigation or, for example, the identification of a range of effective doses.

Screening Versus Advanced Applications

There are two classes of approaches to behavioral testing. The first entails systematic screening techniques such as the Functional Observational Battery (Moser, 1989). These techniques permit a rapid assessment of the range of doses that are likely to be active and the functional domains (sensory, motor, central, peripheral, autonomic, etc.) that might be at risk (see also Vorhees, 1987). The procedures involve spending a small amount of time with any one animal and can be conducted with minimal investment in equipment or (animal) training time. They can be labor intensive and relatively insensitive to subtle effects, and sometimes they require subjective judgment because the results may show high levels of variability.

The second class, advanced applications, permits the examination of behavioral and neural mechanisms of action that may be especially sensitive to low exposure levels and careful description of sensory, motor, or cognitive effects. These designs frequently apply reflexive, Pavlovian, or operant conditioning techniques to develop a specialized behavioral preparation. Reflexive techniques, including sensitization, habituation, and prepulse inhibition (the reduction of acoustic startle by the delivery of a faint tone immediately preceding the onset of a startle tone), have helped to describe ototoxicity (Crofton, 1990; J. S. Young & Fechter, 1983). More advanced conditioning techniques are flexible, sensitive, and highly informative, but they often require extensive animal training time (especially approaches using operant behavior), equipment and software investments, and sophisticated investigators.

Investments in developing advanced applications result in significant returns in sensitivity, quality control, specificity, and with respect to basic research, advancing scientists' understanding of behavior. Consider a widely used procedure such as the fixed-interval (FI) schedule of reinforcement. Under this straightforward procedure, a reinforcer (usually a small bit of food) is delivered after the first response to occur after some fixed amount of time has passed. Thus, under a fixed-interval (FI) 2-minute schedule, the first response after 2 minutes has passed results in reinforcement. A predictable response pattern occurs: low responding early in the interval and a progressively increasing rate as the interval times out. This procedure is an example of schedule-controlled operant behavior, mentioned previously.

An extensive literature on FI schedules of reinforcement can be found in the basic experimental analysis of behavior and the behavioral pharmacology literatures. Therefore, behavioral scientists know what kind of behavioral pattern to expect when this procedure is implemented appropriately (Zeiler, 1977). They also know about the sensitivity of the FI schedule to drug exposures and what patterns of behavior a class of drugs is likely to produce (Branch, 1984, 1991; Kelleher & Morse, 1968). Building on such orderliness yields quantifiable behavioral measures, a consistent pattern across settings and species, and known sensitivity to drugs and chemicals (Newland, Pennypacker, Anger, & Mele, 2003). Successful transfer of technology is more likely when important characteristics of the product can be quantified, when the conditions required for its reproduction can be clearly identified, and when its successful reproduction can be verified (Pennypacker, 1986). This is certainly true of procedures built on conditioning principles. For the FI schedule, for example, measures of response rate and temporal patterns can be examined as quality control measures to ensure that the procedure has been appropriately implemented.

Operant Behavior

Operant behavior, which includes what is commonly referred to as voluntary behavior, involves a three-term operant contingency of reinforcement (antecedent stimuli, response, consequence). Briefly, a response is an operant if its consequence changes its subsequent likelihood of reoccurrence in the same or a similar context. The context can be present at the time of the response (discrimination or generalization, e.g.), or it may have occurred in the immediate or distant past (remembering). The elements of the three-term contingency do not exist in isolation, but the role of different elements can be emphasized to refine the behavioral procedure. Figure 9.2 illustrates how this understanding of the

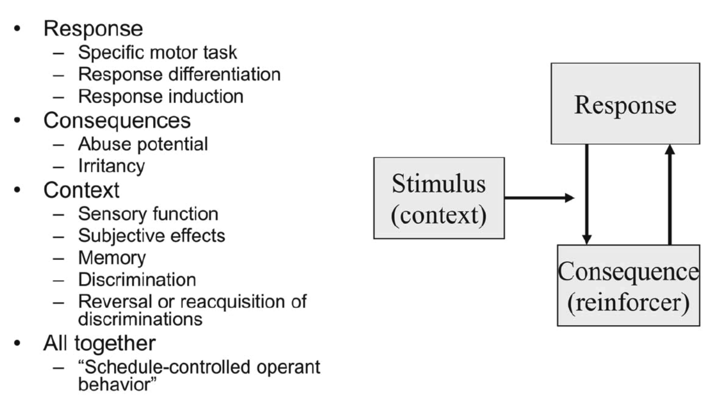

FIGURE 9.2. A schematic representation showing the three-term operant contingency (right) and how a focus on selected elements might be applied in behavioral evaluations (left).

elements of behavior can be applied in behavioral toxicology.

The operant. An operant may be a lever press, but a complex response pattern can itself be placed under a reinforcement contingency. The study of motor function often entails gaining control over precise physical characteristics of the operant, such as its position, the force with which it is executed, its speed, or its duration. These physical dimensions of the operant can be manipulated if one understands the principles of reinforcement. Fowler, McKerchar, and Zarcone (2005) have examined force, rhythmicity, and precision of forelimb forces and tongue movements in rodents. In the water fountain task, rats press with a predefined force on a small disk while licking from a water dispenser that is activated by the application of force. By exerting precise control over the force exerted by the forelimb, this task makes it possible to detect tremor, dystonias, or extrapyramidal effects of neuroleptic drugs and potentially other neurotoxicants.

In the licking task, rats lick an apparatus that measures the force, rate, and periodicity of licking. The task is appealing because it is simple to establish, is sensitive, and yields important information about neurobehavioral function quickly. For example, older rats lick at a slower rate than control rats, and this effect is associated with correlations among lick rate, total licking, and dopamine content in striatal and nigral dopamine (Stanford, Vorontsova, Surgener, Gerhardt, & Fowler, 2003). In other studies, lick force has revealed strain differences and distinguished between neuroleptics that act at D1 versus D2 dopamine receptor systems (Wang & Fowler, 1999).

Even higher order characteristics of operant behavior can be investigated. For example, under a second-order schedule of reinforcement (i.e., a schedule of a schedule), a complex response unit is itself placed under an overall schedule of reinforcement (Marr, 1979). Thus, match-to-sample (Newland & Marr, 1985), a subordinate schedule (Marr, 1979), or the production of a response chain (Thompson & Moerschbaecher, 1978, 1979) can be reinforced under, for example, overarching FI or fixed-ratio (FR) schedules, and the rate and timing of the appearance of these complex units demonstrate schedule-typical patterns. Thus, second-order schedules can be imposed to study how a complex operant emerges or how its structure falls apart with repeated exposures to neurotoxicants (Newland, 1995, 1997).

Antecedent stimuli. Discrimination processes per se can be sensitive indicators of neurotoxic exposure, but we use the testing of sensory systems as an example of the application of this component of the three-term contingency. Sensory testing in a verbally competent person is relatively straightforward: Ask whether someone can see the letter *E* on a Snellen chart or hear a tone through headphones, and increase or decrease the difficulty of the discrimination according to the answer. Doing so in a nonhuman animal can be accomplished by bringing operant responding under the control of an exteroceptive (external) antecedent stimulus so that the traditional psychophysical techniques can be used (Maurissen, 1995; Rice, 1994). The animal is asked, for example, to produce one response in the presence of the stimulus and a second response in its absence. Somatosensory systems have been examined by detecting sensitivity to a vibrating stimulus applied to the finger (Maurissen, 1990; Rice & Gilbert, 1995). Auditory sensitivity can be examined by bringing behavior under the control of the presence or absence of a tone (Burbacher, Grant, Gilbert, & Rice, 1999; Pryor, Dickinson, Feeney, & Rebert, 1984; Rice & Gilbert, 1992). Visual acuity, flicker fusion, contrast sensitivity contours (Burbacher, Grant, Mayfield, Gilbert, & Rice, 2005; Merigan, Wood, Zehl, & Eskin, 1988; Rice & Hayward, 1999a), and pain (Weiss & Laties, 1970) have all been examined using operant techniques. The study of pain is especially interesting because of the development of the tracking, or titration, procedure. Here, the animal's responding controls the stimulus magnitude, so there is no exposure to distressful pain and pain can be studied ethically in individual animals (Laties & Wood, 1984).

Behavior can be brought under the control of an interoceptive (private) stimulus, too. The aforementioned study of pain (Laties & Wood, 1984) is one example. Others can be drawn from the drug discrimination literature (see Volume 1, Chapter 23, this handbook). Just as a response can be brought under the control of whether a light is on or off, so too can a response be brought under the control of whether, say, a drug or biologically inactive vehicle has been delivered. Here, pressing the right lever may be reinforced after a presession drug injection, and pressing the left lever may be reinforced in different sessions after vehicle injections. Such procedures have provided solid behavioral evidence that many organic solvents share interoceptive stimulus properties with sedative hypnotics such as oxazepam, ethanol, or pentobarbital (Rees, Knisely, Balster, Jordan, & Breen, 1987; Rees, Knisely, Breen, & Balster, 1987). These observations are supported by observations at other levels of analysis. For example, oxazepam, ethanol, and pentobarbital all promote activity of the GABAA receptor. Drugs that act at other receptors produce different interoceptive effects, as reported in animal studies of drug discrimination procedures and by humans when asked to describe how they feel. Many subjective effects can be examined using similar methods, including hunger (Corwin, Woolverton, & Schuster, 1990), withdrawal from drugs (Emmett-Oglesby, Mathis, Moon, & Lal, 1990), or anxiety-like states (Leidenheimer & Schechter, 1988).

More nuanced subjective characteristics of chemicals can be examined in humans by drawing on subjective effects questionnaires such as those used to detect subjective effects profiles in human drug users (Preston & Bigelow, 1991). Environmental or occupational neurotoxicants have been linked to self-reports of apathy, depression, excitability, hallucinations, irritability, nervous tension, fatigue, and restlessness (Anger, 1986). Self-report measures such as the Profile of Mood States may provide sensitive measures of low-level exposure when presented in an objective manner, as with testing behaviorally active drugs. Measures such as these are sensitive to cultural differences and degree of education, so care must always be taken in interpreting such data (Anger et al., 2000; Rohlman et al., 2000).

Two examples illustrate the use of subjective effects questionnaires in behavioral toxicology. The first is the use of the Profile of Mood States in the study of manganese neurotoxicity. When manganese is encountered at high exposure levels (e.g., in unsafe mining operations), it produces a neurological syndrome that includes significant motor deficits (Barbeau, Inoue, & Cloutier, 1976; Couper, 1837) and *locura manganica,* which is characterized by mania, hypersexuality, and various subjective effects (Cotzias, 1958). Some of these subjective effects have been captured using the Profile of Mood States, which is similar to measures used to document subjective effects of behaviorally active drugs. People exposed to manganese occupationally, and who also reported drinking more than 400 grams of alcohol per week, reported a constellation of subjective states including anger, vigor, confusion, tension, depression, and fatigue (Bouchard et al., 2003). In a second example, also using the Profile of Mood States, an organic solvent, trichloroethylene, was reported to have effects that resembled those of ethanol (Reif et al., 2003). In this case, exposure was low level and environmental because it occurred in drinking water as a result of contamination of a municipal water supply.

Consequences. As noted earlier (and shown in Figure 9.2), the consequences of behavior influence its future occurrence and establish the importance of the context in which behavior occurs. As with drugs (A. Young & Herling, 1986), toxic substances can serve as both reinforcing and aversive consequent events. For example, in addition to being neurotoxic, some solvents also have significant abuse potential when exposure is voluntary (Wood, 1979). These compounds include toluene (the ingredient that supports glue sniffing), gasoline, and inhalants. This reinforcing property of solvents increases the likelihood that individuals will be exposed to them.

Irritancy is also a toxic property that is readily amenable to behavioral evaluation and quantification in laboratory settings (Wood, 1981; Wood & Coleman, 1995). Examples of irritants include air pollutants such as ozone or particulate matter. The presence of an irritant diminishes the reinforcing activity of exercise, and heavy exercise may increase the irritant properties of ozone (J. L. Tepper, Weiss, & Cox, 1982). In one study, rats ran in a wheel, nose poked to obtain access to a food reinforcer or, in a third experiment, lever pressed for an opportunity to run in a wheel (J. S. Tepper & Weiss, 1986). These conditions were implemented under various concentrations of ozone. Low concentrations decreased wheel running but not the relatively less effortful nose-poking response when these responses led to food reinforcement. Thus, high-effort exercise was selectively sensitive to this irritant. However, when nose poking provided access to the running wheel, the ozone diminished nose poking, indicating that this irritant diminished the reinforcing efficacy of wheel running.

In a series of studies that could serve as a textbook example of how to study the psychophysics of irritancy, Stern, Laties, and their colleagues asked whether rats could detect electric fields, what variables influence their detection, and whether these fields were aversive by giving rats control over the presentation of these fields (here, microwaves or 60-hertz electric fields; Stern, 1980; Stern, Margolin, Weiss, Lu, & Michaelson, 1979). They showed that 60-hertz fields could be detected in a strength-related fashion, with reliable detection at strengths of 10 kilovolts per meter (Stern, Laties, Stancampiano, Cox, & de Lorge, 1983). A series of control conditions revealed that rats were discriminating the electric field rather than artifacts coincident with field onset. For example, by varying field strength, producing a sham exposure in a different area of the same room, covering the chamber with bronze mesh, or shaving the rats, the experimenters showed that the behavior was related to electric field strength and not to vibration, noise, or the stimulation of fur. A later study examined the aversive properties of electrical fields by providing rats with the opportunity to remove an electrical field with a lever press. The rats failed to do so, even at field strengths that were clearly discriminable (Stern & Laties, 1989). The same rats readily terminated ambient illumination using the same lever-press procedure. Thus, in rats, commonly occurring electrical fields do not function as aversive stimuli or as negative reinforcers.

After framing questions of irritancy and abuse in terms of the consequences of behavior, the behavior-analytic approach to examining these particular stimulus properties becomes clear. This is a first step toward providing a picture of the conditions under which a toxicant (such as toluene) will be also be abused or toward identifying the effects of environmental or occupational exposure to irritants such as electric fields (putatively), ozone, airborne contaminants, or solvents.

Pavlovian or Classically Conditioned Behavior

Pavlovian (or classical or respondent) conditioning provides a mechanism whereby a behaviorally neutral conditional stimulus comes to elicit a response by virtue of its pairing with a biologically significant unconditional stimulus. These processes tap sensorimotor, memorial, and emotional response domains and can be long lasting (Stanton, 2000). Otherwise mysterious phenomena, such as multiple-chemical sensitivity syndromes, may be understood by applying an understanding of Pavlovian processes (Siegel & Kreutzer, 1997). Pavlovian techniques have further advantages for testing chemicals because conditioning occurs relatively quickly and can be readily applied in a wide range of organisms, including invertebrates.

Fear conditioning techniques such as conditioned suppression, as well as passive and active avoidance, use classically conditioned pairings between a neutral stimulus and shock delivery to elicit a freezing or avoidance response. These approaches are often used when the goal of behavioral assessment is to examine functional deficits quickly, with commercially available equipment. Passive and active avoidance chambers can be purchased commercially, and investigators can implement procedures with relatively little training in behavioral techniques. Although the procedures can address questions about whether behavioral or conditioning effects occur at some exposure level, the appropriate design of experiments and interpretation of data requires considerable sophistication. Caution should taken with respect to exclusive reliance on Pavlovian procedures because these behavioral processes tap neural pathways different from those tapped by operant techniques, so general statements about effects of a chemical on learning can be misleading or even wrong.

Flavor aversions arise through a pairing of a novel taste (or odor plus taste) and the delayed onset of nausea or illness. This approach has been used to detect adverse effects of toxicant exposure, effects that may otherwise be difficult to detect. In one popular approach, a test compound is administered (often by injection) shortly after the animal has consumed a novel flavor, such as saccharine. Normally, rats will consume water sweetened with saccharine quite readily. However, even a single pairing of certain contaminants substantially reduces subsequent intake of the flavored water. The classes of chemicals that show this effect include pesticides (Mitchell, Long, Wilson, & Kallman, 1989), polychlorinated biphenyls (Nishida, Farmer, Kodavanti, Tilson, & MacPhail, 1997), metals (MacPhail, 1982; Peele, Farmer, & MacPhail, 1988; Peele, MacPhail, & Farmer, 1986), and organic solvents (Balster & Borzelleca, 1982).

Pavlovian mechanisms may underlie clinical syndromes or neurotoxic actions that would otherwise be difficult to understand, including sensitization to irritants or other chemicals, conditioned allergic responses, and flavor aversions (Siegel & Kreutzer, 1997). Sensitization that results from repeated exposures to an irritant may have Pavlovian components that may even result in conditioned allergic reactions. In experimental models, sensitivity to airborne irritants such as formaldehyde has been conditioned (Chang, Steinhagen, & Barrow, 1981; Song, Tschirgi, Swindell, Chen, & Fang, 2001). By virtue of being paired with an irritant, a previously benign stimulus will elicit the same response as the chemical itself (Alarie, 1966). Thus, Pavlovian processes can enhance sensitization to a chemical or condition sensitivity to otherwise unnoticeable stimuli that can appear at random and without an individual's awareness. For these reasons, authors have noted that such conditioning processes might result in phenomena such as multiple-chemical sensitivity (Siegel & Kreutzer, 1997; Song et al., 2001; Wood & Coleman, 1995).

An appreciation of behavioral processes and their links to neural processes can enhance the value of a laboratory model, even if that model does not reproduce the most salient clinical signs. For example, a functional similarity in the acquisition of a conditioned eyeblink response has been demonstrated by some children diagnosed with autism and by rats exposed during development to a drug, valproic acid, that disrupts the closure of the neural tube. Children with autism (Sears, Finn, & Steinmetz, 1994) and valproic acid exposed rats (Stanton, Peloso, Brown, & Rodier, 2007) both showed a rapid acquisition and higher amplitude response during eyeblink conditioning. This behavioral similarity, coupled with similar neuroanatomical changes in both the model system and children, has been used to develop a much-needed rodent model of some aspects of this disorder and to raise the disturbing possibility that prenatal environmental exposures might increase the risk of developing autism (Rodier, 2002).

SUSCEPTIBILITY, MODIFIERS, AND THE BEHAVIOR OF INDIVIDUAL SUBJECTS

Neurotoxic substances do not affect all individuals in the same way. In fact, individual susceptibility is the rule, not the exception. Individuals vary in genetic predispositions, nutrition, exposure to drugs, stressors or other contaminants, environmental enrichment (or its absence), and age, to name just a few effect modifiers that have been identified. The incorporation of individual susceptibility into data or graphical analytic strategies can be highly revealing. Behavioral toxicologists trained in behavior analysis or behavioral pharmacology traditions have brought to the discipline a deep respect for the behavior of individuals and the methods for studying it. This respect has often resulted in highly sensitive preparations and a set of methods that permits the detection of individual susceptibility, a phenomenon that can easily get lost in presentations of group means surrounded by error bars.

An example can be seen in the work of Cory-Slechta and colleagues, who have exploited their laboratory model of environmental lead exposure. Lever pressing under an FI schedule of reinforcement was used as the behavioral marker of neurotoxicity (Cory-Slechta, Weiss, & Cox, 1985). The selection of the FI schedule was based on its ability to produce characteristic patterns of responding across a variety of species as well as on its selectivity and sensitivity to drugs (Cory-Slechta, 1990;

Newland et al., 2003). Figure 9.3 shows FI-maintained lever pressing among a group of lead-exposed rats (bottom panel) and unexposed control rats. Most unexposed rats showed a gradual increase in response rate to about 10 to 20 responses per minute over 40 sessions. Two unexposed rats, however, showed aberrantly high rates of about 40 to 60 responses per minute. Lead exposure inverted this distribution. A drinking water exposure regimen, which models human exposure, increased the number of animals showing abnormally high rates of responding. This elevated rate has been replicated many times in rats, as well as in monkeys, mice, pigeons, and sheep, at environmentally relevant exposure levels (Cory-Slechta, 1986b). Across species and laboratories, lead produces an inverted-U relationship between response rate and dose, similar to that seen with psychomotor stimulants and characteristic of the hyperactivity seen with human lead exposures (Cory-Slechta, 1986b).

Close examination of data from individual subjects frequently identifies responders and nonresponders. The next question is, "Why are these individuals differentially sensitive?" Answers can lie in genetic predisposition or environmental modifiers. Recent studies have identified stress as an important modifier of lead's neurotoxicity. Using the behavior under the FI schedule as the key marker of neurotoxicity, researchers have shown that stress during life and, remarkably, stress that occurs via the mother during gestation, has a lifelong influence on lead's neurotoxicity (Virgolini, Rossi-George, Lisek, et al., 2008; Virgolini, Rossi-George, Weston, & Cory-Slechta, 2008). The stressors used were

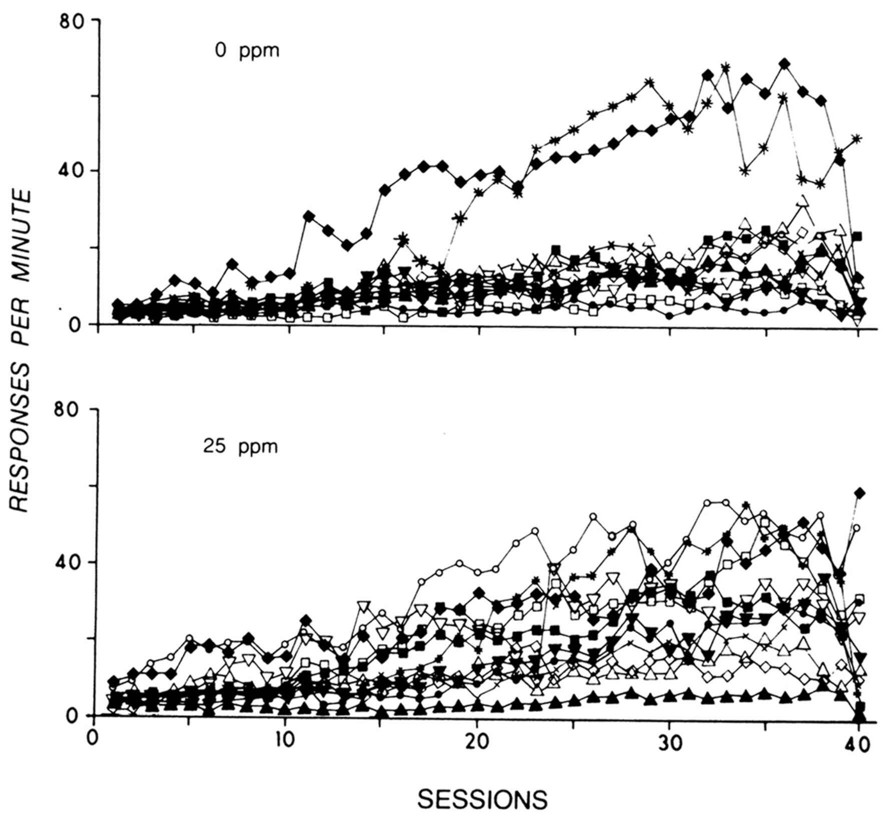

FIGURE 9.3. Individual response rates from rats lever pressing under a fixed-interval schedule of reinforcement. Each line represents a different animal. Animals were exposed to lead (0 or 25 parts per million in drinking water), beginning at weaning. Lead exposure increased the distribution of response rates so that more animals responded at high response rates. From "Performance and Exposure Indices of Rats Exposed to Low Concentrations of Lead," by D. A. Cory-Slechta, B. Weiss, and C. Cox, 1985, *Toxicology and Applied Pharmacology*, *78*, p. 294. Copyright 1985 by Elsevier. Reprinted with permission from Elsevier.

intermittent, infrequent, and relatively modest; they included temporary restraint, placement in water, and placement in a novel arena. The implications are significant, of course, because the results have shown that stress may exacerbate the impact of lead and these methods offer a way to bring it into the laboratory for investigation.

The impact of stressors on lead's neurotoxicity described in these experimental results might help explain the role of variables such as socioeconomic status in modifying the effects of exposure. Lead exposure, for example, had a more significant impact on children of low socioeconomic status than on middle-class children (Bellinger, Leviton, Waternaux, Needleman, & Rabinowitz, 1988). It takes only a little speculation to hypothesize that stressors associated with low socioeconomic status might contribute to lead's neurotoxicity. If a stressful, and perhaps by implication an impoverished, environment can amplify lead's neurotoxicity in humans, then perhaps an enriched one may blunt it (Bellinger et al., 1988). In a recent study (Guilarte, Toscano, McGlothan, & Weaver, 2003), rats were exposed during gestation and lactation to lead at levels that produced detectable behavioral toxicity. After exposure ended, some rats were raised in an enriched environment and others in a standard rodent cage with no enrichment. Even though the enrichment came after exposure, it was effective in preventing the expression of lead's behavioral toxicity in these animals.

HUMAN TESTING

The ultimate goal of studies with nonhuman species is predicting the impact of exposure on people, including predicting effects at the relevant exposure levels, the types of effects that occur, and the impact of risk factors such as age, gender, genetic makeup, or stressors.

The traditional approach to human testing entails standard neuropsychological tests (Rohlman, 2006; Rohlman, Lucchini, Anger, Bellinger, & van Thriel, 2008). As noted in these reviews, these tests are readily available and their psychometric properties (e.g., reliability and validity) have usually been characterized. Because they are typically developed for the diagnosis of serious clinical syndromes, however, they may be insensitive to neurotoxicants, especially at exposure levels that produce subtle dysfunction that falls below the threshold for clinical intervention. Moreover, performance on neuropsychological tests is frequently affected by competence in English, or in the language in which the test was developed, which raises difficulties in studying, for example, populations outside of the United States or immigrant populations in the United States. Finally, because the development of these tests is rarely informed by the nonhuman animal literature, linking performance on these tests with that experimental literature can be quite difficult.

A second approach is to develop new tests for detecting the effects of environmental or occupational exposure to chemicals. These tests will optimally be sensitive to subtle deficits in several functional domains (e.g., motor, cognitive, sensory) and will be applicable to diverse populations. One component of test development in this area is the incorporation of procedures that are also used in animal studies (Davidson et al., 2000; Fray & Robbins, 1996; Paule, Forrester, Maher, Cranmer, & Allen, 1990; Robbins et al., 1998; White & Proctor, 1992), an approach that has numerous advantages. Any test that successfully measures effects in similar functional domains in human and nonhuman species will advance efforts to form empirically sound linkages between human and animal studies, bodies of literature that often make little reference to each other. Thus, reaction-time measures, memory tests, sensory tests, or even tests such as repeated acquisition of behavioral chains can be used to test people with varying levels of linguistic competence as well as laboratory animals (Paule, Chelonis, Buffalo, Blake, & Casey, 1999). Although such development efforts may be time consuming, they are necessary if researchers are to link chemical exposure to nervous system effects or scale up from small-scale implementations to widespread testing (Newland et al., 2003). Such linkages will also contribute favorably to the ability to predict human effects from animal studies, to derive experimental models from discoveries by epidemiologists, and to identify relevant mechanisms of action.

Whatever the approach, many elements have to be in place for effective test development and interpretation. One is an appreciation of behavioral mechanisms that allow for a parsimonious account of responding (e.g., Branch, 1984; Marr, 1990). This element is crucial in the design of test batteries, especially when seeking to compare the results of studies with laboratory animals with those conducted with human populations. A second element is an understanding of the neural mechanisms underlying normal behavior and behavior impaired by chemical exposure.

An example of a research program that has been explicitly designed to compare human and nonhuman species has been underway for more than two decades at the National Center for Toxicological Research, a component of the Food and Drug Administration. Merle Paule and colleagues (Paule, 1990; Paule & Cranmer, 1990; Paule et al., 1990; Paule, Meck, et al., 1999) designed a test battery that they have implemented with humans, nonhuman primates, and rodents. All of the components of the test battery are standard operant procedures used in the animal laboratory. They include progressive-ratio schedules to evaluate motivation, temporal discrimination and differentiation to assess timing, incremental repeated acquisition to evaluate learning, delayed matching to sample to evaluate remembering, and others.

One outcome has been the ability to compare the performance of animals on commonly used procedures from the animal laboratory with that of adults and children on similar procedures. In one interesting extension, Paule, Chelonis, et al. (1999) compared the performance of people on these tests with their scores on an IQ test. Figure 9.4 shows that children's scores on the incremental repeated acquisition correlated well with scores on the Weschler Preschool Primary Scale of Intelligence tests. This correlation was high for the incremental repeated acquisition procedure. It was lower, but still nonzero, for discrimination (color and position), timing, and memory tasks, and the correlation with a motivation task (progressive ratio) was indistinguishable from zero. This result suggests that the IQ test and the incremental repeated acquisition tap some similar functions in humans and, because the other tests did not do so, that this is selective. By extension, this suggests, but certainly does not confirm, that

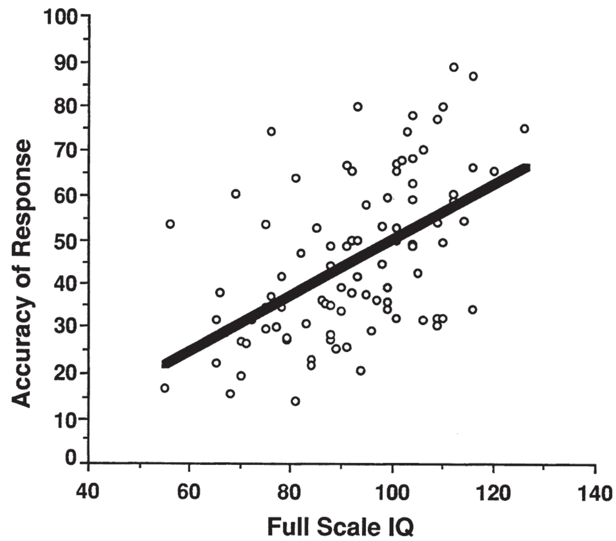

FIGURE 9.4. Correlation between score on an IQ test (Weschler Preschool Primary Scale of Intelligence) and accuracy of responding under an incremental repeated acquisition of behavioral chains procedure. The participants were typically developing children. From "Operant Test Battery Performance in Children: Correlation With IQ," by M. G. Paule, J. J. Chelonis, E. A. Buffalo, D. J. Blake, and P. H. Casey, 1999, *Neurotoxicology and Teratology, 21*, p. 227. Copyright 1999 by Elsevier. Reprinted with permission from Elsevier.

the incremental repeated acquisition task as implemented with animals may share some functional similarity with the IQ task. The simple conclusion might be that this suggests the validity of the incremental repeated acquisition task, but it is worth noting that this similarity also supports the validity of the IQ task.

Scores on traditional neuropsychological tests are heavily influenced by linguistic ability. If testing procedures can be developed that separate performance from language abilities or literacy, then it may be possible to broaden the array of populations that can be evaluated and to identify effects in non–English-speaking cultures. By drawing from an animal literature, one is necessarily developing tests that do not rely on linguistic competence.

Tests that draw from the traditional neuropsychological testing literature must often be implemented with people who have little experience with computers or other paraphernalia associated with clinical testing (Rohlman, Anger, et al., 2001; Rohlman, Bailey, Anger, & McCauley, 2001). This is important in environmental neurotoxicology because the groups with little experience are often those that experience the greatest exposures.

Rohlman, Anger, and colleagues at the Oregon Health Sciences University (Farahat, Rohlman, Storzbach, Ammerman, & Anger, 2003; Rohlman et al., 2003) launched a program of research designed to accomplish testing in a broad array of cultures. This group developed a computerized battery of tests to assess multiple functional domains and examined the tests' reliability, sensitivity, and validity. Although they did not explicitly compare humans and animals, as the group at the National Center for Toxicological Research did, some procedures that they used derived from approaches taken in the animal literature. In early implementations, they even examined ways to shape performance on these tests using only minimal verbal instructions (Rohlman, Sizemore, Anger, & Kovera, 1996). Accomplishing this would contribute to their goal of targeting populations whose reading skills or experience with computerized testing is minimal. Their attempt was successful, and as with animal studies, high levels of performance could be achieved without instructions or with only bare-minimum instructions. Reliance on pure shaping was ultimately judged to be too cumbersome, but the experience led to the development of a battery that could be administered with relatively little reliance on verbal instructions or previous experience with testing procedures. Anger, Rohlman, and their colleagues explicitly applied sound behavioral principles such as step-by-step training, competency training at each step of the procedure, and immediate and frequent reinforcement (Anger et al., 2001; Rohlman et al., 2000). They have compared the performance of groups from Egypt, Asia, South America, and the United States in populations that included the middle class as well as migrant laborers (Rohlman et al., 2000, 2003, 2008). These tests have been able to detect, for example, significant consequences of occupational exposure to pesticides among migrant laborers (Rohlman, Bailey, et al., 2001).

MECHANISMS AND INTERVENTIONS

The mechanism by which a neurotoxicant exerts its effects can lie at the behavioral level (e.g., a distortion in reinforcer efficacy), at the neural level (e.g., a disruption of dopamine neurotransmitter), or both. Mechanisms of action are closely linked to interventions designed to ameliorate or prevent neurotoxicity. The reverse process may be informative, too. The success or failure of an intervention can also be used to test hypotheses about the viability of the hypothesized mechanisms or to raise hypotheses about potential mechanisms.

The value of a behavioral mechanism is nicely illustrated by constraint-induced therapy, a behaviorally based set of interventions that works with a wide array of types of brain damage (described in Volume 1, Chapter 15, this handbook). Because of the large number of functional domains in which consequences shape behavior, a behaviorally based intervention can work with many different neural mechanisms of damage. Edward Taub, who developed constraint-induced therapy after his earlier animal studies of a similar phenomenon (Taub, Uswatte, & Elbert, 2002), described the importance of identifying behavioral mechanisms as follows:

> Because the mechanism of learned nonuse is behavioral in nature, it was reasoned that it ought to be independent of the source and nature of an injury, coming into operation whenever the appropriate contingencies of reinforcement exist in the early postinjury period. (Taub et al., 1994, p. 284)

To illustrate these points, we examine potential behavioral mechanisms linked to motor dysfunction, the role of reinforcement contingencies in perseveration and distortion of reinforcer processes associated with lead and methylmercury neurotoxicity, and the potential modulation of lead's neurotoxicity by environmental stressors.

Motor Deficits

Damage to the cerebellum, basal ganglia, motor cortices, and descending motor pathways all have effects that are expressed in the physical properties of the response (Newland, 1995, 1997). Signs of damage may range from subtle deficits in the precision of movement to outright paralysis or spasticity. The neural mechanisms underlying these effects and the manner in which their expression occurs in specific disorders are described in several texts on clinical neurology (e.g., Kandel, Schwartz, & Jessell, 2000; LeDoux, 2005).

Reinforcement contingencies can influence the recovery of motor function (Taub et al., 1994) as well as the expression of motor deficits. The expression of motor deficits is important in designing behavioral preparations for the sensitive detection of neurotoxicant exposure. For example, behavior under the FI schedule of reinforcement is very sensitive to lead exposure, whereas behavior under FR schedules is not (Cory-Slechta, 1986a, 1986b). Exactly the reverse is the case for exposure to compounds that disrupt motor function. Vigorous, high-rate responding such as that typical of ratio contingencies is difficult for an organism with motor deficits to produce, so the contingencies that produce such responding will be sensitive to neurotoxicants that disrupt motor function.

In one study (Newland & Weiss, 1992), monkeys were exposed to manganese, a metal that accumulates in the basal ganglia and that produces (at high doses) dystonic postures, gait disturbances, and tremor (Guilarte et al., 2006; Mena, Horiuchi, Burke, & Cotzias, 1969; Newland, 1999). Before exposure, the monkeys were trained to produce an effortful, rowing-type action through a 10-centimeter displacement against a spring that resisted movement with a force approximating the monkeys' body weight. Behavior was maintained under a multiple FR–FI schedule of reinforcement; in the multiple schedule, periods of exposure to the ratio and interval schedules alternated through the course of every session so their relative sensitivity could be compared directly within each animal.

With this effortful operant, very few responses occurred during the FI schedule: Rates were one to 10 responses per reinforcer, and they occurred at such a low and intermittent rate that responding was described as casual. The effects of manganese on FI responding were minimal and did not consistently change with continued exposure to the procedures. Unlike what is seen with lead, no rate increase occurred.

The results with the FR schedule were quite different. This schedule maintained a vigorous, high-rate pattern of thrusting and pulling on the response device with occasional incomplete responses that failed to meet the displacement criterion. The high-rate pattern persisted after manganese exposure, but close inspection of the microstructure of behavior showed increases in interresponse times and response durations, a pattern that was irreversible. A striking effect appeared in the number of incomplete responses. During the preexposure baseline, very few incomplete responses were seen, but on exposure this number immediately increased to several hundred times that seen during baseline, even as overall response rate showed little change. Over the course of several months, behavior adjusted somewhat to this impairment in the FR component. The energetic pattern of behavior typical of FR responding was still in place, but examination of the molecular structure of behavior revealed that this responding contained longer response durations, longer interresponse times, and many more incomplete responses than seen before exposure began. Because effects were noted in response topography but not in rate, these results also suggested that manganese exposure did not perturb motivational processes, even as it significantly disrupted motor capabilities (Newland, 1995, 1997). Other types of exposure, even those that affect other neural systems, could be expected to produce a similar pattern of behavioral effects.

Tolerance and Adjustment to Impairment

As with drugs, tolerance to neurotoxicants can occur via physiological or behavioral mechanisms. Behavioral tolerance, which may occur when the chemical effect results in a loss of reinforcement (Corfield-Sumner & Stolerman, 1978; Schuster, Dockens, & Woods, 1966), is specific to the behavior that occurs in the presence of the chemical and to the context in which the behavior is reinforced (Siegel, Baptista, Kim, McDonald, & Weise-Kelly, 2000; Smith, 1999). Thus, this form of tolerance can result in adjustment to impairment that is highly situation specific. It presents significant risk because it could make the impairment difficult to detect by a tester or by the very individual experiencing it, but it may disappear when the situation changes.

Bushnell and Oshiro (2000) investigated behavioral tolerance to the solvent trichlorethlyene using a signal detection task. Rats reported the unpredictable presence or absence of a 300-millisecond light flash by pressing one of two levers. As expected, trichlorethlyene exposure increased the false alarm rate, decreased the hit rate, and increased response latencies. Some rats (the "before" group) were then exposed to trichlorethlyene for 9 consecutive days while performing the task. Others (the "after" group) were given the same daily exposure regimen, but at the end of the session. The opportunity for metabolic or pharmacodynamic tolerance was present for both groups, but only the animals in the before group could develop behavioral tolerance. Within only 3 to 5 days of exposure, both the hit and the false alarm rates returned to baseline in the "before" group, whereas no such tolerance occurred in the "after" group. Moreover, when switched to a "before" condition on Day 10, those rats that had never performed the task while exposed to trichlorethlyene showed a similar pattern of impairment and recovery as the "before" group had earlier. This tolerance was specific to the signal detection portion of the task; little tolerance occurred to the increased latency. So in this experimental model, tolerance by a behavioral mechanism occurred to an attention deficit but not to a motor deficit.

Choice

Behavior does not exist in a monotonous, unchanging world with only one thing to do. Instead, people live in a world of alternatives that are constantly in flux, and somehow their behavior tracks these different possibilities. A huge number of studies with unimpaired people and animals have shown that behavior is allocated among competing reinforcers in an orderly and predictable manner: Response or time allocation approximately matches, or slightly undermatches, the allocation of reinforcers obtained from these alternatives (Davison & McCarthy, 1988; de Villiers, 1977; Kollins, Newland, & Critchfield, 1997; also see Volume 1, Chapter 14, this handbook). So in an experimental setting, if 75% of the reinforcers derive from one response alternative, then approximately 65% to 75% of the available time will be spent on that alternative. This process arises and changes with remarkable speed as reinforcement contingencies change (Davison & Baum, 2000; Mazur, 1992). Because only one thing can be done at a time, this ability to strike the right balance among different possibilities is an important component of adaptive behavior.

Prenatal exposure to lead or methylmercury (Newland, Yezhou, Logdberg, & Berlin, 1994) and developmental exposure to a specific polychlorinated biphenyl congener in rats (Rice & Hayward, 1999b), but not to a polychlorinated biphenyl mixture in monkeys (Rice & Hayward, 1999c), disrupted the allocation of behavior in a laboratory model of choice called the *concurrent schedule of reinforcement*. In one study (Newland et al., 1994), squirrel monkeys were exposed to lead or to methylmercury during gestation and tested when they were several years old. Two response levers were made available to the monkeys, and the reinforcer ratio (left-lever reinforcers:right-lever reinforcers) was changed every few weeks. The main dependent measures were the ratio of responding on the two levers (left-lever responses:right-lever responses) for each reinforcer ratio, the slope of the matching law function (a measure of sensitivity to the choice ratios), and response bias toward one lever (for additional details on the generalized matching law analysis, see Volume 1, Chapter 10, this handbook).

Gestational exposure to a high dose of lead significantly disrupted the orderly allocation of behavior between the response alternatives. Even after extensive training, these monkeys' responding was relatively insensitive to the availability of reinforcement. Instead, they showed extreme response biases and undermatching, with too much behavior on the lean response alternative (which produced relatively little reinforcement) and too little behavior on the rich alternative.

The monkeys exposed to lower doses during gestation resembled control monkeys when behavior reached a steady state, but they took longer to arrive at this steady state. This effect was detected only because the acquisition of choice was carefully tracked after each new condition (with a new reinforcer ratio) was imposed. Monkeys exposed to fairly low doses of lead required twice as many reinforcers as unexposed monkeys to complete half of the transition from one concurrent schedule to a new one.

The possibility that behavioral toxicity included a diminished sensitivity to small changes in reinforcer allocation was tested by making the reinforcer ratios more extreme, a therapeutic intervention that was conducted with particularly insensitive monkeys. For three sessions, the reinforcer ratio was changed from 4:1 to 999:1, so that virtually all reinforcers were obtained from the nonpreferred alternative, and then it was returned to 4:1 (Newland et al., 1994). With this intervention, behavior shifted. After this intervention was imposed, subsequent responding interestingly tracked smaller changes in the relative availability of reinforcers. So, this "behavior therapy" had a long-lasting impact on subsequent behavior.

Perseveration and Behavioral Flexibility

Reversal procedures are used to examine behavioral flexibility. For example, responding on one of two response levers is reinforced, and responding on the other is not. After stable responding occurs, the contingency is switched so that the lever that produced reinforcement no longer does so, but pressing the other lever does. Analyzing the behavior that these procedures engender has considerable value because it is among the phenomena included in the construct of executive function (Dalley, Cardinal, & Robbins, 2004; Robbins, 1996; Robbins et al., 1998). *Behavioral flexibility* refers to the ability of behavior to change in response to a change in the relationship between a stimulus and the response–reinforcer relationship (Robbins et al., 1998). A review of executive function or even of the specific area of behavior flexibility is beyond the scope of this chapter, but a behavioral analysis of at least one task that makes up the construct is possible and may help clarify the behavioral mechanisms underlying it. Perseveration (behavioral or cognitive inflexibility) is suggested to be the outcome of a distortion in the impact of reinforcing events.

Figure 9.5 illustrates a key effect from a recent study of methylmercury's developmental neurotoxicity. Rats were exposed during gestation to methylmercury using an exposure regimen designed to model human environmental exposure. As adults, and long after exposure ended, the rats were trained to perform a response-initiated spatial discrimination procedure. Pressing a lever on the back wall of an operant chamber resulted in the insertion of two choice levers on the front wall. Pressing one of two choice levers was immediately reinforced (with a sucrose pellet), and pressing the other lever initiated an intertrial interval but no reinforcer. After three consecutive sessions with at least 85% accuracy, the discrimination was reversed (an intradimensional shift or discrimination reversal), so that responses to the previously reinforced lever had no consequences, and responses to the previously unreinforced lever now produced pellets (Paletz, Day, Craig-Schmidt, & Newland, 2007; Reed et al., 2006).

Exposed rats resembled control rats in their growth rates and the appearance of developmental landmarks. As adults, they were all alert and responsive. Nearly all exposed rats were indistinguishable from control rats in their initial acquisition of the spatial discrimination, but a striking effect of developmental methylmercury exposure appeared on the first reversal. Figure 9.5 shows the number of correct responses, errors of commission (incorrect responses), and errors of omission (incomplete trials) for an unexposed rat (top panel), a typical exposed rat (middle), and an informative outlier (bottom). As illustrated in the top two panels, the initial acquisition occurred similarly for exposed and unexposed rats. Methylmercury's effects became evident on the first reversal (Session 5 in the top panel and Session 6 in the middle panel). The control rat reversed quickly. The exposed rat (middle panel) did not make its first response on the newly correct lever until after six complete sessions. This rat first perseverated on the originally correct lever, and then response rates dropped such that more incomplete trials than outright errors occurred. Once the newly correct lever was pressed (and that response was reinforced), the rest of the reversal and all subsequent reversals transpired quickly.

The bottom panel of Figure 9.5 shows an extreme case that illustrates a behavioral intervention imposed to overcome neurotoxicity. Here, the initial acquisition occurred slowly (atypically), but note the first reversal. After 17 sessions and more than 1,000 trials into the reversal with only one correct lever press, a therapeutic intervention was

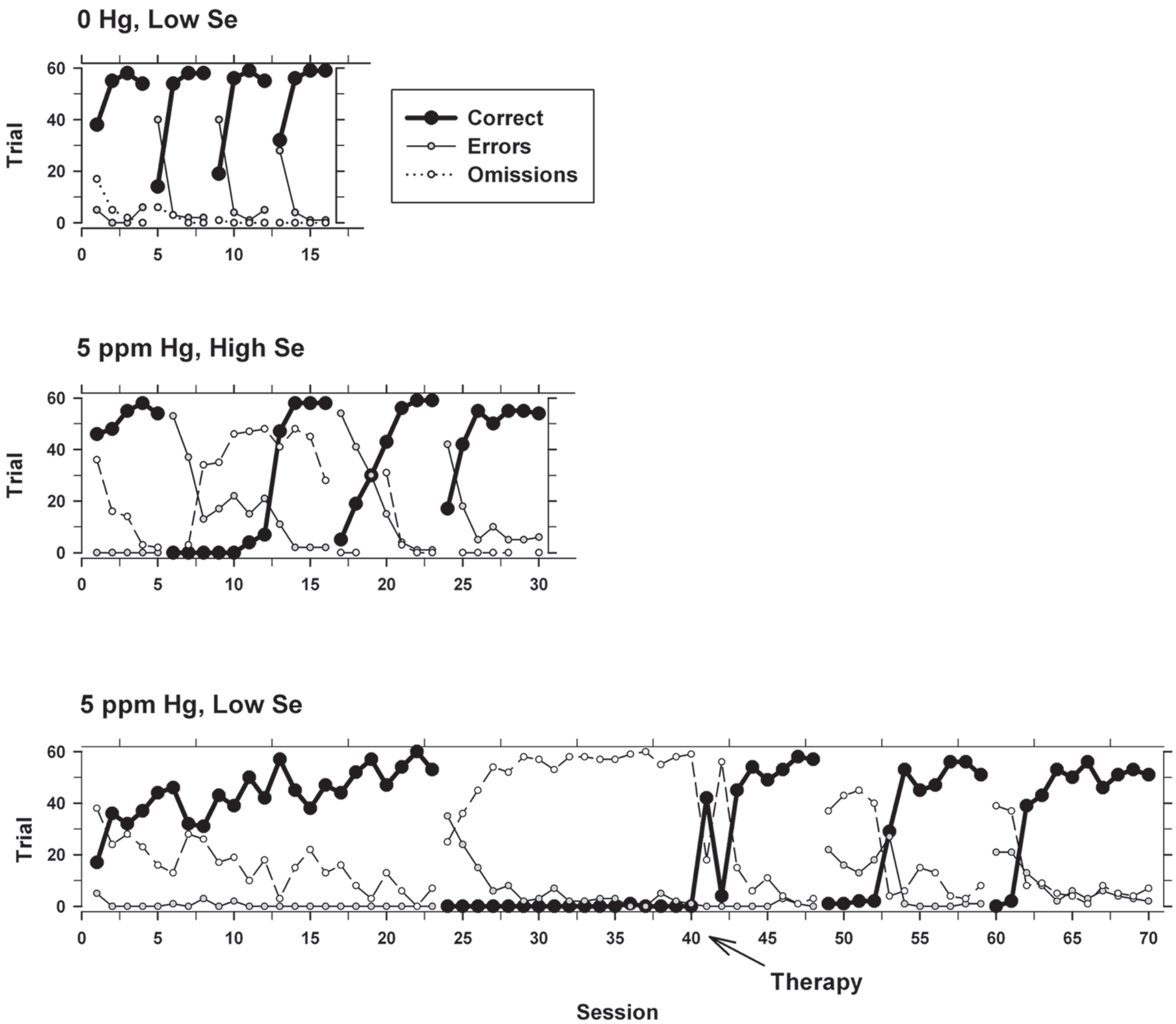

FIGURE 9.5. Representative graphs showing the acquisition and three reversals of a spatial discrimination for a control rat (top panel) and a typical case of a rat exposed via maternal consumption of 5 parts per million of mercury as methylmercury during gestation (middle). The bottom panel shows an extreme case of an exposed rat. Two levels of dietary selenium (Se) were included in the original publication. A reversal occurred after three consecutive sessions at 85% accuracy. At Session 41 (labeled *Therapy*) in the bottom graph, the incorrect lever was removed, and only then did (reinforced) correct lever-pressing commence. From "Gestational Exposure to Methylmercury and Selenium: Effects on a Spatial Discrimination Reversal in Adulthood," by M. N. Reed, E. M. Paletz, and M. C. Newland, 2006, *NeuroToxicology*, 27, p. 725. Copyright 2006 by Elsevier. Adapted with permission from Elsevier.

imposed: The incorrect lever was removed for one session (Session 41). The rat started pressing the correct lever and soon met the criterion for a reversal, and subsequent reversals transpired more rapidly.

Prenatal methylmercury exposure disrupted discrimination reversals regardless of the physical dimension of the discrimination. Exposed rats both perseverated on the previously reinforced response and failed to sample the other lever that was available. For both visual discrimination reversals (Paletz et al., 2007) and spatial discrimination reversals (Paletz et al., 2007; Reed et al., 2006), exposed rats required more reinforcers (and more sessions and trials) to complete the reversal than did unexposed rats. This effect was selective. Exposure had no effect on the acquisition of a spatial discrimination (the bottom panel of Figure 9.5 represents an exception to the general case), it did not disrupt the shift from a spatial discrimination to a visual discrimination (an extradimensional shift), and it did not disrupt the reacquisition of a spatial discrimination after training the visual discrimination. This result is interesting because these classes of procedures apparently reflect the function of different regions of the frontal cortex. Reversal procedures, but not extradimensional, set-shifting procedures, are sensitive to lesions of the orbitofrontal cortex (reviewed in Dalley et al., 2004).

How might these effects be understood? Subsequent work with methylmercury-exposed rats pointed to a distortion in the impact of reinforcers and disrupted dopamine function. Progressive-ratio schedules were used to examine reinforcer efficacy of the same type of sucrose pellets in littermates (Paletz, Craig-Schmidt, & Newland, 2006; Reed, Banna, Donlin, & Newland, 2008). These schedules progressively increase the response requirement until responding stops. They can be used to compare the abuse potential of drugs that are self-administered. A drug that supports a large ratio is considered more reinforcing than one that supports a smaller ratio (Stafford, LeSage, & Glowa, 1998). Rats exposed to methylmercury during gestation tolerated much higher ratios than unexposed animals, suggesting a greater reinforcer efficacy in these treated rats. This finding suggested that an inappropriately large impact of previous reinforcement contingencies can make behavior rigid and insensitive to change (reviewed in Newland, Donlin, Paletz, & Banna, 2006; Newland, Paletz, & Reed, 2008).

Drug challenges conducted with littermates of some of the rats discussed in the preceding paragraph (Reed & Newland, 2009), as well as with rats exposed separately but similarly (Rasmussen & Newland, 2001), showed enhanced sensitivity specifically to dopamine reuptake inhibitors. In separate studies, rats exposed to methylmercury during gestation were trained to lever press under a schedule that arranged differential reinforcement for high response rates (Rasmussen & Newland, 2001) or an FI schedule (Reed & Newland, 2009). In both studies, response-rate changes were observed at lower doses of dopamine agonist for the exposed rats than for the control rats, effects that provide behavioral relevance to observations that developmental methylmercury exposure interferes with the formation of the frontal cortex (Barone, Haykal-Coates, Parran, & Tilson, 1998), a region that participates in reinforced behavior and choice (Dalley et al., 2004; Robbins, 1996; Schultz, Dayan, & Montague, 1997; Schultz, Tremblay, & Hollerman, 2000). These observations support a hypothesis that developmental methylmercury exposure disrupts the development of dopamine receptor systems, with effects that are reflected as disrupted choice, perseveration, and resistance to change (Newland et al., 2006, 2008).

If a behavioral mechanism is identified, then a diagnosis of deficits in executive function or cognitive flexibility is at best a beginning, not an end, because the mechanism suggests functional interventions for treatment. As examples, neurotoxicant-induced disruptions in the allocation of behavior between two alternatives on a concurrent schedule could be overcome by enhancing the discrepancy between the two schedules; persistence in a previously reinforced response in a reversal procedure can be treated by making that response impossible to perform by removing the lever. In each of these examples, distortions in the impact of reinforcing events were overcome by rearranging the environment such that the correct response was certain to occur and be reinforced.

ASSESSMENT OF RISK

Behavioral toxicology has contributed to the formation of evidence-based, data-driven policymaking. Data derived from basic laboratory studies, human epidemiological studies, and studies in private-sector laboratories conducted to register a chemical for a specific use all drive policymaking at several levels of government. Sometimes this process begins with laboratory studies conducted with animals and always includes an attempt to estimate the effects on a population of people at low levels of exposure. A recently developed approach, traceable to a seminal suggestion by Peter Dews (1986), is of interest here (a) because it explicitly incorporates information on the effects of a chemical on individuals into this decision-making process and (b) because it unites good experimental design with the economic interests of the company or industry sector that is affected by policy decisions.

As illustrated in Figure 9.1, experimental studies and often even epidemiological or workplace studies frequently entail exposure levels that are higher than commonly experienced. Researchers want to know about the risks associated with these low environmental levels, but a challenge arises when attempting to extrapolate these risks from the high exposure for which they have data. A formalized process has evolved to account for the uncertainties that always exist in the extant data while estimating the *reference dose,* defined as the dose that is unlikely to have an adverse effect (Committee on Improving Risk Analysis Approaches Used by the U.S. EPA & National Research Council, 2009; Committee on the Institutional Means for the Assessment of Risk to Public Health, 1983; Rice, Schoeny, & Mahaffey, 2003). An early stage of this formal process is the identification of a point of departure, which is the highest dose used in an empirical study that is without effect or the lowest dose that has an effect. The distinction is an important one that carries significant public health and economic consequences. If the relevant studies guiding the risk assessment process do not include a no-effect dose, then the lowest dose that shows an effect is divided by 10 to estimate that no-effect level while (one hopes) erring on the side of protecting the public health.

Much of the safety testing of chemicals is conducted by the company seeking to profit from that chemical, but a conflict of interest may exist because low environmental or occupational exposures can be expensive to maintain. If the lowest dose tested disrupts function, then this company could face the burden of having to keep levels even 10-fold lower than if that dose had been a no-effect level. Thus, there is an incentive to find a no-effect dose. This dose can be identified using a study that is carefully designed to home in on that dose precisely or, a cynic might note, by using a poorly designed or underpowered study that fails to detect an effect, even if exposure levels are high. Poorly implemented studies often have excessive variability so a conclusion of no effect may occur even at relatively high exposure levels. Thus, economic incentives could work against good experimental design to the detriment of the public health.

An approach to estimating effects at low exposure levels, called *benchmark dose techniques,* has been designed to limit extrapolation beyond the data (Crump, 2002; Glowa & MacPhail, 1995; Slikker & Gaylor, 1995). A by-product, perhaps even a second goal, of the benchmark-dose approach is to reinforce good experimental design by adding value to the design of experiments with little variability in the data (i.e., small error bars). If a point of departure is determined in standard-error units rather than by the absence of a statistically significant effect, then an incentive is provided to design studies that produce low variability. The result is good experimental design, a no-effect level that is reasonable, and a process that has greater credibility.

These approaches do this by using error estimates to identify a benchmark dose that, for example, produces a 10% reduction in function in 5% of the population (Crump, 2002). The benchmark is viewed by policymakers as a no-effect level. The standard deviation becomes the yardstick, and the benchmark dose is determined by counting standard-deviation units from some point of departure (this is an oversimplification used to illustrate the process). When much information is available about low-dose exposure, identifying a benchmark dose might be accomplished by modeling a low-dose effect as a normal distribution and estimating effects on the fifth percentile. Well-designed experiments result in more precise estimates of critical doses (Slikker & Gaylor, 1995).

When dose–effect curves are available from individual animals, then an even more powerful approach is available (Bogdan, MacPhail, & Glowa, 2001; Dews, 1986; Glowa & MacPhail, 1995). The data making up the dose–effect curve for individual animals can be used to model the universe of possible dose–effect curves that would result from those data. This modeling is accomplished with a procedure that reassigns data points to virtual subjects iteratively, to produce thousands of virtual dose–effect relationships. A curve is fitted to each reassigned dose–effect relationship. From the thousands of curves generated, select key points (e.g., the dose that produces a 10% reduction in response rate for 5% of the subjects) can be estimated. This process in illustrated in Figure 9.6. Here, four hypothetical animals are administered a range of seven doses, plus vehicle, and response rates are expressed as a percentage of noninjected control rates. Data from four subjects are visible over the vehicle dose, but filled

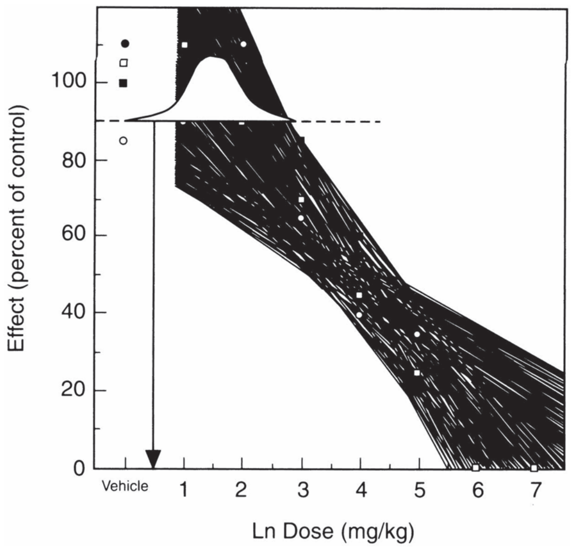

FIGURE 9.6. Hypothetical dose–effect curves taken from individual animals are shown as separate points (only open symbols are visible throughout the data space). Response-rate reductions are determined for individual animals as a function of (natural) log of dose of some neurotoxicant. Individual points can be seen over Vehicle, but lines obscure some data points over the various doses. The points are randomly reassigned to virtual subjects, and an individual dose–effect relationship is generated for each reassignment; each relationship is shown as an individual line. The family of lines is used to estimate important indicators. For example, the dashed line represents a 10% reduction in function. The vertical line points to the dose that would produce such a reduction in 5% of the population of curves. From *Neurotoxicology: Approaches and Methods* (p. 781), by L. W. Chang and W. Slikker Jr. (Eds.), 1995, San Diego, CA: Academic Press. Copyright 1995 by Elsevier. Reprinted with permission from Elsevier.

individual data points are obscured by the lines in the figure. Each dose–effect relationship is represented by a single straight line, which is the result of a linear regression applied to a virtual subject. The bell-shaped distribution counts the number of curves that cross that horizontal line (10% reduction in rate) at a particular dose. This distribution can be used to estimate the dose that produces a 10% reduction in, say, 5% of the population, as shown by the vertical line (for details, see Glowa & MacPhail, 1995). An approach to this process using operant behavior can be seen in Wood and Cox (1995).

We have described ways to derive estimates of tolerable human exposures from controlled laboratory studies of animals and from epidemiological studies of exposed humans, and the U.S. Environmental Protection Agency does just this. This process is open and transparent so that all stakeholders can examine the relevant studies, the assumptions entering the analysis, and the outcome. The process can be updated as new data come to light. Assessments undergo intensive peer review by disinterested scientists, and the results are published in the open literature, often as books published by the National Research Council or as reports available from the U.S. Environmental Protection Agency or the Agency for Toxic Substances and Disease Registry. We mention the process here because its spirit, if not its specifics, might be of value to behavior analysts seeking to translate experimental or clinical studies into public policy. The approach described here might be informative for those policymaking procedures that are transparent, quantitative, and data driven.

HIGH THROUGHPUT

As noted in the introductory comments, more than 80,000 chemicals are registered for commercial use (Roe et al., 1997), and adequate information about toxicity is available for only a tiny fraction of even the high-production chemicals. The chemicals that we know something about include those that have been studied in academic or government labs as well as some, such as pesticides and organic solvents, for which testing is required as part of the process of registering the chemical for commercial use. High-throughput techniques for identifying and characterizing neurotoxicity are required to test the universe of untested chemicals. As of this writing, the answer to the question posed earlier in the chapter, "Can we do behavioral testing more rapidly?" might be "We recognize that this is an important question and we are trying to do so, but we're not there yet." The issue is that rapid assessments frequently have more errors. A "miss" (missing a hazardous chemical) can have significant and long-lasting public health consequences. A false alarm, however, can be economically costly to a company producing the chemical and could even block the marketing of, say, safer pesticides, flame retardants for furniture, or plastic bottles, to name just a few of the compounds that have entered public discussions.

Earlier in this chapter, it was noted that behavior plays a crucial role in neurotoxicity because behavioral measures can address the so-what question, that is, they can reveal the relevance of small changes in the nervous system. This key assumption is held by many who study function, including behavioral toxicologists, but it is not universal. A recent publication by the National Academy of Sciences has called for a shift in emphasis to high-throughput techniques involving the structure of genes, the formation of proteins, or the activity of small networks of cells and cell lines (National Research Council, 2007). These in vitro preparations permit the expeditious study of many chemicals in the environment. This step is necessary, but it cannot stand alone. The difficulty with relying too heavily on such isolated systems was noted in a different publication that has specifically included behavioral assessment as a component of the assessment of risk (Committee on Improving Risk Analysis Approaches Used by the U.S. EPA & National Research Council, 2009). To the extent that behaviorists add value to the scientific understanding of neurotoxic events, behavioral toxicology will continue to have an influence. How scientists add value will be different in the future than it has been in the past.

The future of behavioral toxicology will entail high-throughput screening and alternative testing, but the form that it will take is still emerging (National Research Council, 2007). This issue presents vexing, and interesting, problems for neurotoxicology and behavioral toxicology. No genetic marker and no collection of neural indicators exist for most known behavioral consequences of exposure. One cannot reproduce the FI schedule in a dish. We could note many reasons, but one is that behavior often reflects the full and integrated functioning of the nervous system. At some point, high-throughput screening will entail behaving organisms, but the behavior may be simple and the organism may be a nonmammalian species such as drosophila (Hirsch et al., 2003; Liu, Vinson, Abt, Hurt, & Rand, 2009), zebrafish, or zebrafish larvae (e.g., MacPhail et al., 2009; Peterson et al., 2008; Weber et al., 2008). Traditional laboratory animals such as mice might be incorporated, but only with highly automated and rapid testing procedures. The challenge is to be, at once, quick and effective.

We mention this issue here because it is a challenge faced by many other areas in which basic principles of behavior are being translated into specific applications. They cannot afford the luxurious, highly detailed studies conducted in scientific laboratories. Studies that do succeed will, ideally, be quick, informative, and yet still grounded in a science of behavior. At this point, how this challenge will be addressed is unclear, but it must be met. The next generation of behavioral toxicologists will face it.

ECONOMIC AND SOCIAL COSTS

In its short history, behavioral toxicology has already generated large social and economic benefits, and it is likely to produce more. For example, Reyes (2007) noted that

> estimates indicate that the reduction in lead exposure in the 1970s is responsible for a 56% drop in violent crime in the 1990s and will likely produce further declines in the future, up to 70% drop in violent crime by the year 2020. (p. 36)

Lead removal has also been estimated to cut in half the number of children who receive formal diagnoses of intellectual disability and are therefore eligible for special education (Nevin, 2009), confirming a prediction made two decades ago (Needleman, 1990; Weiss, 1988). A recent attempt to quantify educational costs in a single school district was undertaken in a study of the role of lead exposure and student:teacher ratios on student performance assessments in New Orleans schools (Zahran, Mielke, Weiler, Berry, & Gonzales, 2009). Zahran et al. (2009) reported, as have many others, that lead decreased performance and that lowering the student:teacher ratio improved it. They noted that doubling the number of teachers in the district, a huge expense, would be necessary to compensate for the intellectual damage caused by lead. In fact, actually removing existing lead was estimated to be far less expensive than paying the salaries of the additional teachers, to say nothing of additional buildings. These are the types of costs that were avoided by removing lead from gasoline.

The broader economic benefits of exposure to a neurotoxicant such as lead can be very difficult to estimate. One provocative approach has been taken by building on the correlation between IQ test scores and earnings (Schwartz, 1994). We mention it here because of the earlier discussion linking scores on IQ tests with procedures that build on animal studies, such as the incremental repeated acquisition of behavioral chains (Paule, Chelonis, et al., 1999). Because IQ scores and income are correlated, estimating how much of a loss in earnings results from a 1-point drop in score on an IQ test should be possible. Multiplying this estimate by the U.S. population would yield an estimate of the larger financial burden associated with lead exposure. One estimate was described by Schwartz (1994) and updated by Salkever (1995). Salkever held that a loss of 1 IQ point translates into a 1.9% and 3.2% loss of lifetime earnings for men and women, respectively (lead exposure has a greater economic effect on women than on men). It also translates into an approximately $7.5 billion gain (in constant dollars) in lifetime income for each reduction in blood lead of 1 microgram per deciliter for a single birth cohort (Salkever, 1995). The total savings can be determined by noting that this is only a single birth cohort and that only the effect of reducing blood lead 1 microgram per deciliter is described. The national average blood lead level was about 15 micrograms per deciliter in 1979, which fell to less than 1.9 micrograms per deciliter by 2007 (Advisory Committee on Childhood Lead Poisoning and Prevention, 2007), a drop of nearly 13 micrograms per deciliter.

We elaborate on this point because the removal of lead from gasoline is a major success story not only for epidemiologists but also for behavior analysis. As noted earlier, behavior under the FI schedule of reinforcement is a sensitive measure of lead exposure in experimental models. It is so sensitive and reproducible that one of the key contributors to the removal of lead from gasoline was early studies of laboratory animals' behavior under FI schedules of reinforcement (reviewed in Davis, Otto, Weis, & Grant, 1990). The value of this schedule could not have been anticipated when it was described more than 70 years ago (Skinner, 1938/1981), but the value of the dictum to follow up on orderly data always holds true.

At the other end of the life span, that environmental exposure to neurotoxicants can accelerate aging has become more widely accepted (Cranmer, 2007). To name just one example, the personal and economic costs of environmental exposures that result in early-onset dementia or motor impairments will be borne not only by the afflicted person but also by family members and by the larger society that may have lost an economic asset while gaining a medical cost (Weiss, 2006). These very high costs are preventable, but to prevent them it is necessary to know which toxicants accelerate aging and at what exposure level this occurs.

SUMMARY AND CONCLUSIONS

Application flows from good science, and behavioral toxicology is no exception. By addressing important questions about the functional consequences of chemical exposures, behavioral toxicologists have addressed so-what questions that arise when environmental contaminants cause subtle brain damage. The study of neurotoxicant impact on the nervous system and its functions as expressed in behavior can only yield a fuller understanding of both brain and behavior. Thus, in addition to contributing to fundamental science, behavioral toxicologists' results have led to important policy decisions that guide people's exposure to toxic chemicals. Although far from complete, the regulation of neurotoxicants provides an instructive example of evidence-based policymaking that may guide similar activities in other arenas.

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CHAPTER 10

TOWARD PROSOCIAL BEHAVIOR AND ENVIRONMENTS: BEHAVIORAL AND CULTURAL CONTINGENCIES IN A PUBLIC HEALTH FRAMEWORK

Anthony Biglan and Sigrid S. Glenn

The science of human behavior has advanced sufficiently in the past 100 years to be able, at least in principle, to improve human well-being significantly. For example, the recent National Research Council and Institute of Medicine (NRC & IOM; 2009b) report on prevention documented the availability of interventions throughout child and adolescent development to prevent the most common and costly psychological and behavioral problems. Similarly, clinical treatment research has pinpointed evidence-based treatments for most problems (Biglan, Mrazek, Carnine, & Flay, 2003; Mrazek & Haggerty, 1994; NRC & IOM, 1994), and educational research has delineated teaching and behavior management practices that if used would likely ensure the successful academic and social development of most children (Shinn & Walker, 2010).

The task remaining is to translate all of this knowledge into changes in the behavior of enough people that the resulting social environment reliably enhances human well-being. This statement may seem grandiose, but a careful reading of the evidence has shown that these outcomes are possible, at least in principle. Just as science has transformed the material world beyond the wildest dreams of a person living in the 17th century, the science of human behavior can bring about changes in human behavior that can transform the social world we now know.

What is absent, however, is a framework that relates known behavioral principles to avenues of cultural change. Behavior analysts do not yet have reliable ways to bring about population-wide changes in behavior, nor can they reliably influence the beneficial and harmful practices of organizations that have a powerful influence on behavior. In this chapter, we offer a framework that we hope will aid in translating the extensive progress that has occurred in the science of the behavior of individuals into population-wide improvements in human well-being.

BEHAVIOR ANALYSIS AND CULTURAL CHANGE

B. F. Skinner (1981) summarized the origins of human behavior thus:

> Human behavior is the joint product of (i) the contingencies of survival responsible for the natural selection of the species and (ii) the contingencies of reinforcement responsible for the repertoires acquired by its members, including (iii) the special contingencies maintained by an evolved social environment. (p. 502)

When a significant number of people in an evolved social environment behave in similar ways, that behavior is often called a *cultural practice*. However, that term lacks clear definition and does not lend itself to measurement. We use the term *macrobehavior* for the phenomenon of interest here and define it as the similar but independently existing operant behavior of many people that has a

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cumulative and measurable effect on the environment (Glenn, 2004; cf. Schelling, 1976/2006). For example, sexual behavior that risks HIV infection is a macrobehavior that affects not only infected individuals and their families but also society in general.

Although macrobehavior remains localized with respect to a particular social system, just as operant behavior remains localized with respect to a particular organism, a fundamental difference exists between the two. Operants are lineages of recurring responses that change over time as a function of reinforcement contingencies; therefore, operants can evolve. However, macrobehavior cannot evolve, because it is not a lineage of related recurrences but rather an aggregate—a statistical summary—of operant lineages of many different people. The operant members of a macrobehavior are more similar to gas molecules in a container than to organisms in a biological lineage; they may affect each other's trajectories, but each continues on its own path after contact.

Nevertheless, macrobehavior may be important to the survival of a social system when its cumulative effects on the environment are sufficiently beneficial or harmful to the social cohesiveness and general well-being of that social system's members. Thus, it is in the interest of any social system to identify macrobehaviors with beneficial or harmful effects and to arrange contingencies of reinforcement that produce and sustain operant behavior contributing to the beneficial effects and avoiding the harmful ones.

Evolved social environments involve more than macrobehavior and the operant selection processes accounting for the behavior of each contributing person. They include organizations (schools, factories, research laboratories, restaurants, nongovernmental organizations, government agencies), and each individual school, factory, and so forth exists as a cultural-level entity in relation to its own external environment. The fundamental constituents of such systems are the operant behaviors of humans, but the system is more than the sum total of that behavior. The behavioral components of the system become embedded in interlocking behavioral contingencies (IBCs), recurrences of which result in a product or measurable outcome. For example, products of school IBCs are academic and social repertoires of graduates, products of factory IBCs are goods or equipment, products of research labs are publications, and so on. These products depend on the properties of the IBCs, much as the switch closure of a lever press depends on the properties of the movement. Just as the switch closure defines what counts as an instance of a lever-press operant, the products of IBCs can define what counts as a measure of IBC recurrences. Of course, all the properties of the lever press or the IBC recurrences are not required to enter into selection contingencies, because some may merely accompany those properties the external environment selects for.

The term *metacontingencies* can describe the contingent relations between IBC lineages with their products on one hand and the consequent actions of their external environment on the other (Glenn, 2004; Glenn & Malott, 2004). The external environment of IBC recurrences may encompass the responses of many people or the products of the IBCs of other organizational entities. For example, when consumers purchase organic vegetables, they are part of the selecting environment for the IBCs of an organic farm. However, the selecting environment for the farm IBCs also includes the products of the IBCs of other cultural-level entities: for example, laws passed by legislative bodies specifying farming procedures (IBCs) that merit the label *organic* (Alemanno, 2009).

In the pages that follow, we consider macrobehavior with cumulative effects that are detrimental to society as a whole. It is important to note that if only a few individuals exhibited these problem behaviors, we could view them as matters of individual interest. The cumulative effects on the well-being of large numbers of people make the macrobehavior a social issue (cf. Malagodi & Jackson, 1989). We present a case for treating macrobehaviors with detrimental effects on human well-being as a public health problem. Finally, we suggest ways in which current knowledge about effective treatment practices can help to promote behavior with cumulative effects that improve human well-being.

PUBLIC HEALTH FRAMEWORK

The field of public health provides a framework compatible with our analysis (Committee for the

Study of the Future of Public Health, 1988). Public health practices evolved out of efforts to control infectious disease (Biglan, 2011). The overriding concern was to measure and control the incidence and prevalence of infectious disease (Johnson, 2006). It slowly became clear that achieving this required identification and modification of the risk factors that contributed to the diseases. The classic example is the 1854 cholera epidemic in London. The physician John Snow believed that it was the result of the water in the Broad Street pump. After he convinced the local government to remove the pump handle, the epidemic ended.

This framework has now expanded to encompass health-related behaviors. Although public health began with a focus on infectious diseases, it soon encompassed the control of noninfectious diseases such as heart disease and cancer. Yet behavior is a contributing cause of many of these diseases. Cigarette smoking and poor nutrition are two examples. Thus, the public health community has added the modification of behavioral risk factors for disease to its task list.

From this perspective, it is appropriate to identify macrobehaviors having costly outcomes and to pinpoint and modify their risk factors to reduce the incidence and prevalence of the problematic behavior. To accomplish this, attention to changing the incidence and prevalence of behaviors in a population—the macrobehaviors—must join the traditional behavior-analytic focus on frequency of behavior in individual repertoires (Biglan, 1995).

In our analysis, we expand the public health framework. As opposed to infectious disease, in which antecedents (e.g., exposure to pathogens) are the primary causal mechanisms, macrobehavior with undesirable societal effects involves operant consequences and antecedents. Moreover, the particulars of the environment that function in the operant contingencies of each person whose behavior contributes to the macrobehavior may differ. Thus, to modify the environments of the behavior of many people effectively, identifying environmental events common to the contingencies supporting many behaviors is necessary. As we show, behavior analysts must analyze the consequences of the actions of groups and organizations—the metacontingencies—because, in most cases, they cannot change antecedents and consequences of a behavior for many people unless they change organized IBCs whose products function in those behavioral contingencies.

PROBLEM BEHAVIOR AND PROSOCIALITY

Over the past 50 years, behavioral scientists have delineated the most common and costly problems of human behavior. These problems include aggressive social behavior, risky sexual behavior, depression, substance abuse, academic failure, school dropout, and crime. Each of these problems affects millions of people and causes pain and suffering both to the person with the problem and to those around them. From the standpoint of improving human well-being, these are the macrobehaviors of greatest importance. Taken together, these problems cost the United States an estimated $435 billion or more in a single year (Miller, 2004). Although most research has focused on only one or a few problems, it is now clear that most problems co-occur with others (Biglan, Brennan, Foster, & Holder, 2004; Seeley, Lewinsohn, & Rohde, 1997) and that the same set of conditions contributes to diverse problems (Biglan et al., 2004).

David Sloan Wilson has defined *prosocial behavior* as any belief, attitude, or behavior that contributes positively to others, to society as a whole, or both (Wilson, O'Brien, & Sesma, 2009). Although the public health system evolved to focus on reducing illness and its contributing behaviors, prosocial behavior has received much less research attention. However, concern is increasing that a focus only on preventing problems is myopic (Durlak, 1985; NRC & IOM, 2009a). A society's needs involve not only preventing crime, drug abuse, and depression but also increasing the innovation, vitality, productivity, and compassion of its citizens. Moreover, increasing prosocial behavior may contribute to the prevention of problem behavior (Boles, Biglan, & Smolkowski, 2006). As we show, preventing problems requires environments characterized by prosocial behavior. In this sense, a mature behavioral science will seek to foster environments that both nurture prosocial behavior and prevent problem development.

INCREASING THE PREVALENCE OF NURTURING ENVIRONMENTS

Epidemiological, public health, clinical, and prevention research have converged to show that diverse and interrelated problems of human health and behavior become more likely within a small set of nonnurturing conditions. Biglan and Hinds (2009) analyzed effective educational, preventive, and treatment interventions and delineated four features of environments that nurture prosocial behavior. The absence of such environments makes a wide variety of psychological and behavioral problems more likely. If this analysis is correct, it could aid in organizing more efficient and effective ways to improve human well-being. Drawing on etiological and intervention literature, we describe four ways to promote nurturing environments.

Minimize Toxic and Aversive Conditions

Perhaps the single most important thing people can do to prevent problem development and foster prosocial behavior is to minimize toxic conditions in family, school, neighborhood, and workplace environments. A variety of toxins harm children's development. Certain maternal substance uses during pregnancy have well-established effects. Mothers' smoking during pregnancy has been associated with the development of conduct disorders (Braun et al., 2008) and adolescent delinquency (Brennan, Grekin, Mortensen, & Mednick, 2002). Mothers' alcohol use during pregnancy is associated with both cognitive deficits and the development of antisocial behavior (Jacobson & Jacobson, 2002). Poor maternal nutrition during pregnancy may contribute to obesity and cardiovascular disease in offspring (Barker, 1998).

Children's exposure to lead is associated with lower IQ at age 6 (Jusko et al., 2008), poorer academic performance in elementary school (Miranda, Kim, Reiter, Overstreet Galeano, & Maxson, 2009), attention-deficit/hyperactivity disorder (Nigg et al., 2008), conduct disorder (Braun et al., 2008), and teenage pregnancy and tobacco use (Lane et al., 2008). Other researchers have implicated lead exposure in the relationship between low socioeconomic status and cardiovascular reactivity (Gump et al., 2007). Children's exposure to black carbon has also been found to predict decreases in cognitive functioning (Suglia, Gryparis, Wright, Schwartz, & Wright, 2008; Tang et al., 2008). Chapter 9 (this volume) provides a more extensive treatment of the impact of neurotoxicants on the nervous system and its functions as expressed in behavior.

Some stressful environmental events cause both biological and behavioral harm. The work of Patterson and colleagues on coercive family processes (Dishion, Patterson, & Griesler, 1994; Patterson, 1982) delineated the most important process. Using direct observation methods, they studied family interactions of aggressive and nonaggressive children. They found that in families of aggressive children, family members used aversive behavior such as criticism, teasing, and harsh discipline to terminate the aversive behavior of other family members. This aversive control appears to shape children's aggressive and uncooperative behavior because their behaviors succeed in getting other family members to back off. However, these contingencies fail to establish the prosocial repertoires children need to develop friends and succeed in school. Longitudinal studies of these family processes have shown that young children who develop aggressive and uncooperative repertoires are at high risk of failing school and of engaging in delinquent behavior, risky sexual behavior, and substance use as adolescents (Biglan et al., 2004; Patterson, 1976). More recent research on coercive family processes has shown that such interactions are related to children's becoming hypervigilant to threats, failing to develop self-regulatory behaviors, and tending to react to minor stressors in aggressive ways (NRC & IOM, 2009a).

Problems within the larger context make coercive family interactions more likely. Poverty, economic reversals (e.g., job loss), and other aversive events, such as altercations with neighbors, increase family conflict and may contribute to development of children's aggressive behavior (Conger, Ge, Elder, Lorenz, & Simons, 1994). Such conditions also make parental depression more likely (Lorant et al., 2003). Depressive behavior is itself a behavioral pattern that may result from coercive family interactions (Biglan, 1991) and contribute to developmental problems (NRC & IOM, 2009a).

Schools are stressful environments for many students. Rusby, Forrester, Biglan, and Metzler (2005) reported that 85% of middle school boys and 78% of middle school girls experienced some or frequent verbal harassment in the prior week. Eight percent of boys and 10% of girls reported frequent physical harassment in the past week. In high school, the levels of any verbal harassment in the prior week declined slightly to 77% for boys and 63% for girls. Nine percent of high school boys and 7% of high school girls reported frequent physical harassment.

Given such conditions, it is not surprising that researchers have found high rates of depression and suicidal behavior in middle schools and high schools. A representative sample of Oregon eighth-grade students showed that 14% of eighth graders reported depression in the past week and 8% reported suicide attempts in the past year. Among 11th graders, 15% reported depression in the past week and 6% reported suicide attempts in the past year (Boles et al., 2006). The rates of suicidal behavior were higher among those who reported being harassed (Center for Health Statistics, 1997).

Schools are also stressful environments for many teachers: Studies have shown that teachers have high levels of stress (Evans, 2003) and depression (Jurado, Gurpegui, Moreno, & de Dios, 1998) and higher levels of substance use than those in other professions (Watts & Short, 1990). Teacher distress is a strong predictor of absenteeism, turnover, and teachers leaving the field (Maslach & Leiter, 1999).

Stress is also common in many other workplaces. It is associated with cardiovascular disease and higher health care costs generally. Stress and its health consequences are significantly greater among workers in the lower status levels of organizations (e.g., Wilkinson & Pickett, 2009).

In short, researchers have agreed about the deleterious effects of stressful conditions in families, schools, and workplaces. Prevention and treatment research showing the value of reducing stressful and toxic conditions has confirmed these findings. Several recent works (Biglan et al., 2004; NRC & IOM, 2009b) have summarized this evidence, although space does not permit a thorough review of it here. A large and growing body of experimental studies has identified effective interventions for preventing or treating most psychological and behavioral problems of young people. Most interventions include components designed to reduce coercive interactions. For example, behavioral parenting skills interventions teach parents to replace criticism and harsh punishment with mild, consistent negative consequences, such as time out and chores (e.g., Dishion, Kavanagh, Schneiger, Nelson, & Kaufman, 2002; Forgatch, Beldavs, Patterson, & DeGarmo, 2008; Webster-Stratton & Herman, 2008). The Nurse Family Partnership (Olds, Hill, O'Brien, Racine, & Moritz, 2003) guides poor, single teenage mothers to stop smoking during pregnancy, get proper nutrition, and exhibit patience and love after their babies are born. The Nurse Family Partnership has reduced child abuse and prevented children's problem behavior even into adolescence (Olds et al., 2003). School interventions such as Positive Behavior Support (PBS; Horner & Sugai, 2000) and the Good Behavior Game (GBG; Kellam et al., 2008) help schools reduce punitive practices and harassment by systematically teaching students to follow a small number of rules and by reinforcing their doing so.

To summarize, epidemiological and intervention evidence has shown that a high priority for the successful development of young people and the well-being of adults is the minimization of toxic biological and psychological conditions. Nurturing the spread of nontoxic family, school, and workplace environments should thus be a prime target for cultural evolution.

Richly Reinforce Prosocial Behavior

The idea that environments should positively reinforce prosocial behavior is at the core of behavior analysis (e.g., Skinner, 1953, 1969). Many of the theoretical discussions of recently developed evidence-based prevention and treatment interventions have not emphasized reinforcement. However, inside virtually every evidence-based intervention are procedures that significantly increase positive reinforcement of desirable behavior (Biglan, 2003). Space does not allow us to do full justice to this topic, but we hope that providing a range of examples will make the case. Numerous, well-validated versions of behavioral parenting skills training programs are now available and suitable for all developmental phases from early childhood (e.g., Forgatch & DeGarmo, 1999; Prinz & Sanders, 2007; Webster-Stratton, 1984) through early adolescence (Dishion et al., 2002; Spoth, Redmond, & Shin, 2000) to adolescence (Chamberlain & Mihalic, 1998; Henggeler, Melton, & Smith, 1992). All place heavy emphasis on getting parents to replace harsh and inconsistent discipline practices with positive reinforcement for desirable behavior.

PBS programs in schools (Horner & Sugai, 2000) often involve massive increases in the use of positive reinforcement. The GBG, when played in first grade, can help to prevent substance abuse, antisocial behavior, and suicidality in adulthood (Furr-Holden, Ialongo, Anthony, Petras, & Kellam, 2004; Kellam et al., 2008); it involves simply reinforcing children's cooperation and on-task behavior.

Effective interventions of all types involve joining sympathetically with individuals and families to help them change their behavior. For example, the Nurse Family Partnership (Olds et al., 2003) has nurses befriending high-risk pregnant mothers and supporting them in making the behavioral changes they need to ensure a successful pregnancy, improve their financial situation, and gain social support from friends and family.

All of these examples involve complex programs. However, behavior analysts have also developed many simple practices for increasing positive reinforcement. Embry (2004) has labeled such simple, single-component interventions as *kernels*. Embry and Biglan (2008) identified numerous kernels for reinforcing prosocial behavior, such as praise notes and a prize bowl. Such kernels may be particularly useful for promoting the spread of reinforcing practices because they are simple and easily disseminated. As a public health solution to promoting prosocial environments, then, the problem becomes one of producing macrobehavior made up of such kernels. If policymakers and citizens fully appreciate the importance of reinforcement, they may be motivated to look for ways to promote and spread reinforcing practices. Reinforcing prosocial behavior is a macrobehavior of central importance to human well-being and therefore a critical target for cultural evolution.

Teach and Promote Prosocial Norms and Values

Recent behavior-analytic work on relational frame theory (RFT; Hayes, Barnes-Holmes, & Roche, 2001) has provided a way of analyzing verbally governed behavior that accounts for some of the complexity of human behavior (see also Chapter 18, this volume). This theory is an extension and revision of Skinner's (1957) classic text on verbal behavior. In that text, Skinner viewed verbal behavior as learned relations between environmental events (verbal and nonverbal) and conventional response forms (speech, writing, typing, signing, etc.) acquired via socially mediated reinforcement.

The extension began with the work of Sidman and his colleagues, who studied the conditions under which (a) learning a subset of relations among a set of stimuli could lead to stimulus control by other relations that were never directly taught and (b) stimulus functions acquired by one member of such stimulus sets apparently transferred to other members in the absence of direct reinforcement (see Sidman, 1994, for a detailed review of early work on equivalence relations; see also Sidman, 1989; Sidman et al., 1982). In RFT, the defining feature of verbal behavior is that, as a result of their histories of reinforced relational responding, listeners and speakers derive many types of relations among stimuli *sui generis*. The types of learned relations include not only equivalence but also opposition, distinction, comparison, and others. Once the generalized frames of coordination, opposition, and so forth come under stimulus control of particular contexts (such as the words *equal* or *opposite*), then novel stimuli entered into a particular frame automatically enter into a network of stimuli having the relations characterized by that frame. For example, the word *volunteer* is meaningful in a given context because of a person's history of relating the word to specific volunteering behaviors as well as to various experiences or verbally labeled consequences, such as others' approval and improving others' well-being.

RFT expands the concept of *verbal* to include any stimulus that participates in a relational frame. Thus, for a verbally able human, not only is the word *horse* a verbal stimulus, but the horse itself is also a verbal stimulus because its functions are transformed by virtue of its participation in relational frames with words and the things with which those words are associated (e.g., *swift, brown, strong)*. Considerable empirical evidence has shown that the functions of arbitrary stimuli alter when they participate in relational frames (Hayes, 1994). This insight is important because it provides a way of describing in behavior-analytic terms how the functions of stimuli are established and modified for verbally able humans.

The RFT analysis suggests that behavior analysts can change the reinforcing or aversive properties of a particular stimulus for a verbally able human by altering the relation of that stimulus to other stimuli in their derived relational networks. If one wants many people to value and engage in prosocial behavior, and to reinforce others' prosocial behavior, one needs to develop rich relational networks in the repertoires of many people that tie specific prosocial behaviors to a generalized concept of prosociality and that connect prosociality to numerous positively valued stimuli. The RFT analysis provides a framework for organizing efforts to bring about widespread cultural change in the reinforcing function of particular events, objects, or conditions.

There are many ways to do this. Social recognition of prosocial behavior has the effect of reinforcing the behavior at the same time as it presents that behavior as a model for others. Movies and books can model specific examples of prosocial behavior and its consequences. David Sloan Wilson (2007) has described how literature can be a vehicle for promoting prosociality. Unfortunately, much of the entertainment media that reaches youth model and promote antisocial behavior (Huesmann, Eron, Klein, Brice, & Fischer, 1983).

Several systematic approaches have promoted prosocial norms and values in schools, including PBS (Horner, Sprague, & Sugai, 1996), PeaceBuilders (Embry, Flannery, Vazsonyi, Powell, & Atha, 1996), and Positive Action (Flay, Allred, & Ordway, 2001). These approaches explicitly teach rules for prosocial behavior and then teach students the specific behaviors that count as examples of following rules in each of the school settings. They connect the advocated behaviors with things that young people value, such as social recognition and accomplishments. One school that implements PBS has a lesson each week that teaches about a specific positive social quality. Examples include *creative, thrifty, joyful, kind, patient, honest,* and *cheerful.* Existing evidence has indicated that programs of this sort reduce problem behavior and improve students' academic performance (Horner et al., 2009). Long-term follow-up on the effects of being in a school that promotes prosocial behavior in this way has yet to be conducted.

Set Limits on Opportunities for Problem Behavior

Overwhelming evidence from studies of adolescent deviant behavior over the past 30 years has shown that most problem behavior develops when young people interact with peers in unsupervised situations. Dishion, Bullock, and Kiesner (2008) provided a thorough review of this evidence. Youths whose parents do not monitor their activities outside the home and who fail to set limits on the contacts their children make with peers who engage in problem behaviors are highly likely to engage in problem behavior. Perhaps the strongest evidence of the importance of monitoring and limit setting comes from studies of the efficacy of interventions that encourage parents to increase their monitoring and limit setting (e.g., Chamberlain, 2003; Dishion & Stormshak, 2007; Kumpfer, Molgaard, & Spoth, 1996).

Much experimentation with substance use and other risk-taking behaviors occurs after school, among adolescents who have no supervision at home (Richardson, Radziszewska, Dent, & Flay, 1993). Efforts to alter the macrobehavior of parental monitoring must confront the problem of parental need to work during after-school hours. Webcam technology plus reinforcement contingencies for desired after-school behavior might provide some increase in parental monitoring and decrease in risk-taking behavior of adolescents after school. After-school programs may be another solution. Langberg et al. (2007) reported a randomized trial of an after-school program for middle school youths identified as having learning and behavior problems. Those youths who participated in the after-school program improved significantly more than did control youths on parents' ratings of academic progress, self-esteem, and overall severity of problem. However, effects on teacher ratings were not significant.

In sum, the existing evidence has indicated that the evolution of improved limit-setting practices in families and communities will foster successful development of young people. How to accomplish such macrobehavioral change is less clear.

Promote Psychological Flexibility

The clinical research that RFT has spawned has focused on how people create problems for themselves by following rules about not experiencing unpleasant thoughts and feelings (Hayes, Strosahl, & Wilson, 1999). The term for this behavior is *experiential avoidance*. Experiential avoidance is a risk factor for a wide range of psychological and behavioral problems, including depression, anxiety, and substance abuse (Biglan, Hayes, & Pistorello, 2008; Hayes, Strosahl, et al., 2004). For example, a young woman whose family members frequently criticize her may often think of herself as inadequate. In an effort to get rid of such thoughts, she may seek reassurance from male companions and engage in risky sexual behavior to achieve it. She may avoid challenging subjects in school to avoid the experience of inadequacy. She may smoke to be more appealing to her peer group or drink and take drugs to damp down unpleasant feelings.

Experiential avoidance contributes to psychological inflexibility. Efforts to control thoughts and feelings narrow people's repertoires in ways that make them inflexible. For example, a man who fears flying may focus so much on not feeling anxiety that he misses many valuable business and recreational opportunities. A young woman who feels wronged by a parent may refuse any contact with family members to avoid all the hurt and anger that she feels in contacts with family members. In the process, however, she misses the chance to repair her relationships and experience the love of others.

In contrast, *psychological flexibility* has been defined as "the ability to contact the present moment more fully as a conscious human being, and based on what the situation affords, to change or persist in behavior in order to serve valued ends" (Luoma, Hayes, & Walser, 2007, p. 17). The concept grows out of research on Acceptance and Commitment Therapy (ACT), which has shown that a variety of psychological and behavioral problems can diminish when people become more psychologically flexible (Hayes, Luoma, Bond, Masuda, & Lillis, 2006). Intervention involves loosening the influence of verbal stimuli through experiential exercises and metaphors and helping people to define their values, keep them salient, and act in accordance with those values.

Space precludes a thorough review of this literature (see Chapter 18, this volume). However, the impact of ACT and its grounding in the growing body of empirical research on RFT (Biglan et al., 2008; Hayes, Pistorello, & Biglan, 2008; Stewart & Barnes-Holmes, 2004) have suggested that promoting psychological flexibility could contribute to families, schools, and workplaces becoming more nurturing. For example, evidence has suggested that as people become more psychologically flexible, they become more caring and less likely to get into conflict with others (Biglan, Layton, Rusby, Hankins, & Jones, 2012). Evidence has also shown that they will cope more effectively with stressful environments (Biglan, Layton, et al., 2012; Bond & Bunce, 2003).

Encouraging people to "defuse" from their thoughts and feelings so that they look at them rather than through them may foster a culture in which people are more open to and less threatened by others' beliefs and ideas, which can contribute to people's openness to innovation (Bond & Bunce, 2003) and to the use of evidence-based practices (Hayes, Bissett, et al., 2004).

Value of This Synthesis

These broad generalizations about the need for nurturing environments run contrary to the dominant tendency among scientists to subdivide a field, drill down, and analyze more particulars. There is no question that such scientific refinement of knowledge has been productive; however, it has also contributed to the development of what David Sloan Wilson called the "Ivory Archipelago" (see Wilson, 2007). Each science relevant to human behavior and culture constitutes its own field, with unique concepts, methods, and targets of inquiry, seldom connected with other sciences. Indeed, even within fields such as psychology, numerous subfields have little interaction with each other.

Identifying cross-cutting features of these myriad fields is a vital step toward uniting the human sciences so that they can truly improve human well-being. Each island of the archipelago has important information to offer. Existing knowledge, however, will not achieve its potential unless all the different facts are brought together into a coherent whole. If behavior analysts' generalizations about nurturing environments accurately characterize what is critical to the prevention of problems and the nurturance of prosocial behavior, they can guide the further evolution of human societies.

We suggest that the concept of nurturing environments identifies not only a useful goal but also a practical way of advocating for society-wide action. The concept of nurturing environments is easy to communicate, and it relates to every aspect of people's lives. Promoting nurturance can thus be the core of a public health campaign. Just as the reduction in smoking resulted largely from communication of the harm of smoking, researchers may be able to bring about substantial increases in the prevalence of nurturing environments simply by communicating their nature and value to the population.

STRATEGIES FOR INCREASING THE PREVALENCE OF PROSOCIAL BEHAVIOR

This analysis implies that a central goal for public health should be to increase the prevalence of nurturing behavior in families, schools, neighborhoods, workplaces, and entire communities. We reviewed some of the evidence that treatment and preventive interventions can add to this outcome. Extensive reviews of that evidence are now available (Biglan et al., 2004; NRC & IOM, 2009b). We believe that the evidence is sufficiently strong to justify some behavioral scientists turning to the task of translating this knowledge into widespread changes in the prevalence of nurturance.

The problem is that research testing strategies for bringing about population-wide changes in nurturing behaviors has occurred far less than research on the value of nurturance or techniques to increase nurturance among individuals. One reason is that it has proved very difficult to get evidence-based interventions widely disseminated (e.g., Biglan & Ogden, 2008; Ringwalt et al., 2008). Indeed, some behavioral scientists have become increasingly frustrated by the growing gap between what they know could be achieved and what has actually been achieved (Ringwalt et al., 2003).

In this section, we describe two examples of planned interventions with the goal of producing more nurturing environments. The first concerns a set of practices developed by behavior analysts: Schoolwide PBS. The second is the tobacco control movement.

Dissemination of Schoolwide Positive Behavior Support

Schoolwide PBS is a systematic approach to nurturing prosocial behavior in school settings. It grew out of an accumulation of empirical evidence about the management of behavior in schools. The PBS approach was supported by evidence that interventions could produce reliable changes in problem behavior in school settings, but that the gains were less likely to persist after formal intervention periods ended (Sailor, Dunlop, Sugai, & Horner, 2009). Evidence of the value of PBS for preventing behavioral problems in schools (Bradshaw, Mitchell, & Leaf, 2010) and improving academic success (Horner et al., 2009) has been growing.

Of particular interest for this discussion is that more than 9,500 schools throughout the United States have adopted PBS, which is extraordinary given the difficulties in getting evidence-based interventions disseminated into the educational system (e.g., Carnine, 2000). We have not been able to find systematic empirical studies of the variable or variables influencing this success. However, thorough descriptions of the knowledge and infrastructure that have been guiding this movement do exist. We summarize them here in the hope that they may help to develop an understanding of how to accelerate this and other efforts to influence the spread of beneficial cultural practices.

One factor that seems to influence this movement is the simple accumulation of empirical evidence about what works to ensure appropriate social behavior in schools. Beginning with the Madsen, Becker, and Thomas (1968) study on the value of rules, praise, and ignoring for ensuring appropriate behavior in classrooms, the past 40 years have seen the accumulation of a sizable body of empirical evidence about the value of instruction and setting conditions and consequences for affecting students' behavior. One indication of this accelerating growth in knowledge is the *Journal of Positive Behavior Interventions,* which began publication in 1999. It provides a continuing stream of empirical studies that expand the knowledge base supporting positive behavioral interventions. As the evidence has grown, so too has educators' knowledge; many more teachers, principals, counselors, and school psychologists are aware of the value of these behavioral techniques. This knowledgeable educational community is perhaps a fertile ground for the dissemination of PBS.

Another factor that may be at play is the concern of many educators with the use of aversive techniques to try to control behavior. Sidman (1989) related the social problems emanating from aversive control to findings of basic behavioral research on avoidance and punishment. Singer and Wang (2009) argued that many educational researchers and educators over the past 20 years became increasingly concerned with the aversive methods used to control students' behavior. Mayer's (1995) seminal work documented how schools using high levels of punishment actually increased problem behavior. In addition, a concern existed that narrowly focusing on students' problem behaviors ignored the larger context for the development of a wide range of student skills, interests, and lifestyle outcomes.

This intellectual and moral foundation, coupled with development of an organizational infrastructure, has brought resources to the task of disseminating PBS. Sailor et al. (2009) documented these developments. In 1987, the U.S. Department of Education provided funding to Robert Horner and George Sugai at the University of Oregon to develop a research and training center to foster nonaversive behavior management techniques. In 2003, support from the U.S. Department of Education helped to establish the Association for Positive Behavior Support. In terms of the concepts discussed in this chapter, the Department of Education funding provided metacontingencies that shaped development of the organizations needed to promote PBS.

Sugai, Horner, and Lewis (2009) described the infrastructure supporting implementation and maintenance of PBS. Three levels of organization support dissemination: state, district, and regional teams. Each school that adopts PBS also has an implementation team. At each level, these teams have the responsibility to increase the system's capacity (at the state, district, or school level) to train personnel, provide ongoing coaching to support implementation and maintenance, evaluate the impact of all of these efforts, and coordinate the efficient and effective implementation of plans. Sugai et al. indicated that teams at all three levels require funding, visibility that gives them credibility, and political support that gives them authority and continued resources.

At each level, the teams try to foster a common language and vision regarding what is necessary. Sugai et al. (2009) indicated that the goals and capacity building of PBS have their bases in five foundational constructs. First is the concept of prevention—that it is better to prevent problems than to have to deal with them after they arise. Second, a systematic approach should be in place across the whole school. Third, evidence-based practices are the ones most likely to work. Evidence-based practices are adopted according to three criteria: effectiveness, efficiency, and relevance to the context (i.e., their fit with existing practices, the people who will use them, and the setting or culture). Fourth, teamwork is essential. Fifth, evaluation of practices, even those previously validated somewhere else, must be ongoing.

Many states have set up systems of this sort; Maryland's effort is exemplary. Since its state-level team was set up in 1999, it has trained teams in local school systems, which, in turn, have trained people in 741 schools throughout Maryland.

Unfortunately, empirical research on the factors influencing the spread of PBS has been less than that on the effects of PBS and various PBS-related techniques. However, for the focus of this chapter, both individual- and organizational-level contingencies are important. At the individual level, school personnel are increasingly aware of the evidence for behavioral interventions and are therefore open to training in the systematic practices that constitute PBS. At the organizational level, both federal and state funds flow to districts and schools to support the time and training needed to implement PBS successfully. Whether these funds are distributed contingent on evidence of change in identified macrobehavior in schools, regions, or states is unknown, at least to us; thus, the existence or the effects of metacontingency arrangements are unknown.

Tobacco Control Movement

The tobacco control movement in the United States is an excellent example of organized efforts to change macrobehavior resulting in great social cost. Cigarette smoking is the leading preventable cause of disease and death in the United States, killing more than 400,000 people each year (Centers for Disease Control and Prevention, 2002). By the middle of the 20th century, more than half of all men and more than 33% of all women in the United States were smokers. As of 2001, the rates had declined dramatically to 25% of men and 20% of women. The Institute of Medicine report on smoking said that this achievement was one of the 10 greatest in public health in the 20th century (NRC & IOM, 2007). Pinpointing the key influences that led to this change could contribute to a science of cultural change.

Because of nicotine's addictive properties, once someone has developed the smoking habit, it is difficult to stop. In terms of the present conceptual framework, it is a macrobehavior of high prevalence and social importance. However, to understand the forces affecting smoking prevalence, one must look beyond the individual level of analysis. The actions of the tobacco industry have influenced people to begin and to continue smoking. The prevalence of smoking has diminished in recent years because of countervailing influences on individuals, such as the increased cost of smoking and the social disapproval and inconvenience of having to smoke only in designated areas. Here too, however, the influences impinging on individuals are the result of the actions of numerous organizations working to reduce smoking and ensure smoke-free public environments. Thus, both the individual- and the organizational-level processes need to be understood.

Cigarette smoking spread because the tobacco industry developed effective ways of marketing cigarettes. Cigarette use has declined because the tobacco control movement found ways to minimize smoking's attractiveness and increase its aversiveness.

Several documents have recounted the history of cigarette marketing (e.g., National Cancer Institute, 2008; Pierce & Gilpin, 1995). The tobacco industry has been one of the most innovative in marketing their product. In the 1880s, James Duke found that he could boost sales of cigarettes by putting pictures of scantily clad women in each pack of cigarettes (Jamieson, 2010; Reichert, 2003). In 1913, R. J. Reynolds began advertising Camel cigarettes and gained exclusive rights to ship cigarettes to U.S. troops in Europe during the First World War (Burrough & Helyar, 1990).

Pierce and Gilpin (1995) documented how effective these and subsequent marketing campaigns were in influencing the targeted age cohort to begin smoking. Young women began smoking in the 1920s when the Lucky Strike campaign "Reach for a Lucky Instead of a Sweet" targeted them (Pierce & Gilpin, 1995). Other milestones in the tobacco industry's success were the Marlboro campaign targeting young men, which began in the 1950s; the Virginia Slims campaign targeting young women in the late 1960s and early 1970s; and the Joe Camel campaign of the 1980s, which was the first to erode Marlboro's control of the youth market (National Cancer Institute, 2008).

Research over the past 20 years has clarified how and why these campaigns were so successful (Biglan, 2004; National Cancer Institute, 2008). With increasing sophistication during the second half of the 20th century, cigarette marketing conveyed to young people that popular people smoke. Tobacco marketing associated smoking with images and activities that were desirable to young people—excitement, social acceptance, independence, maturity, relaxation, and sex appeal. The companies understood that inhaling cigarette smoke is initially aversive. They designed marketing practices to make smoking appealing long enough for a young person to become addicted. As one tobacco company analyst put it, "The expected or derived psychological effects are largely responsible for influencing the pre-smoker to try smoking, and provide sufficient motivation during the 'learning' period to keep the 'learner' going, despite the physical unpleasantness and awkwardness of the period" (Teague, 1973, p. 1). By the time they had smoked five packs of cigarettes, most young people had become addicted. They would then find it very difficult to quit.

At the individual level, it is easy to understand the spread of smoking behavior in terms of vulnerable young people trying cigarettes after their exposure to marketing that related smoking to social acceptance, fun, excitement, and a sense of independence and maturity. Research on smoking initiation has made it clear that the young people most likely to take up smoking are those who are strongly motivated to achieve these outcomes and who have few other means of doing so (National Cancer Institute, 2008). Using an RFT analysis, the marketing built relational networks among targeted young people that associated smoking with these desired attributes. Their continued smoking, however, was the result of their inability to stop; efforts to quit caused cravings and irritability that only smoking could relieve.

At the organizational level, the marketing practices of the industry found success on the basis of their contribution to profits. When R. J. Reynolds introduced its Camel campaign in 1913, its market share was only two-tenths of 1% (.002). By 1921, however, Camel had 50% of the market. Similarly, when Lucky Strike targeted women, its sales jumped from 12 billion to 42 billion cigarettes per year. Tobacco company documents have revealed that each company carefully tracked its market share and the impact of its own and its rivals' marketing campaigns. Their sophistication in marketing grew because they retained the effective campaigns and dropped less effective ones on the basis of their impact on sales. The expansion of the cigarette culture in the United States in the 20th century is a story of the evolution of marketing as a result of selection by consequences.

The reduction in smoking began in a similar way. At the individual level, smoking prevalence began to decline when the U.S. Surgeon General's Advisory Committee on Smoking (1964) report indicated that smoking caused cancer. The report led the way to an increasing volume of research on the harmful effects of smoking—on other cancers, on cardiovascular disease, on low birth weight of babies, and so on. Thus, for most smokers, the behavior became embedded in a relational network that associated it with ill health and the risk of death. This association prompted some people to stop smoking, despite the initial aversive effects of abstinence. The reports of this evidence had less impact on young people, probably for three reasons. First, young people paid less attention to the news reports on the harm of smoking. Second, feeling youthful invulnerability and an inclination toward risk taking, they were undeterred by warnings of possible harm far off in the future. Third, they were attracted to the social benefits that cigarette marketing convinced them were available if they smoked (and those social benefits were genuine; marketing not only convinced individual adolescents that smoking was socially appealing, it made smokers more appealing to other adolescents who were exposed to the same positive images of smokers).

As the evidence mounted, the system of publicizing these facts became more sophisticated. One U.S. Surgeon General report documented how exposure to other people's smoke caused about 50,000 cancer and heart disease deaths a year (U.S. Department of Health and Human Services, 2006). This evidence enlisted people who did not smoke to support efforts to reduce smoking. Another report documented the addictive properties of smoking and thus undermined the tobacco industry's argument that people simply chose to smoke of their own free will. A third report documented the influence of marketing on young people's smoking.

The emerging evidence prompted additional political and financial support for more research on the harm of smoking as well as research on what might work to reduce smoking. People who had lost a loved one to lung cancer or heart disease caused by smoking were highly motivated to do something about smoking. Thus, the size and resources of the tobacco control movement grew. Advocacy organizations formed, research on smoking expanded, and the government created agencies such as the Centers for Disease Control and Prevention's Office on

Smoking and Health to address the problem (Centers for Disease Control and Prevention, 1999).

One of the key influences on altering the culture of smoking has been the creative media advocacy of the tobacco control movement. Although it never had the financial resources of the tobacco industry, its members creatively publicized each new fact about smoking. Tobacco control advocates often say, "Cigarettes kill 400,000 people each year. It is like two Boeing 747s crashing and killing everyone on board every day of the year."

Organizations targeting smoke-free environments and decreases in smoking macrobehavior judiciously targeted policy changes that would have cascading effects on smoking. The evidence regarding secondhand smoke was the basis for policies to restrict smoking in restaurants, workplaces, schools, and even outdoor spaces. These restrictions motivated many people to quit smoking (Pechmann, Biglan, Grube, & Cody, 2011). Advocates also achieved significant increases in the tax on cigarettes at both the state and the federal levels. Increased price has a well-established effect in preventing young people from smoking and influencing some smokers to quit (Chaloupka, 2003).

The advocacy also made jurors more sympathetic to people who sued the tobacco companies because of smoking-related illnesses. Juries began to award large settlements to plaintiffs. Then the states filed suit against the tobacco companies to recover the cost of treating smoking-related illness under Medicare. In 1998, the tobacco companies settled out of court with 46 states over public health costs linked to smoking (Insurance Information Institute, 2009).

In terms of this analysis, the macrobehavior of smoking declined as the (verbally established) consequences of smoking became less favorable. However, these changes depended on the interlocking behavioral contingencies of multiple organizations producing literature and counteradvertisements and conducting lobbying activities. The metacontingencies for these organizations were a bit more complicated than those involving the evolution of tobacco marketing. In the case of the tobacco industry, profits selected IBCs that produced increased market share and profit. In the case of the tobacco control movement, government funding and private donations supported IBCs of nonprofit organizations. However, the relationship between the IBCs and that support was not as direct as that between the IBCs of tobacco companies and their profits. For example, the American Cancer Society might promote smoking cessation through television ads. The ads may or may not affect smoking and may or may not prompt people to give money to the American Cancer Society. It is possible that the American Cancer Society could raise money because people perceived that the ads were useful, even if they had no impact on smoking.

This is a classic problem for nonprofit and advocacy organizations—and for a society that depends on their efficacy to maintain human well-being: The activities of advocacy organizations do not directly generate revenues to sustain the organizations. Thus, even if their members engage in effective practices, the organizations may not continue to expand or even to exist. However, in the for-profit sector, a direct relationship exists between action and consequence. If companies do not produce and sell products or services, they cease to exist.

In the case of tobacco control, annual data on the prevalence of youth and adult smoking guided the efforts of the tobacco control movement. These data, coupled with evidence about the key influences on smoking (e.g., taxes, workplace restrictions, advertising), helped them to focus on activities that would affect smoking. When reductions in smoking prevalence faltered, tobacco control organizations adjusted their tactics. For example, in the mid-1990s the prevalence of adolescent smoking began to increase, which led to increased efforts to curtail the marketing of cigarettes to young people (National Cancer Institute, 2008).

In sum, the tobacco control movement provides an excellent example of how even highly prevalent and well-established macrobehavior can be changed. The first step is to marshal evidence about the prevalence and cost of the problem. This evidence will influence further support for research and action to address the problem. The research will produce further evidence about the harm of the problem, but it will also clarify the risk and protective factors that affect it and the things that will work to reduce the behavior or practice. Policies, media, and programs will accumulate as carefully controlled experiments produce evidence of their effectiveness.

This model is relevant to the problem of alcohol use and the marketing of unhealthy food (Biglan, 2011). Substantial evidence has indicated that alcohol marketing influences young people to drink and, indeed, to binge drink. Binge drinking is a significant risk factor for later alcoholism as well as alcohol-related violence and automobile crashes (NRC & IOM, 2004). Similarly, the obesity and diabetes epidemics that have developed in the United States are due, in part, to the marketing of high-calorie soft drinks and foods (Biglan, 2011). In both cases, further research on the role of these practices and other risk factors for these problems, along with research evaluating interventions, would support advocacy, policy formulation, and program implementation. There is no reason why advocacy—coupled with evidence-based policies and programs—could not alter the cultural practices involved in obesity and alcohol use and misuse.

IMPLICATIONS FOR THE PROMULGATION OF NURTURING ENVIRONMENTS

Our analysis relates to the general need to increase the prevalence of nurturing environments. The first priority is to organize existing evidence documenting the importance of nurturing environments (e.g., Biglan, Flay, Embry, & Sandler, in press). Conceptualizing the issue of problematic youth development in these terms would drive further integrative research that would document a growing list of harmful consequences of nonnurturing environments and test comprehensive interventions to increase nurturance. Just as the tobacco control movement has changed the once seemingly unalterable American love of the cigarette, a science-based movement to advocate for nurturance and for policies and programs that support nurturance in families, schools, workplaces, and neighborhoods could change the face of the country. Americans need not have 18% of their children raised in poverty. The accumulated knowledge of the past 50 years has shown that they can have many more caring families and schools and many fewer children who fail academically and socially.

In this section, we outline the activities that our analysis has suggested would hasten the spread of nurturing family, school, neighborhood, and work environments.

Evidence-Driven, Creative Media Advocacy

The two case studies we just presented make us optimistic that the accumulation of scientific evidence—if effectively communicated—can influence the environments that affect human behavior. If researchers can increase epidemiological research on the effects of nurturing environments, the expanding body of evidence can be the basis for increasing public communication about the benefits of nurturing environments and the harmfulness of stressful, coercive environments. Reports from the U. S. Surgeon General, along with reports from the National Institutes of Health, the Institute of Medicine, and the Centers for Disease Control and Prevention, can set the occasion for news reports of the key facts with headlines such as “Stressing Children With Criticism Linked to Disease and Delinquency” and “Parental Poverty a Major Cause of Childhood and Adolescent Disorders.” In this age of the Internet, its power to advocate for nurturing environments should not be overlooked (see, e.g., Anthony Biglan’s blog at http://www.nurturingenvironments.org).

As policymakers and opinion leaders come to a better understanding of the central role of nurturing environments, shifts may be seen in the funding priorities of foundations and government agencies away from a focus on individual problems and toward a focus on the promotion of nurturing environments. As money begins to flow to such activities, it seems likely that it will influence many existing nonprofits to focus on comprehensive efforts to increase nurturance and foster the creation of new organizations specifically dedicated to this outcome.

Thus, advocacy can change people’s valuing of nurturance by embedding its key aspects in a relational network that associates nurturing with desirable outcomes and associates nonnurturing coercion with undesirable outcomes. To the extent that it does so for policymakers, it can influence which policies they deem important and thereby influence the metacontingencies for organizations.

Policies

A judiciously organized advocacy movement for nurturing environments, similar to the tobacco control movement, could influence policymakers to develop and implement policies that directly increase nurturance. For example, living wage ordinances, minimum wage laws, and the earned income tax credit can all help to reduce family poverty. The impact of family poverty on youth well-being has provided a specific empirical basis for expansion of income policies that can ameliorate poverty.

Policies can also create conditions that facilitate the spread of nurturance. For example, multiple reports focusing on the harmful effects of punishment could influence school districts, state education departments, and the U.S. Department of Education to require systematic substitution of nurturing discipline for punishment in schools. The Los Angeles Unified School District (2007) has already adopted such a policy, and the PBS movement has been a prime mover in replacing punishment with positive reinforcement in entire schools.

The evidence should motivate stronger efforts to prevent child abuse. Currently, most government efforts occur after an agency has already detected child abuse. Moreover, these efforts are generally punitive toward parents. Now that evidence-based interventions that can prevent child abuse (Prinz, Sanders, Shapiro, Whitaker, & Lutzker, 2009) are available, creating policies requiring state agencies to provide such preventive interventions is appropriate. Other policies to pursue include government funding of smoking cessation programs for pregnant women and providing omega 3 supplements for them (Embry & Biglan, 2008).

Finally, policymakers should be urged to require the use of evidence-based programs and practices and to fund networks such as those involved in the dissemination of PBS to ensure the widespread and effective dissemination of the most cost-effective prevention and treatment interventions. In essence, policymakers have the power to alter the metacontingencies that affect nurturing practices.

Dissemination of Evidence-Based Programs and Practices

In the previous section, we briefly described the growing evidence of the efficacy of prevention programs directed at families and the programs that are deliverable in schools. Extensive reviews of this evidence are available (Biglan et al., 2004; Embry & Biglan, 2008; NRC & IOM, 2009b). Advocacy and policies requiring evidence-based programs and practices, and creation and maintenance of systems needed to spread and sustain such interventions, could influence schools and family-serving agencies to use practices that increase family and school nurturing. Increased funding of research on effective dissemination would accelerate these developments.

Monitoring Systems

It would be naive to think that evidence-based programs and practices will continue to be effective if their impact is not continuously tracked. It would be as though a manufacturer of high-quality products abandoned quality assurance procedures as soon as it had enjoyed 1 year with fewer than 1% of its products being defective. At the same time as policies, programs, and practices designed to increase nurturance are devised, systems for monitoring population well-being and the reach and fidelity of implementation of evidence-based programs and practices need to be developed.

Systems for monitoring well-being have been spreading over the past 30 years. Mrazek, Biglan, and Hawkins (2005) provided a brief history of such systems and examples of their value for fostering human well-being. They argued that eventually the point should be reached at which every community has accurate and timely data about the level of psychological and behavioral problems among youths and adults. Systems for monitoring youths are more widespread than those for adults because it is easier to collect data on the captive population of a school. It is conceivable that the spread of such systems could contribute to the spread of good practices by influencing schools, communities, and government agencies to retain practices that seem to be associated with good outcomes and abandon or revise those associated with bad ones.

The evidence that disseminated interventions are not effective if they do not occur with fidelity (e.g., Dusenbury, Brannigan, Falco, & Hansen, 2003) has indicated that the systems set up to guide dissemination must have a component that tracks fidelity of implementation. Certainly, this component has been a core feature of the PBS dissemination system.

CONCLUSION

The behavioral sciences have brought people to the point at which there truly is something new under the sun. Science at last can now help to create the kind of nurturing environments necessary for people to thrive. Most work thus far has focused on interventions targeting individual families and schools. The next challenge is to develop an empirical science of intentional cultural evolution that can enable society to translate existing knowledge into widespread benefit. We argue that this effort will strengthen with a focus on (a) how to influence the spread of a behavior by increasing the incidence of reinforcement for that behavior and (b) how to alter the metacontingencies for organizations that select practices contributing to a more nurturing society.

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Chapter 11

BEHAVIORAL APPROACHES TO TREATMENT OF INTELLECTUAL AND DEVELOPMENTAL DISABILITIES

Patricia F. Kurtz and Michael A. Lind

Intellectual disability affects 1% to 3% of the total population (World Health Organization, 2001). By definition, individuals with intellectual disability present with impaired cognitive skills. Moreover, they often exhibit additional deficits, problems, and clinical conditions that are amenable to treatment.

First, individuals with intellectual and developmental disabilities are likely to demonstrate limitations in various domains including language, motor abilities, social skills, leisure skills, and self-care (American Psychiatric Association, 2000). Such intellectual and skill deficits can hinder individuals' ability to participate fully in educational, social, and community activities and may ultimately affect their overall quality of life. Second, individuals with disabilities may require specialized and individualized educational services to maximize learning. Their educational needs may vary greatly, ranging from assessment of student skills and academic progress to development of educational curriculums to management of student behavior in the classroom.

People with intellectual disability are more likely to have physical disabilities, vision or hearing impairments, seizures, and obesity than individuals in the general population (Ouellette-Kuntz et al., 2005). They are also more likely to be diagnosed with chronic medical conditions such as diabetes, gastrointestinal disorders, and infectious diseases (Ouellette-Kuntz et al., 2005). Thus, they have greater health care needs than the general population but in fact have poorer health and health care access than people without intellectual and developmental disabilities. These health disparities are the result not just of a higher risk of comorbid disorders but of modifiable factors such as limited access to physicians with expertise in disabilities, greater exposure to unhealthy or stressful environments, decreased mobility, communication difficulties, and presence of severe problem behavior (Krahn, Hammond, & Turner, 2006; Ouellette-Kuntz et al., 2005).

Finally, in addition to the presence of skill deficits, educational challenges, and health-related problems, individuals with intellectual and developmental disabilities are also at increased risk of a range of clinical conditions, including sleep disorders, pica, feeding problems, psychiatric disorders, and severe behavior problems such as aggression, property destruction, or self-injurious behavior. In particular, the presence of chronic problem behavior increases the likelihood that individuals will require specialized services, including those outside of the home in residential treatment or group home settings (Ouellette-Kuntz et al., 2005).

Interventions based on applied behavior analysis have been demonstrated to improve outcomes for people with intellectual and developmental disabilities across a range of presenting problems and across the life span (Didden, Duker, & Korzilius, 1997; Lovaas, 1987; McEachin, Smith, & Lovaas, 1993; New York State Department of Health, 1999; Rush & Frances, 2000). In this chapter, we review some notable contributions of applied behavior analysis to the treatment of select problems associated with intellectual and developmental disabilities. The advances in behavioral approaches to treatment are

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best understood by reviews of research and application across four major areas: remediation and treatment of skills deficits, treatment in educational settings, treatment of problems associated with medical conditions, and treatment of clinical disorders.

BEHAVIORAL TREATMENT APPROACHES TO SKILL ACQUISITION

Methods of applied behavior analysis have garnered extensive empirical support for promoting skill acquisition and maintenance among individuals with developmental disabilities (Lovaas, 1987; Matson, Benavides, Compton, Paclawskyj, & Baglio, 1996; McEachin et al., 1993; Peters-Scheffer, Didden, Korzilius, & Sturmey, 2011; Weiss, 1999). The impact of applied behavior-analytic programming on skill development has been investigated most extensively among children with autism. These studies have offered overwhelming support for applied behavior analysis, particularly for children for whom intensive treatment (i.e., 30–40 hours per week) was initiated before age 5 (e.g., S. R. Anderson, Avery, DiPietro, Edward, & Christian, 1987; Butter, Mulick, & Metz, 2006; Graff, Green, & Libby, 1998; Harris & Handleman, 2000; Harris, Handleman, Gordon, Kristoff, & Fuentes, 1991; Lovaas, 1987; Peters-Scheffer et al., 2011; Reid, Phillips, & Green, 1991).

The benefits of applied behavior analysis are indicated, in part, by significant increases in IQ or decreased need for special education services for about half of all participants in applied behavior analysis–related early intervention programs (Butter et al., 2006; Weiss, 1999). General findings have suggested that behavioral intervention that begins earlier and more intensively is significantly more likely to increase functioning to within normal limits with regard to IQ, adaptive skills, and language (S. R. Anderson et al., 1987; Harris et al., 1991; Reid et al., 1991). In one seminal study, Lovaas (1987) reported that nine of 19 first graders with autism who received 40 hours per week of intensive applied behavior analysis programming successfully completed first grade and obtained average or above-average IQ scores. By comparison, those in a control group who did not receive intensive services did not achieve significant improvements in functioning. More recent studies have yielded similar results. For example, recent meta-analyses (Eldevik et al., 2009; Peters-Scheffer et al., 2011; Reichow & Wolery, 2009) have found clinically significant differences in increased IQ, receptive language, and expressive language scores for children who received early intensive behavioral intervention compared with children who did not. However, we should note that results were highly variable across studies and participants, suggesting a high level of diversity in skill and symptom presentation within this population.

Teaching Procedures

An applied behavior-analytic approach to skill acquisition and maintenance involves the application of general principles of operant learning theory, namely positive and negative reinforcement, extinction, shaping, and fading (Smith, 2001). Effective intervention is widely regarded as that which occurs in highly structured and contrived conditions as well as in more naturalistic, free-operant situations (S. R. Anderson, Taras, & Cannon, 1996; Ghezzi, 2007). Discrete trials training (DTT), which is typically conducted under tightly controlled analog conditions, is among the oldest and most renowned teaching approaches subscribing to an applied behavior analysis model. Its effectiveness in addressing skill deficits among individuals with developmental disabilities has repeatedly been demonstrated (e.g., S. R. Anderson et al., 1987; Birnbrauer & Leach, 1993; Lovaas, 1987; McEachin et al., 1993; Sheinkopf & Siegel, 1998; Smith, 2001); also, numerous home- and school-based curricula have called for the incorporation of DTT for this population (e.g., Leaf & McEachin, 1999; Lovaas, 1981, 2003; Maurice, Green, & Foxx, 2001; Maurice, Green, & Luce, 1996; Partington & Sundberg, 1998). DTT is generally regarded to be most effective in teaching specific, complex, and conditional discriminations (Cowan & Allen, 2007; Steege, Mace, Perry, & Longnecker, 2007). For example, Grindle and Remington (2005) used DTT to teach three children with autism to identify pictures of emotions.

DTT is rooted in principles of experimental psychology, and a primary goal of DTT is to achieve control over interactions between the teacher and the learner to identify variables contributing to responding (Ghezzi, 2007). Opportunities for learning (i.e., trials) are conducted by presenting the learner with antecedent events (e.g., materials or objects varying across a single dimension), noting the learner's response to these events (e.g., accurate vs. inaccurate responding), and delivering a consequence on the basis of the response (e.g., reinforcement vs. extinction). The delivery of the consequence marks the end of the trial and commencement of the intertrial interval, which immediately precedes the presentation of the antecedent event for the next trial. The teacher controls the duration of the intertrial interval and the extent to which trials are repeated, which marks the primary difference between the DTT and other free operant methods of promoting skill acquisition for which the beginnings and ends of learning opportunities are more vaguely defined and controlled by the learner (Ghezzi, 2007). As trials are repeated, the learner's responses are tracked and analyzed, and shaping or fading of antecedent and consequent events is conducted so that there is progression toward independent and consistent responding.

In contrast to analog methods such as DTT that involve the maintenance of a high level of stimulus control (e.g., trials are conducted in the same setting, the same stimuli and prompts are used repeatedly, and target responses are fixed), methods designed to facilitate generalization are loosely structured and involve the transfer of stimulus control (e.g., trials are learner directed, occur across myriad situations and settings, incorporate multiple stimuli and prompts, and reinforce multiple target responses; Delprato, 2001; Miranda-Linné & Melin, 1992; Stokes & Baer, 1977). Incidental teaching, the most frequently referenced method of naturalistic instruction, involves the promotion of generalization by appealing to the individual's reinforcer preferences (Cowan & Allen, 2007). More specifically, instruction is provided on an ongoing basis within typical activities based on student interest and motivation (McGee, Daly, & Jacobs, 1994), using strategies such as reinforcement (Vladescu & Kodak, 2010) and errorless learning (Touchette & Howard, 1984) to present learning objectives throughout the activities. Typically, the process begins after the teaching environment has been arranged with items and activities the individual is known to prefer and may serve as reinforcers. As the individual exhibits interest in a stimulus, the trial begins, often with the establishment of a motivating operation (e.g., access to the item is withheld). Within this situation, learners' responses are followed with the delivery of reinforcement (e.g., restored access to the preferred item), marking the end of the trial. Then, the teacher waits for the learner to initiate another trial or begins the next trial by reestablishing a motivating operation.

Although incidental teaching was originally designed for preschool-aged children, studies have shown that it can be effective with individuals ranging in age and ability (e.g., MacDuff, Krantz, MacDuff, & McClannahan, 1988; McGee, Morrier, & Daly, 1999). For individuals with intellectual and developmental disabilities, it is most commonly used as an intervention for verbal behavior and the development of spontaneous communication (e.g., Charlop-Christy & Carpenter, 2000; Farmer-Dougan, 1994; Hart & Risley, 1974, 1980; Kroeger & Nelson, 2006). However, studies have also demonstrated its effectiveness in developing social behaviors (e.g., McGee, Almeida, Sulzer-Azaroff, & Feldman, 1992; McGee & Daly, 2007) and academic skills (e.g., McGee, Krantz, & McClannahan, 1986; Miranda-Linné & Melin, 1992). For example, McGee et al. (1986) applied the incidental teaching model to the acquisition of sight-word reading skills among two autistic children. In the context of a preferred play activity, participants were provided with access to preferred toys by selecting the appropriate label for the toy. Both participants demonstrated rapid acquisition of sight words among a field of five choice discriminations as well as transfer of skills to other stimulus conditions.

Despite the distinct advantages of analog and naturalistic teaching methods, each type of approach has limitations. When used alone, the positive effects of DTT may be diminished, particularly when success is measured in nontesting conditions (McGee et al., 1992). Similarly, although the strength of naturalistic methods is in skill maintenance and transfer, they are limited in their effectiveness in promoting the acquisition of skills. Indeed, other approaches that have earned considerable empirical support—including pivotal response training (e.g., Koegel, Carter, & Koegel, 2003; Koegel, Koegel, & Carter, 1999), script fading (Krantz & McClannahan, 1993), direct instruction (Gersten, Keating, & Becker, 1988), and task analysis (Horner & Keilitz, 1975)—contain elements of both DTT and naturalistic teaching methods, suggesting that a combination may be optimal (Cowan & Allen, 2007).

Choosing the First Skills to Target for Training

Among individuals with developmental disabilities, skills that are initially targeted for intervention are typically those of severe deficit (Weiss, 1999), namely language skills, social skills, play and leisure skills, self-help, and other life skills. Language is a particularly vital skill, because difficulties communicating with and understanding others have been linked to challenging behaviors, social problems, and academic and learning problems (Cowan & Allen, 2007). Among the large amount of research that has been devoted to the development of spontaneous (or unprompted) language, the utility of incidental teaching in promoting verbal behavior and spontaneous communication has been especially well documented (e.g., Charlop-Christy & Carpenter, 2000; Farmer-Dougan, 1994; Hart & Risley, 1974, 1980; Kroeger & Nelson, 2006). Many of these studies described procedures similar to those originally developed by Hart and Risley (1974). In their seminal article, Hart and Risley sought to increase the frequency and quality of verbal requests for preferred items for 12 young children. Within each trial, the participant's access to a preferred item was denied, and the teacher progressed through a four-level sequence of least-to-most directive prompts to encourage the participant to exhibit the target verbal response. The first level of the prompting sequence, conducted when the participant exhibited interest in an item or activity, consisted of a 30-second delay. Next, the participant was generally prompted to ask for the desired item. After another delay, a more specific prompt was delivered (e.g., the teacher presented the toy to the learner and asked, "What is this?"). Finally, at the last level, the teacher modeled the correct response, and the participant was prompted to imitate the response. This method was initially used to teach participants to make requests using nouns (e.g., *paints, truck, ball*), then to state an adjective–noun combination (e.g., "some paints," "more ball"), and finally, to use a compound sentence (e.g., "I want a ball so I can bounce it"). Results indicated that as each requirement was made, participants' general use of that aspect of language markedly increased.

The general approach taken by Hart and Risley (1974) has been applied to the development of spontaneous communication skills (e.g., Jones, Feeley, & Takacs, 2007; Koegel, Camarata, Valdez-Menchaca, & Koegel, 1998; Koegel et al., 2003) and a host of other expressive and receptive language skills (Matson et al., 1996). One notable derivation of this method is functional communication training, which involves teaching an individual to exhibit communicative responses that are functionally equivalent to his or her challenging behaviors (Durand & Carr, 1991). In a typical functional communication training procedure, once the reinforcers maintaining an individual's problem behaviors have been identified, these reinforcers are withheld in response to problem behavior and provided in response to an appropriate communicative response. Functional communication training has proven effective in treating a variety of problem behaviors among individuals with disabilities ranging in age and level of functioning (Carr & Durand, 1985; Derby et al., 1997; Durand & Carr, 1991; Wacker et al., 1990).

Teaching Important Life Skills

Life skills—or skills that contribute to successful, independent functioning—have generally been accepted as important to social competence and overall quality of life (Cronin, 1996). Several studies have demonstrated successful use of applied behavior-analytic techniques in the acquisition of life skills, including money management and purchasing skills (e.g., Browder & Grasso, 1999; Frank & Wacker, 1986; Matson & Long, 1986); leisure skills (e.g., Collins, Hall, & Branson, 1997; Jerome, Frantino, & Sturmey, 2007); child care (Feldman & Case, 1999; Feldman, Ducharme, & Case, 1999);

and domestic skills such as cooking, cleaning, and doing laundry (e.g., Graves, Collins, Schuster, & Kleinert, 2005; Miller & Test, 1989; Rehfeldt, Dahman, Young, Cherry, & Davis, 2003; Shipley-Benamou, Lutzker, & Taubman, 2002). In these studies, common techniques include task analysis, modeling, shaping, and in vivo generalization, in which steps associated with a multistepped task are broken down into discrete, sequential steps and teacher support is faded until the learner demonstrates accuracy in an authentic, nontraining situation. For example, Shipley-Benamou et al. (2002) used task analysis and instructional video modeling to teach three individuals with autism and cognitive deficits to independently make orange juice, prepare and mail a letter, feed a pet, clean a fish bowl, and set a table. A multiple-probe design across tasks was used in which the learner was observed in a nontraining situation before and after watching a video that depicted step-by-step execution of the task. Results indicated that these components were effective in increasing accuracy across tasks and individuals, and results were maintained after withdrawal of the video in natural settings and after 1-month follow-up. In another study, Jerome et al. (2007) used backward chaining to teach three adults with developmental disabilities how to use the Internet. Specifically, using a multiple-baseline design across individuals, a most-to-least prompting procedure (i.e., hand-over-hand guidance, then hand-over-wrist guidance, hand-over-elbow guidance, and hand-over-shoulder guidance) was used to guide the learner through a 13-step process for accessing a preferred website. Starting with the last step, and as the learner demonstrated repeated success with the previous prompt, progressively less intrusive prompts were used to promote independent responding for each participant.

Applied behavior analysis has also provided substantial contributions to research on the acquisition and generalization of safety skills. The purpose of these studies are typically to teach individuals to identify and avoid contact with safety threats, escape from threatening situations, and inform others who may be able to provide assistance (Miltenberger, 2008). Often, procedures include instruction and modeling followed by the simulation of threatening situations during which the learner practices safety skills under supervision. Skills are then honed through praise and corrective feedback. Once the learner exhibits success under simulated conditions, procedures are repeated using multiple exemplars and common stimuli to generalize skills to other situations. These procedures, which summarize a behavioral skills training approach (Miltenberger, 2008; Miltenberger et al., 2004), have been shown to be more effective than traditional informational methods (e.g., Johnson et al., 2006; Miltenberger & Thiesse-Duffy, 1988; Wurtele, Saslawsky, Miller, Marrs, & Britcher, 1986) and have been used successfully to teach a wide range of safety skills, including pedestrian safety skills (Branham, Collins, & Schuster, 1999; Yeaton & Bailey, 1978), fire safety skills (Bannerman, Sheldon, & Sherman, 1991; Jones, Ollendick, McLaughlin, & Williams, 1989), the avoidance of firearms (Gatheridge et al., 2004; Himle, Miltenberger, Flessner, & Gatheridge, 2004), and use of self-protection techniques such as preventing abduction (Poche, Brouwer, & Swearingen, 1981; Poche, Yoder, & Miltenberger, 1988) and preventing sexual abuse (Egemo-Helm et al., 2007; Lumley, Miltenberger, Long, Rapp, & Roberts, 1998; Miltenberger et al., 1999; Wurtele et al., 1986).

APPLIED BEHAVIOR ANALYSIS IN EDUCATIONAL SETTINGS

Applied behavior analysis is well known for its contribution to special education practices pertaining to students with intellectual and developmental disabilities. It has greatly contributed to recent advances in education, particularly with regard to student behavior management, instructional design and curriculum development, and assessment (Martens, Witt, Daly, & Vollmer, 1999; Wolery, Bailey, & Sugai, 1988). In this section, we describe the major contributions of applied behavior analysis to special education, highlighting those of particular salience to individuals with intellectual disability.

The relevance of applied behavior analysis to special education is apparent in the features and ideals they share. Behavior analysis is an analytic and technological process that emphasizes the examination of observable behavior change among individuals (Baer, Wolf, & Risley, 1968). These principles are inherent to special education as well; their application is mandated by federal legislation including the Education for All Handicapped Children Act of 1975 and the Individuals With Disabilities Education Act of 1997 (IDEA). The importance of individualization in education is evident in the requirement that every student receiving special education and related services be provided with an Individualized Education Program. The Individualized Education Program describes short- and long-term educational and behavioral objectives in observable, measurable terms. It also includes statements regarding the student's present levels of functioning, appropriate evaluation procedures and schedules for determining whether objectives have been achieved, and projected dates for initiation of services and the anticipated duration of services (IDEA, 1997). Thus, in essence, the Individualized Education Program provides a blueprint for service delivery from an applied behavior-analytic orientation.

With recent reauthorizations of IDEA in 2004 and 2007, the association between applied behavior analysis and special education has become increasingly clear. In an effort to enhance accountability, schools have adopted more extensive data collection practices that provide evidence for effective instruction. Response to intervention and curriculum-based measurement are recent movements toward empirically supported practice in schools. These approaches were recently deemed permissible under IDEA (2004) as means of identifying students in need of special education and related services. Under a response-to-intervention model, students at risk for academic or behavioral problems are identified and monitored on the basis of their responses to evidence-based interventions. Consistent with an applied behavior-analytic approach, data are collected frequently, and assessment is integrated into intervention. Response to intervention involves determining how a student's individualized curriculum, which includes elements such as the content and schedule of instruction as well as the manner in which instruction is delivered (Dunlap, Kern, & Worcester, 2001), may account for educational successes and difficulties. Curriculum-based measurement, an alternative to comparing a student's performances to national norms, is an approach often used under a response to intervention. It involves the measurement of a student's advances toward individual goals relative to past performance and the performance of others who receive the same curriculum (Deno, 2003).

The influence of applied behavior analysis is also apparent in IDEA's guidelines for addressing student behavior problems in schools. With increased evidence supporting functional analysis and the identification of variables maintaining problem behavior (e.g., Iwata, Dorsey, Slifer, Bauman, & Richman, 1982/1994), IDEA (2004) requires that schools conduct a Functional Behavioral Assessment when a student's behavior is deemed disruptive to the educational environment such that it impedes the student's learning or the learning of others. FBA, based on procedures and rationale inherent to functional analysis (Iwata et al., 1982/1994), is the process of gathering information that provides insight into the functional relationships among variables associated with problem behavior. The process is designed to reveal patterns illustrating the contextual influences that set the occasion for and maintain occurrences of problem behavior. Results of the Functional Behavioral Assessment are used to develop individualized interventions on the basis of the problem behavior's function. Currently, IDEA does not stipulate the manner in which Functional Behavioral Assessment should be conducted. Perhaps as a result, functional assessment has involved the implementation of standard functional analyses, direct observation, the use of standardized and non-standardized teacher report measures, and the use of anecdotal observation data (Asmus, Vollmer, & Borrero, 2002; O'Connor et al., 2002). Thus, although the level of experimentation and accuracy involved in identifying behavioral function in schools is variable, the Functional Behavioral Assessment mandate ensures regard for the notion of function over form (Dunlap et al., 2001) and consideration of the contextual influences on behavior.

With increased application of functional assessment procedures in school settings, a shift has occurred away from reactive and punitive school-based behavior interventions toward those that are reinforcement based (Axelrod, 1987; Pelios, Morren, Tesch, & Axelrod, 1999). As stipulated by IDEA (1997, 2004), schools must consider the use of positive behavioral supports (or positive behavioral intervention strategies) as alternatives to those involving aversive or restrictive procedures (e.g., restraint, seclusion). *Positive behavioral support* is a general term that refers to the application of positive behavioral interventions and systems to achieve socially important behavior change (Carr et al., 2002). According to Wacker and Berg (2002), positive behavioral support constitutes a model of service delivery that incorporates procedures associated with applied behavior analysis and applies them at a school- or community-wide level. Although developed initially for students with significant disabilities who engaged in extreme forms of self-injury and aggression (Meyer & Evans, 1993), successful application of the technology has been demonstrated across a wide range of students and contexts at the individual and schoolwide level (Colvin, Sugai, Good, & Lee, 1997; Lewis, Sugai & Colvin, 1998; Todd, Horner, Sugai, & Sprague, 1999). The aim of positive behavioral support is to create and sustain school environments that promote change that is socially significant and culturally appropriate. A continuum of behavior supports is also a characteristic of a positive behavioral support model, with emphases placed on prevention and sustained use of effective practices (Sugai et al., 2000). C. M. Anderson and Borgmeier (2010) described a three-tiered model of increasingly intensive interventions (from schoolwide interventions to those targeting specific groups of individuals to highly individualized interventions) that can meet the needs of all students.

APPLIED BEHAVIOR ANALYSIS IN MEDICAL SETTINGS

Routine and specialized medical care can greatly enhance the health of children with disabilities. However, distress and noncompliance with medical procedures or regimens occur with both typically developing children (Dahlquist, 1992) and children with intellectual and developmental disabilities (Slifer, Babbitt, & Cataldo, 1995). Cooperation with various activities such as medical tests (e.g., venipuncture, endoscopy), electroencephalogram (EEG) or magnetic resonance imaging (MRI) procedures, pill swallowing, or treatments (radiation therapy, positive airway pressure) is necessary for prompt and accurate diagnosis and treatment of medical problems. For children with chronic medical conditions, cooperation and adherence may be crucial for effective health care. However, medical tests or treatments can be especially stressful and frightening for children with intellectual disability, given that they may not understand the rationale for the procedure, cannot perform the tasks required for cooperation, and may be unable to communicate their symptoms, fear, or discomfort (Slifer et al., 1995). Children may exhibit severe behavioral distress or avoidance behaviors including crying, screaming, hitting, attempting to leave the room, and tantrums that interfere with or preclude necessary medical procedures and treatment efforts. Distress and nonadherence may result in use of sedation, restraint, or anesthesia, which brings additional stress and risks to the child.

Methods of behavior analysis have been effectively applied in the medical setting to address a range of challenges faced by typically developing children and those with intellectual and developmental disabilities and consequently increase their opportunities to benefit from medical technology. Early research in this area focused on reducing child distress and anxiety during intensive care unit admissions (Derrickson, Neef, & Cataldo, 1993) and during painful medical procedures such as bone marrow aspiration, self-catheterization, needle sticks, and radiation treatments (Dahlquist, Gil, Armstrong, Ginsberg, & Jones, 1985; Jay, Elliott, Ozolins, Olson, & Pruitt, 1985; McComas, Lalli, & Benavides, 1999; Slifer et al., 1995). Subsequent studies have developed and applied a behavior-analytic model to modify anxiety and distress and increase adherence via the use of simulation of the medical procedure, counterconditioning (a procedure to reduce child anxiety via gradual exposure to the feared stimulus while simultaneously participating in a pleasurable or relaxing activity), distraction, and differential reinforcement. First, a task analysis of the necessary steps for successful completion of the medical procedure is developed. Then, the child's preferred activities (toys, snacks, prizes, etc.) are identified and incorporated into the medical routine. As possible, the medical environment is simulated or modified to make it more comfortable for the child. The child is given opportunities to make choices and to control some aspects of the environment or procedure that will not disrupt medical care, and he or she is gradually exposed to the steps required to complete the task. Using this approach, behavior therapists can simulate the medical environment and procedure and, using basic behavior analysis techniques such as differential positive reinforcement and counterconditioning, teach the child new skills, cooperation, and coping. Cooperation with the procedure and treatment effectiveness are measured by successful completion of steps in the task analysis and by the reduction of occurrence of escape or avoidance behavior. Thus, success with medical procedures can be ensured before expending medical staff time and resources.

To illustrate this approach, epilepsy is a neurological disorder that occurs in many children with intellectual disabilities and autism (Spence & Schneider, 2009). The EEG is a procedure used to record electrical signals from the brain, and results of this test are used to diagnose and monitor seizure disorders and response to pharmacological intervention. The EEG, which requires placement of electrodes or leads on the child's scalp, forehead, and upper face for an hour (standard EEG) or in some cases during sleep (overnight EEG), is often not well tolerated by children with intellectual and developmental disabilities. Unfamiliarity with the equipment, tactile defensiveness, and difficulty inhibiting motion may provoke distress and noncompliance with the procedure. Slifer, Avis, and Frutchey (2008) used modeling, counterconditioning, escape extinction, and differential reinforcement to teach seven children with intellectual and developmental disabilities to cooperate with EEG procedures. During brief training sessions with a behavior therapist, each child was systematically and gradually exposed to the EEG environment, the lab technician, and the EEG leads to counteract conditioned anxiety from negative experiences in previous EEG attempts or other medical procedures. Cooperation, instruction following, and tolerance of completed steps in the task analysis were reinforced with praise and tokens; negative vocalizations were ignored, and escape and avoidant behaviors (e.g., removing the leads) were blocked and ignored. At the end of each session, tokens were exchanged for a tangible reinforcer. Training sessions were paced to challenge and teach the child with minimal distress. Additionally, parents and medical staff were trained via modeling to provide appropriate verbal interaction, differential reinforcement, and escape extinction before the actual EEG procedure. After behavioral training, six of the seven children successfully completed their EEG without sedation, restraint, or anesthesia and with minimal distress. More recently, this training procedure was used successfully with overnight EEGs for 17 children with Smith-Lemli-Opitz syndrome (DeMore, Cataldo, Tierney, & Slifer, 2009).

A similar approach has been used to teach children to cooperate with neuroimaging (Slifer, Cataldo, Cataldo, Llorente, & Gerson, 1993). MRI and functional MRI (fMRI) are noninvasive diagnostic procedures that require the patient to lie still for 20 to 60 minutes inside a loud, enclosed scanner. Slifer, Koontz, and Cataldo (2002) developed a behavioral training procedure to teach participants—two typically developing children, one child diagnosed with attention-deficit/hyperactivity disorder (ADHD) and one diagnosed with ADHD and fetal alcohol syndrome—the motion control and task performance required for fMRI. Training was conducted using a simulated fMRI scanner, consisting of a stretcher, a plastic tube-slide, a scanner façade depicting a spaceship, a helmetlike head coil with attached mirror, and tape-recorded fMRI noises. Head motion (in millimeters) was continuously measured via two potentiometers connected to the child's forehead and a desktop computer, which converted head movement to digital data. Task performance (percentage of correct responses) was assessed via a vigilance task typical of what might be required during fMRI. The child lay in the mock scanner, watched a videotape on a color monitor, and pressed a thumb button when a specified stimulus (e.g., blue square) appeared and disappeared. Seven-minute simulated scans were conducted to evaluate training effects using a multiple-baseline design across participants. During baseline, a brief demonstration was provided on how to lie down in the scanner, hold very still, and perform the vigilance task; no feedback on head motion or task performance was provided. During differential positive reinforcement, baseline session results were reviewed, the participant selected a reinforcer for improved performance, and the baseline demonstration was repeated. After each mock scan, reinforcement was provided contingent on improvement in both head control and task responding. Differential reinforcement was successful in modifying all children's motion control and task performance during simulated scans.

Training procedures based on applied behavior analysis have also been used successfully to teach children with chronic medical conditions and developmental disabilities the skills necessary for them to benefit from prescribed medical care (Babbitt, Parrish, Brierley, & Kohr, 1991; Slifer et al., 1995). In one study, Beck, Cataldo, Slifer, Pulbrook, and Ghuman (2005) taught four typically developing children with ADHD and four children with autism to swallow pills. In baseline, children with ADHD were reported to exhibit behavioral distress (e.g., negative vocalizations), whereas children with autism displayed no distress but engaged in disruptive behavior (chewing the pill; expelling the pill; avoidance behaviors of turning head, blocking with hands, or clamping teeth or lips shut). Training sessions were conducted by behavior therapists in an outpatient psychology clinic using mock pills (cake decorations or capsules) of gradually increasing size (a total of nine different-sized pills or capsules). One-hour sessions were conducted with participants with ADHD; because of cognitive and behavioral characteristics, 10-minute sessions were conducted for children with autism. Given that all children had a history of noncompliance and distress behaviors, a desensitization approach integrating graduated exposure and differential reinforcement was used. The initial session began with presentation of the smallest candy cake decoration in the mock pill hierarchy to create a neutral, safe learning environment and to allow the child to experience success. This success facilitated positive behavioral momentum for subsequent introduction of larger pills in the hierarchy. Specifically, during each trial the child was prompted to open his or her mouth and stick out his or her tongue; the therapist placed the mock pill on the back of the child's tongue and provided a preferred drink for the child to drink and swallow. Disruptive or avoidance behaviors were blocked, ignored, or both. Praise and a preselected tangible reinforcer were provided contingent on pill swallowing. Participants were required to swallow mock pills of the same size on two consecutive trials without exhibiting disruptive behavior before proceeding on to the next larger size in the hierarchy. Concurrent with the child's course of training in the clinic, all parents developed a medication administration routine at home, and parents of children with autism were trained to practice the mock pill-swallowing routine with their child at home between behavioral training sessions. Once each child demonstrated successful swallowing of the terminal pill size (i.e., that which matched their prescribed medication), the actual pill or placebo was presented to generalize skills acquired during training sessions. Finally, parents were trained to administer the actual prescribed medication at home; the protocol was complete when the child successfully swallowed his or her medication for 7 consecutive days. Results indicated that seven of the eight children successfully swallowed medication in the clinic with the therapist, and six of the eight children maintained treatment gains at home with parent-administered medication.

Researchers have also developed behavioral training procedures to increase child adherence to positive airway pressure (PAP) therapy, a medical intervention prescribed for children with persistent obstructive sleep apnea. Obstructive sleep apnea occurs in 1% to 3% of preschool-age children (American Thoracic Society, 1996). Obstructive sleep apnea and related breathing problems can lead to disturbed sleep, daytime behavior problems, poor school performance, and neurocognitive impairment and if left untreated may produce life-threatening complications such as failure to thrive (Koontz, Slifer, Cataldo, & Marcus, 2003). For children who do not improve with adenotonsillectomy or who are not candidates for this surgery, PAP therapy is the most frequently recommended alternative intervention. PAP devices produce either continuous delivery of air at a constant pressure or the pressure during exhalation may be lower than that of inhalation (bilevel PAP). The forced air is administered to the child via a snug-fitting mask that is worn over the nose and mouth during sleep. PAP therapy is very effective when compliance is high. However, adherence with PAP therapy is difficult because children often verbally or physically resist attempts to put on the mask or they develop conditioned anxiety, and parents have difficulty managing child distress and avoidance behaviors. Behavioral interventions have been shown to be effective with typically developing children with medical complications who resist PAP application (Koontz et al., 2003). In that study, a task analysis (ordered sequence of component steps) of child behavior necessary for PAP compliance was delineated, and a treatment package of differential positive reinforcement, graduated exposure to the PAP equipment, counterconditioning via provision of distracting or reinforcing activities, and avoidance prevention strategies was developed. Children and parents who received either (a) a 90-minute behavioral consultation plus written recommendations or (b) structured behavioral therapy (one to three appointments) were able to achieve PAP compliance at home, leading to effective obstructive sleep apnea management; in contrast, PAP compliance did not increase for patients and families who did not participate in services.

More recently, Slifer et al. (2007) adapted the Koontz et al. (2003) training procedures for pediatric inpatients with developmental disabilities who required PAP therapy. Four preschool-age children with developmental disabilities, serious health impairments (diabetes, cor pulmonale, failure to thrive), and severe resistance to bilevel PAP therapy participated. During baseline, each child was observed during PAP placement attempts at naptime or bedtime. Data were collected on adherence to each step in the PAP task analysis and adherence to mask wearing during each 1-hour interval of sleep. A treatment package consisting of provision of preferred activities for distraction and counterconditioning, graduated exposure to steps in the task analysis, differential reinforcement of adherence, and extinction for avoidance and escape behaviors was implemented by behavior therapists and evaluated using a nonconcurrent multiple-baseline design across participants. After treatment, parents and nurses were trained using modeling, verbal and written instruction, role play, in vivo behavioral reversal with the child, and provision of corrective feedback. Results indicated that all of the children were able to successfully tolerate PAP and increase hours of PAP adherence per day from 0 to a mean of 8 hours per day in treatment.

BEHAVIORAL TREATMENT APPROACHES TO CLINICAL CONDITIONS

Applied behavior analysis may be best known for its success in the assessment and treatment of clinical conditions related to intellectual and developmental disabilities. Three clinical disorders—autism, ADHD, and severe behavior disorders—are covered in Chapters 12, 14, and 15 of this volume, so we address them only briefly here. First, as previously discussed, considerable empirical evidence has documented the efficacy of comprehensive, intensive behavior-analytic treatment for young children with autism (Lovaas, 1987; Matson et al., 1996; McEachin et al., 1993; Smith, Groen, & Wynn, 2000). The substantial gains across social, cognitive, language, and education domains first demonstrated by Lovaas (1987) and McEachin et al. (1993), although not fully replicated, have been supported by studies comparing intensive behavioral treatment to standard early intervention programs for children with autism and to special education programs for children with disabilities (Eikeseth, Smith, Jahr, & Eldevik, 2002; Howard, Sparkman, Cohen, Green & Stanislaw, 2005; see also Chapter 12, this volume).

Applied behavior analysis has played a similarly critical role in the development of effective treatment approaches for ADHD. Applied behavior analysis is now viewed as an essential component of intervention for ADHD (Arnold et al., 2004; Jensen et al., 2001); indeed, Denckla (2008) noted that applied behavior analysis should be considered the infrastructure that supports medication and other aspects of multimodal intervention (see Chapter 15, this volume).

One of the most serious problems exhibited by individuals with intellectual and developmental disabilities is severe problem behavior. Problem behaviors such as self-injurious behavior (head banging, self-biting), aggression (hitting, kicking others), and property destruction not only cause injury to the individual or caregiver and disrupt the environment but also present significant challenges for caregivers and service providers. More important, the presence of behavior disorders often results in increased social isolation and decreased educational, vocational, and leisure activities and increases the likelihood that individuals will require specialized services, including those individuals outside of the home in residential treatment settings or group homes (Schroeder et al., 2001).

With regard to treatment of behavior disorders, psychotropic medications are often administered to people with intellectual and developmental disabilities. Indeed, studies have shown that between 25% and 40% of individuals in community settings and 35% and 50% of those living in institutions were prescribed psychotropic medication (Jacobson, 1998; Pyles, Muniz, Cade, & Silva, 1997). There are multiple concerns with this approach, including questionable efficacy, risk of negative side effects, and overmedication. Reviews by Baumeister and Sevin (1990) and Matson and colleagues (Matson et al., 2000; Matson & Neal, 2009) examining psychopharmacological treatment research over three decades all came to two similar conclusions: First, use of such medications for severe behavior problems has limited empirical support at best; second, despite the demonstrated efficacy of behavioral interventions (reviewed shortly), they are to some extent ignored in clinical practice.

The research literature has, however, provided extensive support for the use of functional analysis procedures and function-based intervention as the best practice in assessment and treatment of severe behavior problems (Iwata et al., 1982/1994; Iwata et al., 1994; see also Chapter 14, this volume). Functional analysis consists of a multistage process for identifying variables that may occasion or maintain problem behavior. Hypotheses as to possible functions served by the behavior are first derived via interview with caregivers. Subsequently, analogous conditions are arranged in a controlled setting that mimics circumstances in an individual's environment that have potential to evoke and maintain problem behavior. Typically, such conditions involve manipulations of the levels of attention for problem behavior, the availability of escape from tasks, or the removal of preferred items, or they simulate an understimulating environment (Iwata et al., 1982/1994). A control condition is also arranged in which each variable is accounted for; typically, it includes high attention, absence of demands, and the availability of highly preferred items. Differential responding in any of the conditions demonstrates that the variable in question maintains problem behavior. Epidemiological and empirical studies have demonstrated that in most cases, problem behavior serves to communicate situational social needs, such as seeking attention from others, obtaining preferred items, or escape from nonpreferred activities (Carr & Durand, 1985; Hanley, Iwata, & McCord, 2003; Iwata et al., 1982/1994). Once a function for problem behavior is identified, a function-based intervention is derived on the basis of assessment results (e.g., a child exhibiting attention-maintained problem behavior is taught to appropriately request adult attention).

Functional analysis procedures have also been successfully applied to other clinical conditions associated with intellectual and developmental disabilities. For example, elopement (leaving an area without supervision or caregiver consent) is a serious behavior problem exhibited by individuals with disabilities (Jacobson, 1982). Elopement may interfere with participation in educational, social, or vocational activities, but of greater concern is that it may place the individual at risk for injury (e.g., running into traffic; Piazza, Hanley, et al., 1997). Despite the prevalence and seriousness of the problem, research on assessment and treatment of elopement has been limited, in part because of the difficulty in understanding the contextual variables and because of the challenges in safely assessing the behavior. Lang et al. (2009) reviewed the literature on behavioral treatment of elopement. Two major findings were that (a) elopement may often be maintained by operant contingencies and (b) functional analyses and function-based treatments were most effective in reducing elopement. To illustrate, Piazza, Hanley, et al. (1997) conducted functional analyses of elopement exhibited by three children with developmental disabilities admitted to an inpatient unit. Specifically, functional analysis procedures (Iwata et al., 1982/1994) were modified to identify potential environmental variables maintaining elopement. Ten-minute sessions were conducted in a setting that simulated the natural environment in which elopement was likely to occur for each participant but that was safe for repeated sessions. Attention, tangible, and demand sessions were conducted to determine whether the child engaged in elopement to gain access to adult attention, tangible items, or escape from tasks, respectively. In cases in which functional analysis results were unclear, reinforcer assessments were conducted to clarify behavioral function. Results indicated that for two children, elopement was maintained by access to tangible items, and for a third participant, elopement was maintained by access to adult attention. More recently, Tarbox, Wallace, and Williams (2003) successfully replicated this function-based approach to assessment and treatment of elopement in a study conducted in the natural environment, with parents serving as therapists during assessment and treatment sessions.

Beyond the treatment of autism, ADHD, and severe behavior problems, methods of applied behavior analysis have also been successfully applied to the assessment and treatment of a range of other clinical problems and conditions. For example, individuals with disabilities often exhibit feeding problems such as food refusal (the refusal to eat all or most foods presented), food selectivity (consumption of select foods or food groups and refusal of others), and meal-related problem behaviors (head turning, crying, throwing food, vomiting). In most cases of food refusal, there is a comorbid medical diagnosis such as gastroesophageal reflux, cardiopulmonary conditions, neurological conditions, food allergies, or anatomical anomalies (Williams, Field, & Sieverling, 2010). The prevalence of feeding problems among children with intellectual and developmental disabilities is quite high, with estimates ranging from 35% (Dahl & Sundelin, 1986) to as high as 90% in children with autism (Kodak & Piazza, 2008). The complications from feeding problems can be serious and include malnourishment, lack of growth, failure to thrive, and reliance on supplemental tube feeding (Williams et al., 2010).

Much of the behavioral research has focused on treatment to increase acceptance and decrease problematic mealtime behavior in children with disabilities; results have indicated that treatments based on operant consequences are effective (e.g., Ahearn, Kerwin, Eicher, Shantz, & Swearingin, 1996; Cooper et al., 1999). Research on the assessment of feeding problems has focused primarily on functional analysis of inappropriate mealtime behaviors. In the first such study, Piazza et al. (2003) conducted initial descriptive assessments with six parents and their children to identify potential reinforcers for inappropriate mealtime behaviors. Parents were observed feeding their children a meal as they typically did at home. Data were collected on the child's appropriate (accept a bite of food or swallow a drink) and inappropriate (head turning, throwing food or utensils, crying, food expulsion, vomiting, self-injury, aggression) behavior. Data on parent responses were also collected, specifically parent provision of verbal attention (reprimands or coaxing), removal of the bite or meal termination, or delivery of a preferred food or toy within 10 seconds of an inappropriate behavior. Results were consistent across parents in that all provided a variety of consequences contingent on food refusal behaviors, including attention, escape, and tangibles. All parents provided attention and removed food after inappropriate behavior, and half of the parents provided access to a tangible item. Next, Piazza et al. conducted functional analyses (e.g., Iwata et al., 1982/1994) of food refusal behaviors for 15 children to determine the extent to which each of these consequences functioned as reinforcement for inappropriate behavior. Brief meal sessions were conducted by behavior therapists wherein a bite of food and a verbal instruction were presented, and data were collected on appropriate and inappropriate behaviors as described earlier. Inappropriate mealtime behaviors resulted in one of three types of consequences—removal of the spoon of food (escape condition); provision of verbal coaxing or statements of concern (attention condition); or provision of preferred toy, food, or drink (tangible condition). A baseline (play) condition was also conducted. Functional analysis results indicated that all children exhibited inappropriate mealtime behaviors during the test conditions.

Indeed, 90% of participants displayed problem behavior sensitive to negative reinforcement, suggesting that escape plays a primary role in the maintenance of feeding disorders. Also, more than 50% of children exhibited behavior maintained by positive reinforcement. Overall, these finding suggest that functional analyses could serve to identify the reinforcers for feeding problems. More important, as seen with self-injury and other behavior problems, functional analysis results can be used to guide development of highly specific and effective interventions (i.e., those based on the function of the behavior) for inappropriate mealtime behavior.

More recent studies have replicated and extended Piazza et al.'s (2003) research in several ways: assessment and treatment of mealtime behavior problems that are maintained by multiple sources of reinforcement (Bachmeyer et al., 2009), feeding problems of children with autism (cf. review by Volkert & Vaz, 2010), descriptive analyses of 25 children with feeding problems (Borrero, Woods, Borrero, Masler, & Lesser, 2010), and functional analyses of inappropriate mealtime behaviors among six autistic children with parents serving as therapists during sessions (Najdowski et al., 2008).

Another problem affecting both children with disabilities and their families is disorders of sleep (see Chapter 17, this volume). Sleep problems include irregularity in sleep–wake patterns, decreased total hours of sleep, night and early morning waking, and behavior problems at bedtime. Children with intellectual and developmental disabilities experience a greater prevalence and greater severity and chronicity of sleep problems than typically developing children (Ingrassia & Turk, 2005). Estimates of the prevalence of sleep disorders in children with disabilities have ranged from 30% to 51% (Didden, Korzilius, van Aperlo, van Overloop, & deVries, 2002; Quine, 1991); the prevalence is higher among children with more severe intellectual disability (Didden et al., 2002) and children with autism (Polimeni, Richdale, & Francis, 2005). Sleep difficulties also have a broader impact, as evidenced by findings that sleep problems are associated with more severe child behavior problems (Didden et al., 2002) and increased stress, depression, and anxiety in mothers (Chu & Richdale, 2009).

Treatment of sleep problems in children with disabilities typically involves use of medication or behavioral interventions. With regard to medication, the research on its use with children with disabilities is limited, and most of the studies are uncontrolled or use small sample sizes (Sajith & Clarke, 2007). However, clonidine (Ingrassia & Turk, 2005) and melatonin (Sajith & Clarke, 2007) have shown some promise, and melatonin in particular seems to be free of serious adverse effects. Behavioral interventions such as chronotherapy (systematically delaying bedtime until the individual goes to bed and falls asleep at the desired time; e.g., Piazza, Hagopian, Hughes, & Fisher, 1998), bedtime fading (delaying bedtime and, over the course of multiple nights, adjusting bedtime in 15- to 30-minute intervals to approximate the target bedtime), and extinction (ignoring the children's bedtime behavior problems) have been shown to be effective in improving sleep difficulties (Didden & Sigafoos, 2001).

One behavioral intervention that has been successful in reducing sleep problems of children with intellectual and developmental disabilities is faded bedtime with response cost (Piazza & Fisher, 1991). This intervention involves systematically delaying the child's bedtime, removing the child from bed if sleep is not initiated within 15 minutes (response cost), and gradually advancing (fading) the bedtime back to the child's target bedtime. Piazza and Fisher (1991) evaluated faded bedtime plus response cost with four children with disabilities and severe behavior problems admitted to an inpatient hospital. All children had histories of unsuccessful medication trials for sleep problems. Throughout the study, 24-hour direct observation data were collected by staff using a 30-minute momentary time-sampling procedure; data were collected on whether the child was awake, asleep, in bed, or out of bed. During baseline, the child was permitted to sleep or wake; however, sleep was interrupted for meals, daily care, medical procedures, and therapies. In the evening, a bedtime routine was followed, and the child was periodically prompted to go to bed, similar to what parents reported was done at home. After baseline and review of sleep–wake data, a later bedtime at which rapid sleep onset (i.e., within 15 minutes) was highly probable was determined. Developmental norms of appropriate hours of sleep were used to determine the average number of hours of sleep required for each child; target sleep and wake times were then set in consultation with parents. The child was not allowed to go to bed or fall asleep before the bedtime and was not allowed to sleep past the scheduled wake time. If the child fell asleep within 15 minutes of the set bedtime, the bedtime was made 30 minutes earlier the next night (faded). If the child did not fall asleep within 15 minutes of the bedtime, he or she was removed from bed and kept awake another hour and then returned to bed (response cost); this procedure was repeated until the child fell asleep within 15 minutes of bedtime. Results indicated that all four children had increased nighttime sleep after treatment; additionally, two of the four children had decreased daytime sleep, and three of the four experienced decreased night wakings.

The faded-bedtime-with-response-cost protocol has been compared with other behavioral interventions. Piazza, Fisher, and Sherer (1997) randomly assigned 14 children with developmental disabilities and severe behavior problems to either a faded-bedtime-with-response-cost group or a bedtime scheduling group. Results indicated that children in the faded-bedtime-plus-response-cost group had significantly improved sleep (reduced night waking, early waking, and delay to sleep onset) compared with children in the bedtime scheduling group. Similar to Piazza and Fisher's (1991) study, this study was conducted with children admitted to an inpatient unit; however, the faded-bedtime-plus-response-cost intervention was successfully replicated in a home setting with parents as therapists (Ashbaugh & Peck, 1998).

CONCLUSION

In this chapter, we have reviewed research from the field of applied behavior analysis on the treatment of conditions associated with intellectual and developmental disabilities. Although by no means exhaustive, our review has highlighted effective behavioral interventions for skill deficits, educational problems, medical problems, and clinical conditions that have led to improved health, quality of life, and outcomes for this population. Additional research is needed, however, in areas such as early identification, intervention, and prevention for many conditions and problems as well as treatment of problems associated with aging in people with intellectual and developmental disabilities.

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Chapter 12

BEHAVIORAL APPROACHES TO THE TREATMENT OF AUTISM

William H. Ahearn and Jeffrey H. Tiger

Autism spectrum disorders (ASDs), which include autism, Asperger's disorder, Rett's disorder, childhood disintegrative disorder, and pervasive developmental delay—not otherwise specified, are a complex set of neurobehavioral developmental disorders that are diagnosed in every 110 to 150 live births (Centers for Disease Control and Prevention, 2006, 2007). These and other recent estimates of prevalence have suggested that about 1% of the population is diagnosed with an ASD (e.g., Kogan et al., 2009). Many have referred to autism as an epidemic with an assumption that this increase has some underlying environmental cause (e.g., Hertz-Picciotto & Delwiche, 2009). However, the rise in autism prevalence is most likely primarily the result of improved recognition, surveillance, and the expansion of diagnostic criteria (e.g., Shattuck, 2006; Wing & Potter, 2002).

The causes of these disorders are not known, although a combination of genetic and environmental factors is believed to contribute to their development (e.g., Grafodatskaya, Chung, Szatmari, & Weksberg, 2010; Nicolson & Szatmari, 2003); despite wide speculation, it is clear that autism does not result as a side effect of childhood vaccinations (for a review, see Institute of Medicine, 2004). The diagnosis of an ASD is made on the basis of three categorical markers of behavioral deficits and excesses. Specifically, ASDs are characterized by impairments in communication, by decreased interest in the social environment, and by the presence of restricted activities, interests, and behavior (American Psychiatric Association, 2000; World Health Organization, 1994).

ASDs are considered a spectrum disorder in that children may show varied levels of impairment both within and across behavioral categories as well as in the presentation of related behavioral symptoms (i.e., cognitive impairment, problem behavior). That is, some children may present with very severe social and communicative deficits, and others may show marginal impairment in either category (Helt et al., 2008; Wing, 1988, 1992). In addition to variability in severity, children will also vary in age at symptom onset (e.g., Charman & Baird, 2002; Fein et al., 1999; Filipek et al., 2000). For instance, severe communication deficits may become apparent by 18 to 24 months. In other cases, children may meet their normal milestones until 48 to 60 months before showing a rapid deterioration in communication; this particular pattern is characteristic of individuals with childhood disintegrative disorder (Mouridsen, 2003).

The untreated prognosis for individuals with ASDs varies on the basis of the disorders' severity, but one thing is clear—their outcomes are optimized by structured behavioral interventions targeted at addressing the core and associated deficits of autism (Eldevik et al., 2010). In this chapter, we cover one such approach, frequently called behavioral or applied behavior analysis (ABA), which is based in a functional analysis of the idiosyncratic interactions between individuals' behavior and their environment. In what follows, we make the case that the ABA approach has the greatest amount of empirical support for its effectiveness and summarize some of the foundational assumptions of behavior

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and intervention techniques that characterize this approach to treating autism.

EVIDENCE SUPPORTING THE APPLIED BEHAVIOR ANALYSIS APPROACH TO TREATING AUTISM

The development and validation of behavioral interventions for treating autism spectrum and related intellectual and developmental disorders, problem behavior, and learning deficits has an approximately 50-year history (see Volume 1, Chapter 4, this handbook). The socially significant outcomes produced by applying the principles of behavior analysis have led to a new perspective on the importance of a behavioral approach to understanding human behavior. From this perspective, disorders of development and delays in learning are treatable, not static. Focused intervention can produce marked improvement. Although we focus on the application of behavior analysis for treating people with ASDs, behavior analysis has been applied to nearly every population, including people with other intellectual or developmental disabilities, learning disabilities, traumatic brain injury, and other neurologically based problems (see Austin & Carr, 2000). Behavior analysis has also been used in teaching typically developing children and adults. These applications have ranged from individual consultation to organizational management, but behavior analysis has been most thoroughly applied and recognized in the educational and clinical management of autism.

The importance of developing effective interventions for ASDs is not in question. Given the aforementioned prevalence of ASDs, caring for individuals who cannot function independently as adults has substantial societal costs. Teaching those with ASDs the skills to become as independent as possible and to be productive members of society is a wise long-term investment (Ganz, 2007; Jacobson, Mulick, & Green, 1998). ABA has become accepted as an effective treatment for autism (e.g., American Academy of Pediatrics, 2001; National Institute of Mental Health, 2007; New York State Department of Health, 1999a, 1999b, 1999c; U.S. Department of Health and Human Services, 1999); no other intervention strategy can claim to be more effective.

The best-known studies of ABA were conducted by Lovaas and his colleagues (Lovaas, 1987; McEachin, Smith, & Lovaas, 1993; Sallows & Graupner, 2005; T. Smith, Groen, & Wynn, 2000). The initial Lovaas studies (Lovaas, 1987; McEachin et al., 1993) showed that 47% of the young children who received approximately 40 hours per week of intensive ABA for 2 to 3 years were successfully transitioned into a typical school setting. Only 2% of the comparison group achieved this outcome. Subsequent findings suggested that the percentage of children who successfully integrated into the public school setting may be lower than that in the initial Lovaas (1987) study. For example, T. Smith et al. (2000) provided intensive ABA for 25 hours a week for approximately 33 months, but only four of 15 children were successfully transitioned to a typical school setting. We should note that 13 of the 15 children in this study were mute at the start of intervention, a much higher percentage than in the initial Lovaas study. Additionally, the intensity of service was also lower.

A more recent study by Sallows and Graupner (2005) replicated the initial Lovaas (1987) results while randomly assigning subjects to a group that received clinic-directed services similar to those provided in the original study or to a group for whom services were as intense but were parent directed (i.e., parents were trained to implement services with support from applied behavior analysts). Children in both groups had comparable gains in intelligence test scores and adaptive function, with 48% of children across groups being successfully integrated into the public schools by age 7. They also found that success was best predicted by a child's preintervention language, imitation, and social skills (i.e., children presenting with higher baseline skills tended to be those most sensitive to the effects of intensive ABA). However, tangible benefits also seem to occur even for those children who require substantial supports in a regular education setting or who require specialized educational and clinical services relative to those that do not receive intensive ABA services (e.g., Kasari, 2002).

As of the writing of this chapter, at least 10 controlled (with about 25 other systematic comparisons with lesser control) group-design treatment comparisons have supported the efficacy of early intensive behavioral intervention for autism (for a thorough description of the components of this intervention strategy, see Green, Brennan, & Fein, 2002). These studies have been criticized on several variables that could affect their outcomes. One such variable is sample size (e.g., Kasari, 2002). To address this concern, Eldevik et al. (2009) conducted a meta-analysis of nine of these studies (one controlled treatment comparison, Dawson et al., 2010, was not published before the meta-analysis). The intensive ABA treatment group had 297 children with an ASD, a control group had 105 children with an ASD, and a comparison treatment (i.e., not intensive ABA) group had 39 children with an ASD. The meta-analysis suggested that intensive ABA produced a large positive effect on full-scale intelligence scores (effect size = 1.1) and a positive moderate effect on adaptive behavior (effect size = .66). A second criticism of the studies of intensive ABA for autism has been that they were not randomized clinical trials. However, two randomized trials have been conducted (Dawson et al., 2010; T. Smith et al., 2000), with early intensive behavioral intervention showing gains similar to those reported in the meta-analysis by Eldevik et al.

We should note an important caveat when comparing ABA intervention with standard early intervention services or "eclectic" treatment that may include behavioral intervention. The available evidence has suggested that eclectic intervention does not produce a positive impact (Eldevik et al., 2009; Howard, Sparkman, Cohen, Green, & Stanislaw, 2005). Howard et al. (2005) found that after more than a year of service delivery, children in the intensive ABA group had gained substantially more skills than either of the two comparison groups, one of which consisted of eclectic treatment including behavioral intervention. These findings suggest that ABA alone is superior to an eclectic intervention that combines ABA with unproven treatments, which may be the result of the time allocated to the unproven treatments reducing the amount of time allocated to ABA.

Early intensive ABA for children with autism is geared toward directly teaching developmentally appropriate skills (i.e., those that same-aged typically developing peers are exhibiting) and designing clinical interventions for their problem behaviors. Dawson and Osterling (1997) outlined the common elements of effective service provision to children with autism. These elements include curricula, or specific instructional procedures, geared toward teaching children to more effectively attend to the world around them. Some of the most important skill sets to teach children with autism include imitation (observational learning or learning effectively on the basis of consequences that others experience is a higher order form of imitation that is also important), communication (expressive and receptive), play, and social behavior. Dawson and Osterling added that these skills should not only be taught but that clinicians and educators must also design interventions so that they maximize the probability that skills will generalize across relevant contexts (see Stokes & Baer, 1977, for a useful discussion of techniques for promoting generalized behavior change). Another critical component of effective intervention noted by Dawson and Osterling is the use of functional assessment technologies in the treatment of problem behavior (see Chapter 14, this volume). For example, functional assessment and intervention have proven effective in the treatment of problem behavior such as self-injury and aggression, which are present in 6% to 30% of individuals with autism (Bartak & Rutter, 1976; Schroeder, Schroeder, Smith, & Dalldorf, 1978).

BASIC TOOLS OF BEHAVIOR ANALYSIS

Before we endeavor to explain ABA therapy, a brief primer on the principles of learning on which this therapy is based is warranted. ABA therapy is heavily grounded in the principles of operant conditioning. Simply stated, nearly every behavior affects an individual's environment. Some of those behaviors create an improvement in the immediate environment, and as a result these behaviors are more likely to happen in the future. When a consequence follows a behavior, and the behavior becomes more likely to occur in the future as a result, it is referred to as *reinforcement,* or the strengthening of behavior by environmental consequences. For instance, saying "please" may increase the likelihood that people's requests are honored and therefore they are more likely to say "please" in the future. When a response results in the addition of something to the environment, it is referred to as *positive reinforcement*. Behavior may also be strengthened by the contingent removal of something from the environment. For instance, a person may press the "off" button to terminate the sound of an alarm clock. This example illustrates negative reinforcement (because a stimulus is removed from the environment contingent on behavior).

The effects of reinforcement on behavior are not necessarily permanent. Just as the delivery of a particular event may result in an increase in behavior, if the behavior ceases to produce that consequence, the behavior will decrease. This process is evident when placing coins into an out-of-order vending machine or attempting to twist the doorknob of a locked door. Inserting coins, pressing buttons, or twisting the doorknob will persist briefly but will eventually stop when the reinforcer (soft drink or an open door) is not forthcoming. This process is referred to as *operant extinction* and is critical for the reduction of problem behavior.

Through operant conditioning, people learn not only what behaviors will result in reinforcement but also when they will result in reinforcement. For instance, when approaching a plugged-in vending machine with the lights illuminated, people are more likely to insert their coins than when they encounter a darkened machine with a severed cord. In this instance, people's behavior is under stimulus control. Stimuli associated with the availability of a reinforcer are called *discriminative stimuli* (S^Ds). An individual's behavior is described as discriminated when it is more likely to occur in the presence than in the absence of the S^D.

Finally, not all consequences of behavior result in an environmental improvement; some result in a worsening. When the worsening occurs contingent on a behavior and the subsequent probability of that behavior decreases, it is referred to as *punishment*. Punishment may involve either the removal of reinforcers (negative punishment) or the presentation of aversive stimulation (positive punishment).

Effective behavioral intervention for autism is thoroughly grounded in these principles of learning theory. That is, behavior analysts arrange conditions to (a) reinforce important social and communicative behaviors, (b) bring these behaviors under stimulus control, and (c) arrange for the extinction or punishment of problematic behaviors such as aggression or self-injury. Operant learning research has provided an understanding of how people learn, which has laid the foundation for designing procedures to teach skills to those with learning deficits.

FIRST STEPS TO INTERVENTION: ADDRESSING PROBLEM BEHAVIOR

Individuals with autism present with a higher frequency of problem behavior such as aggression and noncompliance than do their typically developing peers. Not only are these behavior problems dangerous to the individual and his or her caregivers, but they also hinder learning of important adaptive skills and thus serve as an impediment to the efficacy of other educational intervention efforts. Therefore, therapists and interventionists will typically address problem behavior as a first step of the ABA therapy process. Iwata, Dorsey, Slifer, Bauman, and Richman (1982/1994; see also Iwata, Pace, Dorsey, et al., 1994) demonstrated that self-injurious behavior is frequently the product of identifiable relations between environmental events that either precede or follow responding (see Chapter 14, this volume, for a discussion of this procedure). That is, the common reactions of caregivers to self-injurious behavior, such as expressing concern or terminating a task that upsets the child, can serve to reinforce that behavior. These reinforcers most commonly involve members of the social environment providing access to attention or activities after instances of problem behavior (i.e., social positive reinforcement) or withdrawing an unpleasant activity (social negative reinforcement). In some instances, problem behavior will generate sensory consequences that serve as reinforcers for problem behavior (termed *automatic* in that they are not mediated by a member of the social environment).

As a result of numerous demonstrations of the efficacy of functional assessment and function-based treatment for problem behavior, the subsequent working assumption of many behavioral clinicians treating problem behavior has been that responses such as self-injury are functionally equivalent to communicating one's wants, needs, or preferences. Identifying appropriate behavior as a functional alternative and establishing it as more probable than problem behavior is a generic description that fairly summarizes the general approach to treating severe problem behavior.

Treatment of Problem Behavior Maintained by Social Reinforcement

The foundation of function-based intervention is eliminating the reinforcement that commonly follows problem behavior. Procedurally, how these interventions are carried out will depend on the reinforcer identified by the functional analysis. For example, in the case of problem behavior maintained by attention, extinction would involve ensuring no social interaction followed an instance of aggression (sometimes called *planned ignoring* or *EXT [attention]*). In the case of problem behavior maintained by escape from self-care or academic tasks, extinction would involve prohibiting escape from the tasks (sometimes referred to as *follow-through* or *EXT [escape]*). In the case of problem behavior maintained by automatic sources of reinforcement, extinction would involve attempting to mitigate the sensory consequences directly produced by problem behavior (e.g., wearing a padded helmet to minimize the sensation generated by head hitting; *EXT [sensory]*).

Iwata, Pace, Cowdery, and Miltenberger (1994) demonstrated the importance of accurately matching extinction procedures to the reinforcer type identified by a functional analysis by arranging both indicated (matched) and contraindicated (mismatched) extinction procedures on the self-injurious head banging of three children with developmental disabilities. When applied to head banging maintained by automatic reinforcement (as indicated by the functional analysis), EXT (attention) and EXT (escape) had no effect on the occurrence of head banging, whereas the indicated EXT (sensory) resulted in rapid and sustained decreases in head banging. In a case in which head banging was shown to be maintained by escape from demands, EXT (escape) resulted in reductions in head banging, whereas EXT (sensory) had no effect on levels of head banging. In a third case in which head banging was maintained by attention, EXT (attention) resulted in sustained reductions, whereas EXT (sensory) had no effects on head banging. In each case, only the extinction procedure indicated by the functional analysis affected reductions in head banging.

Although extinction alone is an effective behavioral intervention to reduce problem behavior (e.g., Iwata, Pace, Kalsher, Cowdery, & Cataldo, 1990), extinction is rarely implemented in isolation. Instead, the reinforcer that had previously maintained problem behavior will typically be (a) delivered independent of behavior, termed a *noncontingent reinforcement procedure* (e.g., Kahng, Iwata, Thompson, & Hanley, 2000; Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993); (b) delivered contingent on a more desirable alternative behavior, termed a *differential reinforcement of alternative behavior procedure* (e.g., Carr & Durand, 1985; Piazza, Moes, & Fisher, 1996); or (c) delivered contingent on the absence of problem behavior, termed a *differential reinforcement of other behavior procedure* (e.g., Lindberg, Iwata, Kahng, & DeLeon, 1999; Vollmer et al., 1993).

Despite conducting functional analyses and arranging effective differential reinforcement and extinction procedures, some cases will require additional behavior reduction intervention components (i.e., the use of punishment). There has been much commentary on the use of punishment procedures in a variety of professional literatures. These procedures are sometimes necessary to obtain important reductions in severe behavior problems, and behavior analysis has a base of knowledge on which to ensure that these procedures are as effective as possible, mitigating the long-term need for their implementation.

Behavior analysis has a long history of questioning the long-term effectiveness of punishment (Skinner, 1953). Perhaps the most significant variable in this sentiment is that punishment suppresses responding, but the consequences that serve to maintain problem behavior still support the occurrence of problem behavior, which often results in a temporary suppression of problem behavior. That said, before the development of effective functional assessment procedures, punishment was one of the most commonly reported effective behavioral interventions (Pelios, Morren, Tesch, & Axelrod, 1999).

Some of the most severe cases of self-injury were found to be significantly suppressed by applying faradic stimulation (i.e., electric shock applied dermally) contingent on self-injury and were unresponsive to a multitude of other interventions (e.g., Linscheid & Cunningham, 1977; Linscheid, Iwata, Ricketts, Williams, & Griffin, 1990).

Again, it is critically important to note that identifying the functional relation between problem behavior and the consequences it produces is the most likely means of avoiding punishment, and if punishment is necessary, this information will effectively inform the clinician as to how to arrange complementary procedures and eliminate, as quickly as possible, the aversive contingencies. We recommend readers to Lerman and Vorndran's (2002) review of the status of knowledge on the use of punishment.

Treatment of Problem Behavior Maintained by Sensory Consequences or Automatic Reinforcement

The previous discussion of treatment for problem behavior focused primarily on approaches for behavior maintained by social sources of reinforcement. However, in many cases behavior may be reinforced by its direct sensory products (e.g., the visual stimulation generated by hand flapping or the sensation generated by head hitting). One highly prevalent example in the autism population is stereotypic behavior. Stereotypic behavior is particularly important in the treatment of ASDs because it is among the diagnostic criteria for autism (e.g., Lewis & Bodfish, 1998), and although it occurs in all populations, it occurs more frequently and at greater intensities in people with autism relative to those with other disorders of development (Bodfish, Symons, Parker, & Lewis, 2000). Stereotypy can interfere with learning (e.g., Dunlap, Dyer, & Koegel, 1983; Morrison & Rosales-Ruiz, 1997) and can produce adverse social consequences (e.g., Jones, Wint, & Ellis, 1990; Wolery, Kirk, & Gast, 1985). Many studies have functionally assessed the maintaining variables associated with stereotypy, and although some research has suggested that stereotypic behavior (both vocal and motor responses) can be maintained by social consequences, most studies have implied that it is maintained by the sensory consequences produced by stereotypy (e.g., Ahearn et al., 2007; Kennedy, Meyer, Knowles, & Shukla, 2000; Lovaas, Newsom, & Hickman, 1987; Mace, Browder, & Lin, 1987; Vollmer, 1994). Treatment for these problems follows a similar logic, except that implementing extinction (withholding the sensory consequence) is more challenging, as is arranging that same form of stimulation to be accessed through a different means.

Many clinical researchers have relied on the interruption of stereotypic behavior (sometimes referred to as *response blocking*) to decrease such automatically reinforced problem behavior (Ahearn et al., 2007; Fellner, LaRoche, & Sulzer-Azaroff, 1984; Hagopian & Adelinis, 2001; Lerman & Iwata, 1996; Rincover, 1978; R. G. Smith, Russo, & Le, 1999). Although generally thought of as a form of extinction, in that it mitigates contacting sensory reinforcers (R. G. Smith et al., 1999), response interruption may also serve as a punishment procedure (Lerman & Iwata, 1996); the implementation of this type of intervention is less directly informed by the functional cause of problem behavior.

Other alternative or complementary procedures are necessary to establish appropriate functional alternatives to automatically reinforced behavior. The most likely long-term approach to developing functional alternatives involves teaching play, leisure, and social skills to those individuals with stereotypy. Such responses would presumably compete with stereotypic behavior. One critical component of effectively competing with automatically reinforced behavior is precisely determining what sensory consequences are produced by behavior. Toys and leisure activities that produce these same sensory consequences are often most likely to effectively compete with automatically reinforced problem behavior (e.g., Goh et al., 1995; Piazza, Adelinis, Hanley, Goh, & Delia, 2000). However, we should note that access to dissimilar forms of sensory stimulation for which the child demonstrates a preference can also lead to lower levels of automatically reinforced behavior (e.g., Ahearn, Clark, DeBar, & Florentino, 2005; Vollmer, Marcus, & LeBlanc, 1994; for a comprehensive review of treatments for stereotypy, readers are referred to Tiger, Toussaint, & Kleibert, 2010).

DEVELOPING ADAPTIVE BEHAVIOR

Once concerns regarding problem behavior are minimized, direct instruction for establishing important prosocial behavior is the most valuable tool of the behavior analyst. Early behavioral intervention involves systematically and directly teaching social, communicative, and self-care skills to children with autism; teaching children the skills essential for independent functioning in their typical school and home settings is often an intensive and resource-heavy endeavor. Before developing teaching strategies, assessment of a child's skills relative to those of typically developing peers is necessary. These assessments should guide goal selection and ordering on the basis of individual children's needs and aptitudes. For instance, if during such evaluation the child is found to be significantly behind in a skill domain, such as expressive communication, then teaching procedures can be developed to address these deficits, and other domains (e.g., motor imitation or matching) may not need to be addressed. The complete discussion of all skills that may need to be addressed among children with autism is well beyond the scope of this chapter. Several comprehensive curricula for children with autism have been developed and should be consulted by practitioners.

One example of such a curriculum, with a particular focus on the area of communication skills, is the Verbal Behavior Milestones Assessment and Placement Program (Sundberg, 2008). This program provides an assessment of specific language and social skills related to language that then suggests a starting point for teaching a child relative to his or her current skills. This type of assessment provides a useful baseline of skill level and allows for ongoing evaluation of progress from basic to higher order learning. For instance, one of the most common deficits in expressive communication for developmentally delayed children is the absence of an effective and varied requesting repertoire. Fifty percent of children with an ASD lack functional speech and consequently require intensive interventions to develop communication skills (Tsiouri & Greer, 2003). Teaching children to exhibit appropriate vocalizations has proven to be beneficial for increasing the child's social and educational skills (E. A. Smith & Van Houten, 1996). Assessment is also necessary for other skill domains such as activities of daily living and vocational skills and those domains related to specific academic skills such as math and reading, and it is critical for designing interventions.

The most recognized form of instruction is commonly referred to as *discrete trial teaching*. This approach is characterized by highly contrived instructional sessions in which a teacher will present a child with a relevant S^D, a prompt to occasion a target response, and a reinforcer for that response; the next learning trial is then rapidly presented. Over time, the goal is to fade out teacher prompting (see Wolery & Gast, 1984, for a review of prompting and fading procedures), transferring the control of the response by the prompt to the relevant S^D. For instance, if one was attempting to teach a child to say "red" (target response) in the presence of a red card and the question "What color?" (relevant S^D), one might begin by presenting the vocal prompt "Say *red*" and then providing a small edible item immediately after a correct response. One would then re-present the red card to initiate another teaching trial and gradually decrease the volume with which the prompt "Say *red*" is presented until the child is responding "red" when only the card and question are presented.

An alternative form of teaching is referred to as *embedded* or *incidental teaching* (e.g., Halle, Baer, & Spradlin, 1981; Hart & Risley, 1975, 1978; Tate, Thompson, & McKerchar, 2005). Rather than contriving learning opportunities, these teaching models involve conducting teaching directly in children's natural environments. For instance, in teaching a child to label red objects, teachers may intentionally bait the child's home, bedroom, or classroom with red objects and provide teaching opportunities as the child encounters these stimuli. Similar prompting and reinforcement procedures as those discussed in the context of discrete trial teaching are typically used.

In the following sections, we give examples of how targeted intervention may appear as it relates to the core deficits in autism (i.e., delays in communication and social behavior), with a particular focus on the earliest foundational skills that may need to be addressed, specifically, developing expressive and receptive language, imitation, and social skills.

Communicative Impairments in Autism

The delayed onset of communicative behaviors is one of the earliest identifiers for parents and caregivers of individuals with autism (Landa, 2007; Sigafoos, Schlosser, O'Reilly, & Lancioni, 2010). The ABA approach to treating the communicative impairments presented by children with autism is to identify the deficient skill repertoires and to systematically teach skills addressing these deficiencies. As noted earlier, given the range of verbal deficits presented by children with ASDs, behavioral assessment and individualization of programming is crucial to effectively teach verbal behavior.

Teaching prerequisites. In some cases, children with ASDs lack the prerequisite skills necessary for developing verbal language. That is, to engage people in the social environment, children must first attend to social stimuli. Attending responses are often taught by first teaching children to make eye contact with other individuals (Foxx, 1977; Hall, Maynes, & Reiss, 2009; Hamlet, Axelrod, & Kuerschner, 1984; Hanley, Heal, Tiger, & Ingvarsson, 2007; McConnell, 1967; Risley & Wolf, 1967). For instance, Risley and Wolf (1967) described a teaching procedure in which they would hold a preferred item (commonly a small piece of food) next to the therapist's face. Children tended to orient their gaze toward the preferred item, and when their gaze moved to the therapist's face, Risley and Wolf would then immediately provide praise and access to the preferred item. Across repeated trials, the food item would gradually be moved away from the therapist's face such that the child would continue to orient toward the therapist's face under more typical conditions.

After teaching appropriate attending and orientation, therapists will very often initiate imitation training. Baer, Peterson, and Sherman (1967) first described an approach to teaching motor imitation by presenting children with the instruction "Do this," followed by modeling of a simple motor act (e.g., clapping one's hands). The therapist would then immediately physically guide the learner to engage in the motor act and deliver a small bite of food as reinforcement. Across repeated trials, the therapist would reduce the force of his or her physical guidance until the learner engaged in the response independently after the instruction "Do this." After mastery of the first motor imitation, the therapist would then introduce the next model (e.g., raising one's arm). After the introduction of many instructed imitations, the participants would begin to imitate any novel motor response that was preceded by the instruction "Do this" (see also Burgess, Burgess, & Esveldt, 1970, and Steinman, 1970, for similar procedures).

Vocal imitation training proceeds similarly except that the initial instruction is typically of the form, "Say _______," and it includes a reliance on shaping desirable responding in lieu of physical prompting. Sherman (1965) provided an example of such an approach. After establishing eye contact, Sherman initiated vocal imitation training by providing bites of food contingent on any vocalization to increase the frequency and variability of vocalizations from which to select. The next step was to teach vocal responding after an instruction; Sherman began by placing a bite of food by his face and stating, "Say *food.*" He initially delivered reinforcement after any temporally close vocalization. He then gradually altered his requirements such that closer approximations to *food* were required. After teaching the imitative response *food,* Sherman reported an increase in other forms of vocal imitation as well. Similar procedures have also been reported by Brigham and Sherman (1968); Clark and Dameron (1978); Garcia, Baer, and Firestone (1971); and Young, Krantz, McClannahan, and Poulson (1994).

Developing verbal operants. Once these prerequisite skills are in place, ABA therapists can then begin developing expressive and receptive language. We should note that the ABA-based approach to language development (sometimes also referred to as the *verbal behavior* or *applied verbal behavior approach*) is a departure from many characterizations of how language develops held by traditional psychology. The ABA approach to treating communicative impairments is based largely on Skinner's (1957) conceptual analysis of verbal behavior. That is, similar to other "voluntary" behaviors, Skinner considered language to also be operant behavior that was maintained by the environmental consequences of engaging in that behavior. He developed a unique taxonomy of language based on its operant function (i.e., the nature of the S^Ds that occasion a response and the characteristic consequences that serve to reinforce the response) rather than on its structural characteristics. Although a fairly radical departure from more traditional accounts of language and communicative development, this approach has proven extremely useful for developing communicative behavior among individuals with language deficiencies, including children with autism. We outline the particulars of the four main units of Skinner's taxonomy and highlight how the literature has incorporated this approach into autism intervention. For a complete curriculum based on this approach, we again recommend the Verbal Behavior Milestones Assessment and Placement Program (Sundberg, 2008).

Mand. Skinner (1957) defined a *mand* as a verbal operant emitted under a state of deprivation or aversive stimulation (i.e., the relevant antecedent events) that is maintained by a characteristic consequence (i.e., reinforcer). In more common parlance, a mand can be considered a request; however, by focusing on the relevant environmental accompaniments, it also suggests the appropriate teaching conditions for individuals with deficient manding repertoires. That is, to teach a mand, one needs to establish a relevant state of deprivation from a reinforcer, prompt the response one wishes to teach, and then deliver a characteristic consequence for that response.

Bourret, Vollmer, and Rapp (2004) provided an example of mand training with children with autism. For one participant named Will, their goals were to teach the vocal responses "music" and "video" as mands to gain access to a radio and a movie that were previously identified as preferred materials, but for which Will did not ask. During an initial baseline period, the experimenters placed the items in Will's visual range but did not allow access to them (i.e., arranged a state of deprivation); Will did not engage in either vocal response during this baseline. The experimenters then began mand-training conditions, during which each trial included a brief (5-second) opportunity for Will to engage in the target response. If Will did not engage in the target response, he was then vocally prompted by the experimenters to do so using a series of instructive prompts. Will began to engage in both the targeted responses before the experimenters' prompts across trials; thus, Will developed independent manding for both items.

Although mand training typically starts with relatively simple one-word responses, comprehensive language training can and should increase the complexity of responses over time. Hernandez, Hanley, Ingvarsson, and Tiger (2007) provided an example of this approach with young boys with developmental delays. These experimenters initially taught the boys single-word mands to gain access to particular sets of play materials (e.g., "Say *cars*" to gain access to a set of toy cars) by withholding access to those materials and prompting the children, "Say ____." This mand was reinforced with 30-second access to the requested materials. After acquisition of a single mand, the experimenters then restricted the reinforcement contingency such that the reinforcing items would only be delivered if the mand took the form, "I want ________, please." On the basis of this manipulation, the experimenters increased the complexity and social acceptability of the mand. Moreover, requiring this "framed" mand for one item resulted in generalization such that the children began engaging in appropriate framed mands for items that were not directly targeted.

Mands may also be reinforced by consequences other than food and toys. For instance, Ingvarsson and Hollobaugh (2010) taught children to mand for information. In this study, they asked children with autism several questions, such as "Where do you live?" and "Where do you buy groceries?" Children did not initially respond accurately to these questions, so rather than attempt to teach children to answer each question individually, Ingvarsson and Hollobaugh taught children to mand, "I don't know, please tell me" to a subset of questions, after which the experimenters provided praise and the answer to the original question. Children began to engage in this request not only for information for the specific questions trained but also in the presence of novel unknown questions. Moreover, being told the correct answers, children began to independently learn to correctly answer these questions.

Mands may also be reinforced by the termination of nonpreferred activities (note the portion of the definition regarding aversive stimulation). The role of manding has become particularly important in the treatment of problem behavior. For instance, some individuals may engage in aggressive or self-injurious behavior to terminate nonpreferred activities such as chores or academic tasks (Iwata et al., 1990, 1994). A common intervention for problem behavior of this type is to teach these individuals to engage in a more appropriate manding (e.g., requesting assistance; Carr & Durand, 1985).

Tact. A *tact* is a verbal operant emitted in the presence of a nonverbal S^D that is reinforced by a generalized social reinforcer. A person emits a tact, and that instance of verbal behavior brings others into contact with events the speaker has experienced. In more common language, a tact describes verbal behavior emitted in the presence of a tangible object (e.g., saying "cup" in the presence of a cup or "dog" in the presence of a dog; emitting the name of a person who walks into the room; saying "it's for you" on answering a ringing phone when the call is for someone else in the room) that is reinforced by a nonspecific reinforcer from a social community (e.g., someone saying, "That sure is a cup!"). In other words, a tact is akin to a label. Again, focusing on the environmental circumstances surrounding the response provides guidance on how to teach a response. In the case of a tact, one would want to ensure that a clear S^D was provided for the individual to respond to and that a nonspecific form of reinforcement was provided for the correct tact.

Williams, Carnerero, and Pérez-González (2006) used this approach to teach six children with autism to tact actions engaged in by a model. Specifically, a teacher would walk into the room and engage in either ball playing (bouncing and throwing a ball) or sleeping (placing her head on a desk and making exaggerated snoring sounds). A second teacher then prompted the student to engage in the correct tact (e.g., "Ana is sleeping" or "Ana is playing ball") and provided praise after a correct response.

Echoic. An echoic response is a verbal operant that is occasioned by a preceding verbal S^D; the response shares a formal, point-to-point correspondence with the preceding verbal stimulus and is reinforced by a nonspecific social reinforcer, for instance, saying "train" when someone else says "train." The establishment of an echoic repertoire is essentially identical to that described earlier as vocal imitation (they are identical procedurally, just described from a different taxonomy). The development of echoic behavior is extremely useful in that echoics are frequently used in the establishment of other verbal operants. For instance, in teaching a mand or a tact, teachers will frequently present the relevant stimulus situations (e.g., presenting a ball) and then provide an echoic prompt ("say *ball*") and across time attempt to transfer the stimulus control from the verbal antecedent (i.e., "say *ball*") to the nonverbal antecedent (i.e., the ball). We discussed echoics as a prerequisite skill for this reason; a strong echoic repertoire is likely to facilitate the acquisition of other verbal operants.

Intraverbal. An *intraverbal* is a verbal operant emitted in the presence of a verbal S^D but that shares no point-to-point correspondence with the preceding S^D. The most common examples of intraverbal behavior are behaviors such as question answering and taking conversational turns. For instance, Goldsmith, LeBlanc, and Sautter (2007) taught four children with autism to answer questions such as "What are some things you wear?" and "What are some colors?" After presenting children with these questions, the experimenters occasioned a response by presenting pictures of some answers (i.e., occasioning a tact response), and over time the questions alone were sufficient to occasion the correct intraverbal responses.

Independence between verbal operants. In addition to its pragmatic value, Skinner's (1957) approach to verbal behavior has gained support because of some unique predictions it makes that are inconsistent with more traditional views of language. Specifically, a traditional view would suggest that once individuals learn the meaning of a word they would be able to use it in multiple circumstances; however, given Skinner's analysis, one would predict independence between verbal operants. That is, simply because a word may be used as a tact under appropriate stimulus controls does not necessarily mean that the word would also be used as a mand under other conditions.

The independence of verbal operants was first demonstrated in a classic study by Lamarre and Holland (1985) in which they assessed children's mand and tact repertoires using topographically identical responses. That is, they taught children to either tact an object as being on the left or on the right and then assessed their ability to mand for the experimenter to place a toy on the left or on the right. A second group of children was taught the mand form of the response but subsequently failed to engage in the tact form of the response. Despite instruction to engage in a response under one set of conditions, the participants failed to engage in the same response under the other set of conditions without direct instruction (see also Wallace, Iwata, & Hanley, 2006).

Lerman et al. (2005) provided further evidence for the independence of verbal operants in the development of a functional analysis of developing language. They identified spoken words emitted by four children with developmental disabilities and assessed which stimulus conditions would occasion a response. In particular, they developed a test condition for mands, tacts, intraverbals, and echoics; each condition also had a matched control. For instance, during a mand test, the experimenter initiated a session by presenting a preferred object (e.g., a baby doll) and then placing the object out of the participant's view (to create properly motivating conditions). After the response "baby," the experimenter would provide access to the doll for a brief period (i.e., the specific consequence). During mand control sessions, the child had continuous access to the doll, such that the motivating condition was eliminated. During tact test sessions, the participant had continuous access to the target item (i.e., the nonverbal S^D) and was prompted to emit a tact every 20 seconds with the experimenter prompt, "What is that?" A correct response resulted in praise (the nonspecific social reinforcer). During the intraverbal test, the object was not present, and every 20 seconds the experimenter presented a verbal S^D in the form of a fill-in-the-blank (e.g., for the target response "baby," the prompt may have been, "Cry like a _______"). Correct responses again resulted in praise. During the intraverbal control condition, every 20 seconds the experimenter would provide a similar statement for which the target item would be an incorrect response (e.g., "I ride the __________"). Finally, during an echoic test, every 20 seconds the experimenter would state the target response (e.g., "baby") and provide praise if the participant engaged in the same response. During the echoic control, the experimenter did not interact with the participant. The unique finding of this study was that participants would engage in the target response under some conditions but not others. For instance, one participant, Jim, engaged in the response "toy" only under the mand test condition, not during the tact or intraverbal test conditions. By contrast, Karen demonstrated that the response "baby" occurred under the tact test condition, but not under mand test conditions. Similar procedures and results were also provided by Kelley, Shillingsburg, Castro, Addison, LaRue, and Martins (2007).

Again, the value of such assessments beyond their interesting conceptual implications is that the outcomes lead directly to the conditions under which training need be directed. A response that occurs solely under tact conditions would also need to be trained to occur under mand and intraverbal conditions (see Kelley, Shillingsburg, Castro, Addison, & LaRue, 2007).

One of the other unique features of Skinner's (1957) analysis is that it does not specify the form of the communicative response; it is not limited to vocal communication. This is important to consider because many children with autism present with severe communication deficits; it may take prohibitively long periods to establish simple forms of communication (e.g. Bourret et al., 2004), and some may not develop vocal language. Communication can still be developed in accordance with Skinner's (1957) analysis using sign language (Carr, Binkoff, Kologinsky, & Eddy, 1978; Carr & Kologinsky, 1983), picture-exchange or card-exchange communication systems (Bondy & Frost, 1994), or voice output systems (Durand, 1993, 1999). The decisions regarding the selection of a communication system are not easy and are made on an individual basis in consultation with the child's caregivers and other professionals. Developing communication using an augmentative system and later transitioning to vocal communication may be possible. No definitive blueprint for selecting a communicative system or modality exists, but we present a few considerations.

To what extent does the individual engage in vocal communication? If a child engages in some form of vocal language, the likelihood that additional language can be taught is higher, and thus vocal responding would be the indicated communicative modality. If the answer to this question is "very little to none," then an augmentative system should be strongly considered.

To what extent does the individual engage in stereotypic hand movements? If a child engages in high-rate stereotypy with the hands (e.g., hand flapping), it may be particularly difficult for his or her conversation partners to discriminate between target and nontarget hand movements associated with sign language, thus selection-based systems (e.g., picture-based communication systems) may be more appropriate.

To what extent does the individual make conditional discriminations? To effectively use selection-based systems, such as a picture-exchange communication system or voice-output systems, an individual must be capable of scanning an array of pictures or symbols (taking into consideration the individual's sight as well) and making discriminations among the symbols. This repertoire may be more challenging among people with intellectual disabilities than is typically appreciated (Michael, 1985; Wraikat, Sundberg, & Michael, 1991), and common language interventions may create a false impression of discrimination between symbols (Gutierrez et al., 2007). (We provide a lengthier description of these important and complex conditional discriminations later in this chapter.)

To what extent does the verbal community recognize sign language? For sign language to be an effective communication strategy, the members of the speaker's community must recognize instances of sign language and be trained to be responsive to that system. By contrast, systems such as a picture-exchange communication system or voice-output systems require very little training for listeners to respond appropriately. The frequency of staff turnover in the context of the learner is also an important consideration (i.e., the time, effort, and cost associated with teaching new staff members to learn sign language).

Developing Symbolic Language

Most learning involves establishing responding under relevant stimulus conditions (i.e., bringing behavior under stimulus control). Children with autism have been noted to have distinct communicative deficits relative to their typically developing peers, and systematic instruction is required to remediate these deficits. For instance, a picture of a dog, the written word *dog,* and the vocal response "dog," although conceptually related, are distinct stimuli. Typically developing children learn to respond to these stimuli as related to each other through interactions with their parents and others who socially interact with them. This learning is reliant on social interaction. Given that children with autism have profound social deficits, this type of learning is often impaired; they must be instructed systematically and more intensely to learn the relations among conceptually related stimuli. More than 35 years of behavioral research into discrimination learning has established how physically dissimilar stimuli, such as a spoken word and a picture representing the same concept as the spoken word, come to be responded to as conceptually related and distinct from other concepts. Serna, Dube, and McIlvane (1997) summarized this research and outlined a taxonomy for organizing discrimination learning and stimulus control as a hierarchical model for this type of symbolic learning (see Chapter 6, this volume, for a more complete discussion).

This taxonomy starts with simple discrimination learning, in which an S^D (e.g., the sound of one's name or a ringing telephone) occasions a previously reinforced response (answering the person or the telephone). More complex conditional discriminations may be trained when behavior is controlled by a second conditional stimulus that alters the discriminative function of the S^D (see Saunders & Spradlin, 1989, 1990, 1993; Sidman, 1980). For instance, a ringing phone is an S^D if one is in one's home (home functioning as a conditional stimulus) and would occasion one's picking up the phone, but the same sound should not function as an S^D when one is in a store or someone else's home. Conditional discriminations underlie most complex human behavior such as thinking, communicating, reading, and mathematical computation. These conditional discriminations can be effectively taught in educational settings (see Mackay, 1985; Stoddard, Brown, Hurlbert, Manoli, & McIlvane, 1989; Stromer, Mackay, & Stoddard, 1992) and need to be directly addressed to help treat individuals with autism.

Social Deficits in Autism

As mentioned previously, deficits in social behavior are a defining characteristic of autism (American Psychiatric Association, 2000). Among some commonly noted social deficits in people with autism are inconsistent or absent eye contact with others, impaired reciprocal interaction with others (including joint attention), failure to imitate the actions of others, and deficits in social play skills (Folstein, 1999). Imitation and joint attention have been a particular focus because these responses may be predictors, along with communication skills and preintervention IQ, of a child's responsiveness to intervention (Charman, 2003; Helt et al., 2008; Mundy, Sigman, & Kasari, 1990).

Joint attention has been defined as "the capacity of the young child to use gestures and eye contact to coordinate attention with another person in order to share the experience of an interesting object or event" (Mundy, Sigman, & Kasari, 1994, p. 389) and "the ability to coordinate attention between interactive social partners with respect to objects or events, or to share an awareness of the objects or events" (Dawson et al., 2002, p. 346; see also Mundy, Sigman, Ungerer, & Sherman, 1986). Joint-attention deficits have been noted to be one of the earlier social deficits apparent in children with autism (e.g., Carpenter, Pennington, & Rogers, 2002). Joint attention is a fairly complicated repertoire of behavior, and it has many components. Nonverbal joint-attention responses, such as shifts in gaze from an object in the environment toward a familiar person, begin to be emitted by typically developing children between ages 9 and 12 months (Bakeman & Adamson, 1984). Children learn additional social skills as they age, and these learned responses are expressed in the context of joint attention. For example, gaze shifts come to be combined with gestures toward the object or event, and the child eventually emits various combinations of gaze shift, verbalizations, eye contact, pointing, reaching, or showing an object to a person (Seibert, Hogan, & Mundy, 1984).

Joint-attention behavior has two other important distinctions, joint-attention responding and joint-attention initiation. *Joint-attention responding* involves a child responding to a familiar person when the familiar person initiates the interaction (Whalen & Schreibman, 2003). A child will typically look at a parent when the parent calls the child's name or orient toward an event the adult points out to the child (e.g., a family pet entering the room). Joint-attention responding is distinct from joint-attention initiation. Joint-attention responding is maintained by the familiar person's behavior and could be considered compliance with the familiar person's mand for the child's attention (i.e., the child is following directions; Dube, MacDonald, Mansfield, Holcomb, & Ahearn, 2004).

Joint-attention initiation consists of the child observing some environmental change and shifting his or her gaze from the event to a familiar person. This class of responding is best characterized as a child manding for the familiar person to attend to the environmental change (Dube et al., 2004). The familiar person's attention to the event corresponds with the person's then reacting to the event. This reaction provides a model of behavior for the child. If the event is pleasurable (e.g., the friendly family dog), engaging with the event will follow (e.g., petting the dog leads to the dog licking the child's face). If the event is aversive (e.g., a menacing wild animal), then avoiding the event will follow. Additionally, value is likely added in having others attend to the events the child encounters in that they are more fun to do together or less aversive with company.

Joint attention may not be the most foundational social deficit, but it is likely one of the most studied behavioral markers of autism. Among other deficits in social behavior, children with autism have been noted to fail to attend to social stimuli such as spoken words, eyes, and gestures (e.g., Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Leekam, Hunnisett, & Moore, 1998). Therefore, many responses related to interacting socially may be important to target when teaching social behavior. The most basic response is likely looking at others. Eye contact is frequently the starting point for teaching children with autism, and it is sometimes referred to as a pivotal skill that, once taught, may foster the development of other social behavior (Koegel & Koegel, 1988). Imitation, a child engaging in a response similar to a response emitted by another person, is another pivotal skill and a frequent early target of ABA instruction (e.g., Ingersoll & Schreibman, 2006; Lovaas, Freitas, Nelson, & Whalen, 1967).

Other frequently targeted social skills include verbal behavior, which we covered in the section Communicative Impairments in Autism earlier in this chapter. Although the case is that communication will always be social in nature, certain communicative responses may require special attention, and additional instruction beyond establishing the verbal response, for social interaction to occur. Some of these responses include greeting others, responding to verbal responses of others, and engaging in extended conversations. Moreover, many of these responses occur in the natural environment during play (Leaf & McEachin, 1999; Lovaas et al., 1967). Although a complete review of effective teaching techniques for each of these skill areas is beyond the scope of this chapter, we describe in this section the social skills most frequently targeted for children with autism during ABA instruction, touching on commonly effective teaching procedures.

Teaching social behavior. Communication training and teaching social skills overlap greatly. For example, imitation is a critical skill for both types of behavior, and without this skill, both social learning and verbal behavior would be difficult to teach. Teaching social skills, as with teaching verbal behavior, involves starting with essential prerequisite skills and building on this foundation systematically (see Green, 1996, and Taylor & McDonough, 1996, for a discussion). Taylor and McDonough (1996) suggested that each child should be assessed on a variety of skills to determine their entry point into instruction. Once a child's skills are assessed, those skills that are present but that do not occur consistently and those early skills that are absent are typically the initial skills targeted for instruction.

Starting points. Most early social and communicative skills are learned through social interaction that consists of actions and verbal instruction from an adult. For such instruction to lead to learning, the child must look at the adult. Therefore, the first teaching objective, if this skill is absent, is typically establishing eye contact. Several studies have identified effective procedures for teaching this skill (e.g., Foxx, 1977; Taras, Matson, & Leary, 1988). However, establishing eye contact in many situations is often necessary before it will occur consistently during instruction (Taylor & McDonough, 1996). The starting point for teaching eye contact is sitting across from the child and stating the child's name. If the child does not establish eye contact on hearing his or her name, a variety of prompts can be used to foster this response. Taylor and McDonough (1996) described the common procedure of simultaneously stating the child's name and presenting a small piece of preferred food or activity near the adult's eyes. Once the child looks, the preferred item is provided to him or her. As this response is acquired, the adult inserts a delay between stating the child's name and placing the preferred item near the eyes while providing access to the preferred item as soon as the child establishes eye contact. Access to preferred items reinforces eye contact.

Brief eye contact is usually not difficult to teach as long as a child's preferences are readily identified, but increasing the duration of time the child looks at the adult and increasing the variety of situations in which eye contact occurs is sometimes more difficult. The duration of eye contact is often taught by increasing the delay between the child looking at the adult and the delivery of the reinforcer. Increasing the variety of situations in which eye contact occurs, such as during play and classroom instructional activities, often requires repeating the teaching procedures during those activities. Once eye contact is occurring consistently, other responses can be taught. The next class of skills targeted for instruction is imitation.

Although we mentioned imitation earlier in the Communicative Impairments in Autism section, more discussion of this behavior is warranted here. Baer and Sherman (1964) referred to imitation as a response that resembles an S^D. The S^D, in this case, is a response emitted by another person. Baer and Sherman referred to generalized imitation as the occurrence of imitation by the child in a novel situation. Numerous studies have identified effective procedures for teaching imitation (e.g., Baer et al., 1967; Ingersoll & Schreibman, 2006; Metz, 1965). Baer et al. (1967) described a fairly common strategy for teaching imitation skills while testing to determine when generalized imitation has been established. In this study, a large pool of responses to imitate was identified (e.g., raising an arm, touching an object or body part, moving an object, placing an object in a location). Each child was taught by an adult providing a vocal cue (e.g., "Do this"), then modeling the action for the child to imitate, providing a physical prompt to engage in the act, and then delivering a reinforcer once the act occurred. The prompting by the adult was gradually faded. Additionally, some responses were not taught, and no reinforcement was provided if these untrained responses were imitated. These untrained responses served as a means of determining whether generalized imitative responding was established. For each of the three children, imitation did not occur before instruction and generalized imitation emerged after instruction. That is, each child eventually imitated acts for which he or she did not receive instruction or reinforcement.

Establishing imitative responding is crucial for social learning. Even if a child engages in a response, such as making eye contact, if the response does not reliably occur, the child is unlikely to benefit from opportunities to learn. When an adult (or peer) engages in behavior, it could be construed as a learning opportunity. The adult's behavior serves as a model for the child, and if the child attends to the adult's behavior, the model can prompt the child to act as the adult does in that situation. The modeling of behavior, then, once imitation is firmly established, can promote the occurrence of novel behavior on the part of the child. Imitation, once learned, has been noted to be correlated with several positive developments, such as increases in language and play skills as well as increases in joint attention (e.g., Ingersoll & Schreibman, 2006).

Other key social responses. Most social skills can be taught in the same manner that we described earlier for establishing imitation. Systematically targeting skills that are not present in the child's social repertoire will require a combination of instruction and providing opportunities to determine whether previous learning has fostered the emergence of untrained behavior. As mentioned at the beginning of this section, joint attention is behavior that has been noted as a characteristic deficit in people with ASDs. Once key prerequisite responses such as eye contact and imitation are learned, joint attention can be assessed and, if necessary, targeted for instruction.

Opportunities for the child to demonstrate joint-attention behavior usually consist of an adult emitting occasional prompts for the child to emit joint-attention responses during an activity such as playing with toys (e.g., MacDonald et al., 2006; Whalen & Schreibman, 2003). Among the child responses measured during these opportunities are following the adult's prompts to emit behavior, shifting the gaze from toys to the adult, vocalizing or gesturing to the adult, eye contact, pointing, reaching, and showing toys to the adult. Responses that do not occur reliably can then be taught. Gaze shifts have been taught using prompting procedures similar to those described earlier.

Whalen and Schreibman (2003) used a graded set of tasks and prompting procedures to teach five 4-year-old children with autism to follow an adult's gaze-shift cue. The training was provided while the child had access to toys. The toys served both as targets for adult prompts to gaze shift and as reinforcers for the children's responses (i.e., access to the toy was provided if they followed the adult's prompt). The children were provided training using six forms of prompts provided in the presence of the toys. Training started with bringing the child into contact with toys (e.g., placing the child's hand on the object), progressed to more abstract prompts such as pointing to the toy, and terminated in providing access to toys only after the child followed the adult's gaze toward the toy. All children learned to follow the adult's gaze after prompts that were faded and contingent access to the toys.

Klein, MacDonald, Vaillancourt, Ahearn, and Dube (2009) also established following an adult's gaze shift through systematic instruction. However, in place of fading prompts, instruction in this study involved remote-control activation of toys that was gradually delayed as the child emitted shifts in his or her gaze from the toys to the adult. Other joint-attention responses can be targeted with similar procedures. However, limited generalization of joint attention has been noted to occur, and training may be necessary in the naturalistic settings with the child's parents and other caregivers (see Kasari, Gulsrud, Wong, Kwon, & Locke, 2010).

Teaching social skills to children with autism often requires that foundational skills be established and that an adult arrange opportunities to build on those skills. Many skills that naturally emerge in typically developing children will require prompting and reinforcement for children with autism to engage in social behavior with their peers. For example, a child with autism may readily learn communication skills but not emit them in the presences of peers. Early stages of ABA involve intensive instruction with an adult care provider, but ultimately the child must be provided opportunities to engage in social behavior in the natural environment. Among the skills targeted in the natural environment are reciprocal play, conversational skills, and other forms of social interaction. Many of the same teaching procedures discussed previously are effective when targeting these skills, but several additional procedures have been noted to be particularly useful when teaching more complex social skills.

Although all of the techniques discussed in this chapter involve an adult providing instruction, adult mediation for social interaction with adults and peers involves both teaching skills through prompts and reinforcement and arranging the opportunities to socially interact. The opportunities to interact are often provided during naturally scheduled activities such as small-group instruction, recess on a playground, or circle time in the classroom (e.g., Krantz & McClannahan, 1998; Taylor & McDonough, 1996). Prompting of behavior can occur during or before the arranged opportunity or, initially, during the opportunity with the prompts being faded out or made more subtle. For example, Charlop, Schreibman, and Thibodeau (1985) taught children with autism to greet a person entering the room by first arranging for adults to enter a room and providing the child with a vocal model of a social greeting. They then faded this prompt out by gradually increasing the amount of time between when the adult entered the room and when the prompt to greet them was delivered. All the children learned to greet the person entering the room in the absence of prompting.

Engaging in social interaction certainly requires more than a greeting, and it is also important for children with autism to learn to interact with their peers. An example of establishing more extended interaction with peers was described by Krantz and McClannahan (1993). Four children with autism were provided opportunities to initiate interaction with peers while participating in an art class. Before instruction, these children rarely initiated interactions. They were provided instruction in the form of written scripts that provided models of relevant vocal statements (e.g., "I like your painting"). Each child with autism had been taught to read and had learned to follow written instructions. The therapists prompted the children to read the written script, and the number of words in the scripts was gradually decreased and eventually faded out (i.e., there were no written words). Each child demonstrated increased initiations to peers once the scripts were faded and initiated interactions with these peers in a novel setting (e.g., playing with puzzles).

Script fading and similar procedures have been used to teach a number of other responses such as more extended conversations and requesting assistance from adults and peers (see McClannahan & Krantz, 1999, for a thorough overview). It is important to note that instruction for such social behavior requires several prerequisite skills. In the Krantz and McClannahan (1993) study, it was necessary for the children to read and follow written instructions. Additionally, prompts by an adult were necessary for these responses to then emerge during the opportunity to socially interact. Many other teaching procedures have also been shown to be effective in establishing social behavior. One well-studied procedure is video modeling.

Video modeling is a procedure that involves videotaping responses that have been identified as relevant targets for instruction and showing the video to the child before an opportunity to engage in the relevant behavior (e.g., Hitchcock, Dowrick, & Prater, 2003; Neumann, 2004). The procedure has been shown to be effective for teaching a variety of skills to children with autism, including daily living skills (Rehfeldt, Dahman, Young, Cherry, & Davis, 2003; Shipley-Benamou, Lutzker, & Taubman, 2002), communication (Charlop & Milstein, 1989; Charlop-Christy, Le, & Freeman, 2000; Sherer et al., 2001), and perspective taking (LeBlanc et al., 2003). Video modeling has also been used to teach both solitary and cooperative pretend-play skills (e.g., MacDonald, Clark, Garrigan & Vangala, 2005; MacDonald, Sacramone, Mansfield, Wiltz, & Ahearn, 2009; Roberts, MacDonald, & Ahearn, 2007). The modeled segments typically consist of a specific series of scripted actions or vocalization related to an opportunity to engage in the behavior targeted for instruction. The videotaped model is shown two or three times, and then the child is directed to perform the scripted behaviors. Video modeling has produced more rapid acquisition and greater generalization than in vivo modeling (Charlop-Christy et al., 2000), and many studies have shown that overt prompting and reinforcement were not necessary for learning to occur (Charlop-Christy et al., 2000; D'Ateno, Mangiapanello, & Taylor, 2003; MacDonald et al., 2005).

Certainly, the scope of social deficits in people with autism varies widely across individuals, and the importance of remediating these impairments is influenced by numerous variables such as the level of the person's communication skills, the setting in which instruction is provided (e.g., at school, in the home, in the community), and the resources available for providing service (Matson & Swiezy, 1994). However, as we suggested in the preceding section, several foundational skills need to be targeted before teaching more complex social behavior.

COMMON OBSTACLES TO EFFECTIVELY IMPLEMENTING BEHAVIOR INTERVENTION

Implementation has many critical aspects, including identifying a clinician who is qualified to assess the child's performance and guide intervention (more on who is qualified to implement behavioral interventions later); garnering the support of school personnel, parents, and members of the child's community; accessing the resources necessary to carry out effective intervention; and effectively training caregivers to implement interventions. A comprehensive plan of action for addressing these needs is the best means of ensuring long-term effective treatment.

All psychologists face a constant struggle to translate their field's technical language into information easily digested by those in the lay community. Behavior analysts often face specific types of translational issues. The process of functional assessment, for instance, identifies environmental causes, and people's everyday language presumes that behavior is caused by internal traits. Portraying the events that the child experiences or viewing the world from the child's perspective is often helpful in showing why a child has the difficulties that are producing the referral for service. However, even before a clinician evaluates a child, he or she should be working to establish positive and cooperative relationships with the people responsible for the child's care and education. A discussion of the problem as viewed by all involved parties and the goals they see as most important for the child's well-being should be part of this relationship building. A child's parents and teachers are often the most critical resources for effectively intervention, but they may also have differences of opinion about what the child's problems are and how to address them. The clinician must serve as an advocate for the child starting with the child's present situation and what is necessary for the child to have the best chance to succeed with independence in the school and community.

Many behavioral interventions require frequent and sometimes constant contact with a caregiver. The nature of the behavioral intervention most likely to be effective will determine how it should be implemented and who will need to provide the intervention. Some differential reinforcement procedures or antecedent strategies can easily be managed in a typical school classroom or the child's home. The success of these interventions then lies in the clinician's skill in developing treatment and training caregivers.

Intensive instructional programming often requires individualized face-to-face teaching by a well-trained teacher. Arranging such intensive intervention is beyond the scope of this chapter, but it is adequately covered in other sources (see Lovaas, 1996; Scott, 1996). If the child is already provided educational services continuously or intermittently by a direct aide, then the clinician can focus on effective caregiver training. Otherwise, a discussion with school personnel and other caregivers will be necessary to determine whether the required resources are available or what additional arrangement can be made.

Because behavioral interventions involve skills that are very different from those a teacher, teacher's aide, or other caregiver will likely come to the situation with, training these skills will be a critical component of the success of implementing treatment. However, before training begins, it is important to review the types of procedures that will likely need to be carried out, along with a clearly stated rationale for why the procedures are being selected. A plain-language description of the child's situation and how the environment currently does not support the kind of appropriate behavior that should be occurring should be the primary focus of the behavioral clinician. The caregiver should have an opportunity to express his or her feelings about whether he or she can implement the planned intervention with training and ongoing support. The success or failure of any intervention will critically depend on the integrity of the treatment's implementation. Establishing open lines of communication with a plan for supervision and ongoing support will help the clinician to operate more effectively and will provide the caregivers implementing treatment a clearer understanding of the cooperative nature of successful service provision.

Caregiver training has been the focus of a great deal of behavioral research. This research literature includes training teachers and teacher's aides in school settings, behavioral therapists who implement a variety of techniques, and parents. These types of caregiver training have much in common, particularly the training techniques that produce treatment implementation with a high degree of procedural integrity. One comprehensive study arranged to hierarchically expose parents to training techniques for implementing treatment for pediatric feeding problems (Mueller et al., 2003). The simplest training technique is verbal instruction delivered via didactic interaction that includes the review of written instructions for implementing the behavioral intervention. Many programs can be readily implemented by some caregivers with this minimal level of instruction. Other programs and some caregivers require more involved training. The next component of training added to the didactic instruction in Mueller et al. (2003) was the behavioral therapist's modeling correct implementation of the behavioral intervention for the caregivers. Again, this is sufficient for some caregivers and programs; however, having the trainee role-play implementing the intervention, the next level of training intensity, is sometimes necessary. Finally, if this role-play is not effective in producing the desired level of programming implementation with procedural integrity, then observing the trainee in vivo with the child and providing specific feedback on what is and is not implemented correctly is the most resource-intensive form of training. The complexity of the behavioral programming may indirectly imply the intensity of training necessary for success, and for those interventions that are generally beyond the scope of the trainee's established skills, starting with the most comprehensive and intensive training is a good idea.

AUTISM TREATMENT WORK: NOW WHAT?

Our primary purpose in this chapter has been to provide an overview of the logic behind and mechanics of behavioral interventions for people with ASDs. In this last section of the chapter, we outline several remaining challenges related to behavioral intervention for people with ASDs. The most daunting challenge is likely meeting the demand for behavior-analytic services with competent clinicians and educators. Over the past 30 years, particularly since the groundbreaking Lovaas studies (Lovaas, 1987; McEachin et al., 1993), the demand for behavioral services has been increasing exponentially.

Qualified Practitioners

Determining who is qualified to implement behavior-analytic services is a priority that has been recognized by behavior analysts for quite some time, and it is also gaining notice by consumers and governmental agencies. Toward this end, the Behavior Analyst Certification Board (BACB; 2005) was formed, and specific guidelines for qualifying for certification, guidelines for responsible conduct, ethical guidelines, and disciplinary standards were developed. This not-for-profit corporation was modeled after the state certification program established in Florida.

There are two nationally accredited levels of behavior analysts. The primary certification level is the board-certified behavior analyst. Clinicians with this certification have obtained a master's degree with a minimum of 225 hours of graduate-level coursework in behavior analysis, met a substantial supervision requirement, and passed a certification exam. Continuing education is required to maintain certification, and a doctoral-level certification is offered for doctoral-level behavior analysts. A lower level certification, the board-certified associate behavior analyst, is offered to behavioral therapists with a bachelor's degree and instruction and supervision in applying behavior analysis. The BACB maintains an interactive database of certified behavior analysts that shows where these clinicians are located and provides contact information.

To date, the BACB has credentialed more than 9,000 board-certified behavior analysts and board-certified associate behavior analysts worldwide. The BACB has approved course sequences for certification eligibility at 120 universities in the United States and 31 universities in 15 other countries. The BACB is accredited by the National Commission on Certifying Agencies, the accrediting arm of the National Organization for Competency Assurance. In accordance with National Organization for Competency Assurance's accreditation standards, the BACB has also established supervised experience requirements, ethical guidelines, disciplinary standards, and continuing education requirements. The BACB credentials are recognized by the U.S. Department of Defense (2007), which mandated coverage of ABA intervention for ASDs by the military's health plan (TRICARE). They are also recognized in laws and regulations in many states as well as in the policies of many public and private health insurance plans. However, given the exponential growth of autism diagnosis, the demand for qualified service providers still greatly outweighs the speed at which new providers are entering the workforce.

How Will These Services Be Paid For?

How access to services is obtained is a complicated subject and well beyond the scope of this chapter. That said, we offer a general summary. Pediatricians, developmental specialists, parental advocacy groups, and service providers are the best sources of information for how to access services in ones community. The Individuals With Disabilities Education Improvement Act (2004) is a federal law mandating a free and appropriate education for all eligible children with disabilities. Children with ASDs are considered eligible for services under this act. From birth to age 3 years, each state has a designated lead agency that determines eligibility for and coordination of services. These services are typically provided either in home or through center-based facilities, but they are often not specifically geared to address the needs of children with ASDs. Parental advocacy to access services by a qualified provider and for an adequate amount of service provision may be critically important.

Early intervention services are intended as a bridge to preschool services. Preschool, elementary, and secondary school services are provided via local educational providers that receive state funding. Thus, the financial costs of providing services to school-age children with developmental disabilities have fallen largely on the public schools. Funding for special services in the United States varies from state to state and from one school district to another within a state. Generally, communities with higher socioeconomic standing have more resources for providing services, and the role of parental advocacy in demanding validated treatment is critically important. Some school districts are formally or informally linked to qualified behavioral services providers, but again, parental advocacy for services from qualified providers and an adequate amount of service may be necessary.

Many large companies, such as Microsoft, self-insure their employees' health benefits and provide reimbursement for behavioral services rendered by a board-certified behavior analyst for children with autism (Stuebing, 2009). Microsoft has provided this benefit since 2001, and other large companies such as Eli Lilly, Home Depot, Halliburton, IBM, Intel, Michelin, and Symantec also cover behavioral services. Additionally, TRICARE, the U.S. military's health plan, provides a similar benefit. Some states, such as Colorado and Louisiana, have pursued state legislation for covering behavioral services for children with autism. These bills, which name board-certified behavior analysts as qualified service providers, passed in 2009 and were enacted in 2010.

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CHAPTER 13

THE ANALYSIS OF VERBAL BEHAVIOR AND ITS THERAPEUTIC APPLICATIONS

James E. Carr and Caio F. Miguel

In 1957, Skinner published what he would later (Skinner, 1978) suggest was his most prominent work, the book *Verbal Behavior*. In its introductory chapter, Skinner described the book as "an exercise in interpretation rather than a quantitative extrapolation of rigorous experimental results" (p. 11). Although this nonempirical contribution appeared at odds with Skinner's original inductive tradition of scientific investigation, he viewed language as nothing more than a complex form of behavior, a subject that he had been studying for years (Skinner, 1938). Thus, in *Verbal Behavior,* Skinner used the same principles of behavior developed through careful laboratory experimentation to interpret the variables responsible for human language. The need for a separate, but not qualitatively different, analysis of language was likely the result of the complexity of its controlling variables. Thus, *Verbal Behavior* represented Skinner's attempt to organize and interpret aspects of language in terms of operant functional relations.

For Skinner (1957), the behavior of the speaker (or writer, signer, etc.) rather than the behavior's effects on the listener was the main topic to be addressed. Most theories of language development have considered speaking and listening to be different manifestations of the same underlying mental processes; these manifestations are typically referred to as *expressive* and *receptive* language (Bishop, 1997). This notion implies that a central agency is responsible for the observed performance (Vargas, 1998). By contrast, Skinner considered speaker (expressive) and listener (receptive) repertoires to be under the control of distinct environmental variables, thus requiring separate analyses. The speaker, in the act of speaking, emits operant behavior that produces stimuli that in turn affect the behavior of others. The listener is, therefore, not engaged in the reception of information per se but is being affected by stimuli generated by the speaker's behavior. Thus, a behavioral analysis of language, as proposed by Skinner, replaces the notion of the transmission of ideas with an account based solely on the interactions of the operant responses of two or more individuals (i.e., the verbal episode). Such an approach is consistent with the overall behavior-analytic model of causation that assumes behavior to be a function of its consequences and correlated antecedent stimuli and not a product of underlying mental processes (Skinner, 1974).

Skinner's (1957) analysis of verbal behavior is "inherently practical and suggests immediate technological applications at almost every step" (p. 12). Thus, our purpose in this chapter is to describe the fundamental concepts of Skinner's system and illustrate some of the ways they have been successfully used in understanding and teaching language. The chapter is organized in the following way: First, we provide a definition of verbal behavior and follow it with a primer on the main elements of the verbal behavior taxonomy. We devote the remainder of the chapter to therapeutic concepts and applications, which include the concepts of functional independence and assessing and teaching verbal behavior on the basis of its defining taxonomic features, as well as various applications for generating new verbal behavior with and without explicit teaching efforts.

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DEFINING *VERBAL BEHAVIOR*

Skinner (1957) defined *verbal behavior* as the behavior of an individual that has been reinforced through the mediation of another person's behavior (i.e., the listener). Its reinforcement is thus indirect, whereas nonverbal behavior is reinforced through the direct manipulation of the environment. For example, when having dinner, one could obtain the salt shaker indirectly by requesting it or directly by reaching for it. The historical relation between behavior and consequence determines whether a behavior is classified as verbal, not the specific consequence produced by a single verbal response. In other words, responses are not defined as verbal on the basis of the consequence they produce but on the basis of their reinforcement history. Moreover, for a response to be considered verbal, the listener must have learned to respond "precisely in order to reinforce the behavior of the speaker" (Skinner, 1957, p. 225). In other words, the stimulus produced by the behavior of the speaker (e.g., the sound produced by the vocal musculature) needs to influence the specific operant behavior of the listener, whose response products in turn serve to reinforce the behavior of the speaker. Writing a note would be considered verbal behavior if such behavior has, in the past, produced specific reinforcing consequences mediated by a listener who has learned to react to the note (i.e., by learning how to read and respond appropriately to text). Thus, writing the note "knock before coming in" could be considered verbal behavior because the listener has been specifically conditioned to knock in the presence of the textual stimulus *knock*. In other words, the communicative function of the note has been shaped by the prior reactions of listeners.

It is important to note that on the basis of this definition, verbal behavior does not need to be vocal or spoken. This is a source of confusion for those first learning Skinner's (1957) approach, given that his use of *verbal* is different from the common use of *verbal* as a synonym for *vocal*. As examples, behaviors such as pointing, gesturing, writing, and signing are also developed through a history of indirect reinforcement provided by listeners and, thus, should also be classified as verbal. The difference between asking for water by raising an empty glass or by saying, "Water, please" is not so interesting to a behavioral analysis of language because they are both members of the same operant class (i.e., they have the same meaning). In other words, they were both produced by wanting water and have likely both been successful in producing water in the past.

ELEMENTARY VERBAL OPERANTS

Skinner (1957) classified various forms of verbal behavior on the basis of their function rather than their topography. In other words, Skinner's classificatory system was solely based on the specific variables that determine what someone says, gestures, or writes rather than on what the behavior looks or sounds like. For Skinner, the behaviors of raising an empty glass or calling the waiter in a restaurant would both be classified the same way if they were evoked by the same variable (wanting another drink) and have historically been reinforced by the same consequence (getting another drink). Skinner proposed several categories of verbal functional relations that he termed *verbal operants:* mand, tact, echoic, textual, intraverbal, transcription, and audience relations. As mentioned earlier, these verbal operants were defined on the basis of the relations between their controlling variables and verbal response products, or what is said, written, signed, and so forth. Two other relations were also described under transcription: copying a text and taking dictation. As a refinement of Skinner's functional taxonomy, Michael (1982) suggested the categories *codic* and *duplic* as a way to reorganize Skinner's system as well as classify forms of verbal behavior that were not previously classifiable. A brief overview of Skinner's classificatory system, including Michael's refined categories, is described next.

Mand

The *mand* is a type of verbal behavior in which the response form or topography (i.e., what is said, written, or signed) is controlled by the speaker's motivation (Michael, 1988) and reinforced with a specific consequence. The speaker's motivation is termed the *motivating operation,* and it is defined as any event that might (a) increase the value of an event as a reinforcer and (b) evoke all behaviors that have been reinforced by that event in the past (Laraway, Snycerski, Michael, & Poling, 2003). Colloquially, a mand is a type of verbal behavior in which what is said is determined by what the speaker wants from the listener. The mand relation has also been referred to as *requesting* or *demanding*. Mands can appear in many forms, such as speaking, writing (including texting and e-mailing), signing, and finger spelling, among others. The reinforcement for a mand is specific to what is said. Thus, the reinforcer for the mand "I want a tall skinny latte" is receiving the latte. Complex mands can appear in many forms, such as "Would you mind buying me some coffee?" in which the mand seems to require verbal action only ("yes" or "no"), when in fact something more effortful than verbal action is actually being manded (the coffee). Another example of a complex mand would be saying, "I am so tired" not as a description of an internal state but as a way to obtain coffee. These are typically referred to as *softened mands* and *disguised mands,* respectively.

According to a recent quantitative review of the verbal behavior literature (Sautter & LeBlanc, 2006), the mand relation has been the most extensively studied verbal operant. Not only has the mand received considerable research attention, but it has also been evaluated across diverse topical areas in recent years. For example, research has shown that (a) individuals with disabilities can be taught to mand for information from others (M. L. Sundberg, Loeb, Hale, & Eigenheer, 2002), (b) mands for information can lead to acquisition of other kinds of verbal behavior (Ingvarsson & Hollobaugh, 2010), (c) individuals taught to mand under one motivational state can mand under different motivational states without additional training (Lechago, Carr, Grow, Love, & Almason, 2010), and (d) mand training in combination with additional contingencies can reduce problem behavior of individuals with disabilities (Hagopian, Fisher, Sullivan, Acquisto, & LeBlanc, 1998).

Tact

The *tact* is a type of verbal behavior in which the response form is controlled primarily by an immediately prior nonverbal stimulus such as an object, action, relation, property, and so forth. For example, saying, "I'm nervous" or "Check out that crazy hairdo" in the presence of a fluttering stomach sensation or mohawk haircut, respectively, would be considered tacts if they produced general social reinforcement from another person. Whereas with the mand, what is said (the response topography) is controlled by a variable correlated with the differential value of a specific reinforcer, with the tact, what is said is controlled by a variable correlated with the differential availability of a reinforcer (Michael, 2004). As with all of the elementary verbal operants except the mand, the primary consequence for the tact is usually generalized conditioned reinforcement.[1] This form of reinforcement frees the tact from any motivational control. If specific rather than nonspecific consequences are delivered contingent on verbal behavior, then the verbal response becomes partially under the control of motivational variables or what the speaker wants from the listener. The terms *pure* and *distorted* have been used to qualify tacts on the basis of having no and partial motivational control, respectively. The tact is sometimes referred to using everyday terms such as *naming, labeling,* and *describing*. Although tempting to use, these terms are technically inaccurate because tacts are defined by their antecedent and consequent variables only. For example, saying "thank you" in response to someone holding the door open for you can be classified as a tact (Skinner, 1957) but not as a name, label, or description. Another good reason for not using the term *naming* as a synonym for *tacting* is the fact that *naming* is already a technical term used to describe a higher order verbal operant (Horne & Lowe, 1996), as we discuss later.

According to Sautter and LeBlanc (2006), the tact relation has been the second most-studied verbal operant. Unlike the mand, which has often been the exclusive focus of investigation, the tact has most often been studied in relation to other verbal operants, most likely as a result of the tact being maintained by relatively less complicated operant control than the mand relation. That is, the tact

[1]It is important to note that for the mature speaker, Skinner (1957) suggested that "the action which a listener takes with respect to a verbal response is often more important to the speaker than generalized reinforcement" (p. 151).

occurs in response to a nonverbal antecedent stimulus and is maintained by nonspecific reinforcement, whereas the mand is under the control of a motivational state and is generally maintained by specific reinforcement. In recent years, research on the tact has generated several findings, including that (a) the tact can be used to teach other kinds of verbal and nonverbal behavior (Goldsmith, LeBlanc, & Sautter, 2007; Miguel, Petursdottir, Carr, & Michael, 2008), (b) tact training can sometimes generate untrained mands (Wallace, Iwata, & Hanley, 2006), and (c) children with disabilities can be taught to tact the actions of others (G. Williams, Carnerero, & Pérez-González, 2006).

Echoic

The *echoic* relation is a special type of verbal operant under the control of verbal stimuli in which the response produces a sound pattern similar to the antecedent verbal stimulus or model. Here, a *verbal stimulus* is defined as the product of someone else's verbal behavior, such as the sound pattern produced by someone's speech (i.e., an auditory stimulus). With the echoic relation, every part or subdivision of the auditory stimulus directly controls parts and subdivisions of the vocal response, for instance, saying "car" when hearing someone say "car." This relation between stimulus and response has been termed *point-to-point correspondence* (Skinner, 1957). The echoic plays an important role in the development of other forms of verbal behavior (Horne & Lowe, 1996; Lowenkron, 1998) and in practice can be used to prompt specific forms that can be placed under the control of other antecedent stimuli. For example, when teaching a child to tact a picture of a car, one could show the picture and at the same time present the vocal model "car" to evoke the correct verbal response. Over time, the vocal model could be faded out, transferring the stimulus control from the vocal to the visual stimulus (M. L. Sundberg & Partington, 1998). Although echoic behavior is clearly a building block for the development of early language skills, it continues to play an important role in the behavior of the mature speaker, as when one repeats something heard (Skinner, 1957) or as a mnemonic device when repeating some instruction that needs to be followed (Lowenkron, 1998). The echoic repertoire has also been identified as playing an important role in more complex forms of language and in language-mediated behaviors such as listening with understanding (Schlinger, 2008a) and categorizing (Horne & Lowe, 1996).

An effective behavior-analytic procedure for teaching echoic repertoires (i.e., generalized vocal imitation) has been available since the 1960s: multiple-exemplar training and differential reinforcement (Kymissis & Poulson, 1990). This procedure has been well studied (Young, Krantz, McClannahan, & Poulson, 1994) and thoroughly disseminated in teaching systems for individuals with language impairment (Lovaas, 2003). Thus, recent research attention to the echoic has generally focused on using the echoic relation to generate other kinds of verbal behavior such as mands and tacts (Kodak & Clements, 2009) and intraverbals (Watkins, Pack-Teixteira, & Howard, 1989).

Textual

The *textual* relation consists of response patterns under control of verbal stimuli in the form of text. In the textual relation, the stimulus is visual (written or printed words), and the response consists of speaking. As with echoic behavior, the textual stimulus and the vocal response have point-to-point correspondence. However, in the case of textual behavior, both stimulus and response product do not resemble each other—the stimulus is visual and the response produces auditory stimuli. In everyday parlance, textual behavior is reading out loud, without the assumption that the reader necessarily comprehends or can react in any other way to what is being read. Understanding what is being read involves being able to react to the sounds being produced (either overtly or covertly) as a listener (Greer & Longano, 2010).

Various behavior-analytic studies have been conducted on the effectiveness of behavioral procedures to teach reading comprehension to typically developing children (e.g., Daly & Martens, 1994; De Rose, De Souza, & Hanna, 1996; Melchiori, De Souza, & De Rose, 2000). However, very few of these studies have incorporated Skinner's (1957) taxonomy. Nonetheless, a vast literature is available on how to produce textual behavior that involves not only responding vocally to printed words but also comprehending them (Sidman, 1994).

Intraverbal

The *intraverbal* is a type of verbal behavior occasioned by what someone else says (signs or writes). However, unlike the echoic and the textual relations, the stimulus and response have no point-to-point correspondence. The intraverbal is the basis for most of people's conversational skills, because most of what people say does not directly match what they hear. An example of intraverbal behavior would be saying "car" as a result of hearing someone say "vehicle." Other examples include responses to the verbal stimuli "What is your name?"; "Boston, Seattle, and Chicago are all _____"; and "Which occupations use a stethoscope?" As with the other verbal operants, intraverbal behavior can occur in many forms, such as speaking, writing, signing, and so forth, as a result of someone's vocal, written, or signed behavior. Moreover, as with all other verbal operants, with the exception of the mand, the reinforcer for the intraverbal is generalized or nonspecific.

According to Sautter and LeBlanc (2006), the intraverbal relation has received the most recent research attention after the mand and tact relations, respectively. Most research on the intraverbal has focused on teaching methods, especially those that involve the emergence of intraverbals after training of verbal operants. For example, Finkel and Williams (2002) used textual and echoic prompts to teach a boy with autism to answer personal questions (intraverbals), Partington and Bailey (1993) showed that tact training was insufficient for generating untrained intraverbals among preschool children, and Ingvarsson and Hollobaugh (2010) showed that mand training resulted in the emergence of untrained intraverbals among children with autism.

Transcription

Other than speaking, a great part of people's verbal behavior involves writing. Two forms of written behavior that are encompassed by the descriptor *transcription* are copying a text and taking dictation. As with echoic behavior, copying a text consists of a verbal response with point-to-point correspondence with the stimulus as well as formal similarity because the stimulus and the response product visually resemble each other. Also, as with echoic behavior, the reinforcement for copying a text depends on the exact correspondence between stimulus and response. When written responses are controlled by what someone says, as in taking dictation, the response still has point-to-point correspondence with the stimulus; however, stimulus and response have no formal similarity. For example, the relation between the written and dictated word *elephant* is arbitrary and based on social convention. The written and auditory stimuli do not resemble each other in any physical sense. Transcription in the forms of copying a text and taking dictation plays an important role in the mature speakers' verbal repertoire (e.g., taking notes during a lecture), and it is supported by subtle forms of reinforcement (e.g., subsequently being able to study the notes). Procedures developed to teach reading comprehension also include teaching transcription repertoires (De Souza, De Rose, & Domeniconi, 2009).

Duplic and Codic Behavior

Michael (1982) proposed a new classification for implied categories in Skinner's (1957) work. These two new categories, duplic and codic behavior, have suggested new forms of verbal relations that were otherwise unclassifiable. The *duplic* involves verbal behavior in which the response form and verbal controlling stimulus have point-to-point correspondence, are in the same sensory modality (e.g., visual, auditory, tactile), and resemble each other (i.e., look alike, sound alike, feel alike). The subcategories of the duplic relation are based on the specific stimulus and response topographies. The echoic and copying a text mentioned earlier would fall under this category. Other relations such as the *mimetic relation,* in which the stimulus is visual (someone signing) and the response is signing (M. L. Sundberg & Partington, 1998), would also be considered a form of duplic.

The *codic* is a type of verbal behavior in which the response form and verbal controlling stimulus have point-to-point correspondence, are in different sensory modalities (e.g., visual, auditory, tactile), and do not resemble each other (i.e., look alike, sound alike, feel alike). The subcategories of codic behavior are also based on the specific stimulus and response topographies. The textual relation and taking dictation would fall under this category. Other forms of verbal behavior may be classified as codic as well, such as reading Braille.

Audience

Audience is a term used to describe the control exerted by the listener over the emission and form of verbal behavior of the speaker. Because the listener mediates reinforcement for the verbal response, he or she acquires important control over what is said (written or signed) by the speaker. The audience typically exerts its control in combination with one or more of the other variables responsible for the emission of specific response forms. This example is the first and probably the simplest of multiple causation of verbal behavior mentioned by Skinner (1957). For example, in the presence of a chocolate chip cookie and an English-speaking audience, a bilingual person might say "cookie" as a tact. However, in the presence of a Portuguese-speaking audience, the same person might say "biscoito." Thus, in this example, the form of the response (what is said, signed, or written) is multiply determined by the object and the audience. The audience is considered a fairly important variable because it might determine whether verbal behavior occurs, the subdivision of language in which it occurs, and also what is talked about (Skinner, 1957). In other words, no verbalization occurs as a function of a single variable in Skinner's analysis; there is (at least) always the audience (which can sometimes be the speaker) to add another layer of control over the emission of verbal behavior.

Autoclitic

The basic operants we have described are said to be "raw material out of which sustained verbal behavior is manufactured" (Skinner, 1957, p. 312). The processes by which responses are arranged to effectively communicate to the listener are often referred to as *grammar* and *syntax,* which Skinner described as autoclitic processes. The *autoclitic* is considered to be a form of secondary verbal behavior that is under control of some aspect of one's prior, current, or upcoming primary verbal response or the controlling variables for that verbal response. Autoclitics serve to describe, qualify, quantify, and comment on verbal behavior and, thus, increase the effectiveness of the listener's reaction to the primary response. This increased communicative effectiveness serves as the primary reinforcer for the autoclitic response. The descriptive autoclitic "I am sure" in the sentence "I am sure it's warm in São Paulo" serves as a tact of the strength of the response "It's warm," whereas "I read" in "I read it will be sunny in São Paulo" informs the listener that the primary response is under the control of a textual stimulus. The autoclitic allows the listener to respond appropriately to the speaker's behavior. The autoclitic "I guess" in "I guess it will be warm and sunny" may lead the listener to pack more than just summer clothes. It has been suggested that all types of autoclitics can be categorized as either autoclitic tacts or autoclitic mands (Peterson, 1978; M. L. Sundberg, 2007). As in the previous examples, the autoclitic tact is under control of the specific variable that is responsible for the emission of the primary verbal operant. Thus, "I see," "I hear," and "I feel" inform the listener that the primary response is under control of a visual, auditory, and tactile stimulus, respectively. Other forms of autoclitic such as "vice versa" or "quote–unquote" may serve to request or mand something from the listener, in the first case to reverse the sentence and in the second not to take the statement literally (Skinner, 1957). Although early verbalizations such as "I see Granny" may seem to consist of the autoclitic "I see" as a tact informing that the source of control of the primary response "Granny" is visual, it is possible that during language acquisition the sentence "I see Granny" serves, initially, as just one unitary response (M. L. Sundberg, 2008). Thus, in a language intervention program, autoclitic relations are typically targeted after the primary verbal relations have already been acquired.

MULTIPLY CONTROLLED VERBAL BEHAVIOR AND COMPLEX VERBAL RELATIONS

It is important to note that the preceding presentation of Skinner's (1957) taxonomy is quite introductory and that a thorough analysis would be beyond the scope of this chapter. A detailed treatment of a functional account of complex and secondary verbal relations is presented in the later chapters of *Verbal Behavior*, but unfortunately, much of Skinner's work has yet to be empirically explored (Hayes, Barnes-Holmes, & Roche, 2001). Additionally, as we have mentioned, one should not dismiss the fact that all verbal behavior is determined by a multitude of variables. As Skinner (1957) suggested,

> Two facts emerge from our survey of the basic functional relations in verbal behavior: (1) the strength of a single response may be, and usually is, a function of more than one variable and (2) a single variable usually affects more than one response. (p. 227)

The simplest example, such as the answer to the question, "What do you eat that is yellow?" can be further analyzed as having multiple causation. The word *eat* would strengthen many possible intraverbal responses related to food, and the word *yellow* would further assimilate these intraverbals into one or a few responses now jointly controlled by "yellow" and "food." Let us not forget the control exerted by the audience and whatever motivational variable may be present for answering the question (Axe, 2008). Awareness of the multiple variables controlling verbal responses can be a great asset to language training (e.g., Hall & Sundberg, 1987). For a more extensive treatment of multiply controlled verbal behavior, we refer the reader to Michael, Palmer, and Sundberg (2011).

THERAPEUTIC CONCEPTS AND APPLICATIONS OF VERBAL BEHAVIOR

Before its therapeutic utility is illustrated, we address some common misconceptions about Skinner's (1957) analysis of verbal behavior. In 1959, Chomsky published a review of *Verbal Behavior* in the journal *Language*. This review has been described as "scathing" (Benjamin, 2007, p. 211) and even as one of the leading causes of the cognitive revolution (Amsel, 1992). Among Chomsky's criticisms were that Skinner's analysis of verbal behavior was unsupported by direct evidence and that it included no new psychological principles to explain human language. Regarding this latter point, Chomsky was not convinced that the richness of human language could be adequately explained without internal representations and processes. Although Chomsky's criticisms have been sufficiently rebutted elsewhere (MacCorquodale, 1970; Palmer, 2006), we should note that the remainder of this chapter indirectly addresses the criticism that Skinner's analysis was purely theoretical and lacked sufficient evidence. Skinner himself stated that his analysis of verbal behavior was "an exercise in interpretation rather than a quantitative extrapolation of rigorous experimental results" (p. 11). However, as we illustrate in the remainder of this chapter, Skinner's analysis of verbal behavior has stimulated considerable research such that a technology of effective language intervention has emerged in the 50 years since the publication of *Verbal Behavior* (Marcon-Dawson, Vicars, & Miguel, 2009; Oah & Dickinson, 1989; Sautter & LeBlanc, 2006; Schlinger, 2008b).

Functional Independence of Verbal Operants

One of Skinner's early predictions about verbal behavior was that the elementary verbal operants are functionally independent of each other early in the developmental period. Skinner (1957) asserted,

> In the terminology of meaning, we say that the word *doll* is used at one time "to ask for a doll" and at another "to describe or refer to a doll." When the response Doll! has been acquired as a mand, however, we do not expect that the child then spontaneously possesses a corresponding tact of similar form. (p. 187)

Skinner's (1957) prediction was that as learners mature and acquire a learning history with other members of their verbal community, their verbal operants would become functionally interdependent. In other words, one would expect a typically developing adolescent who acquires the tact "crescent wrench" to be able to say the words when the need for arises (i.e., as a mand).

The existence of functional independence and its relation to the developmental period has largely been supported by empirical research. A variety of investigations have been conducted to determine whether teaching one verbal operant results in the emergence of other verbal operants with young children and individuals with language disorders (e.g., including those with developmental disabilities), populations for whom functional independence would be more probable. For example, Partington and Bailey (1993) showed that teaching tact relations to typically developing preschoolers had relatively little impact on the development of corresponding intraverbals. Similarly, Shillingsburg, Kelley, Roane, Kisamore, and Brown (2009) taught the concepts of "yes" and "no" to three boys with autism and demonstrated functional independence of the mand, tact, and intraverbal relations. For example, one child was taught to say "yes" as a mand, but the corresponding tact and intraverbal relations did not emerge without additional training. Several similar demonstrations of functional independence have been reported (e.g., Lamarre & Holland, 1985; Petursdottir, Carr, Lechago, & Almason, 2008; M. L. Sundberg, San Juan, Dawdy, & Arguelles, 1990). However, several other investigations have demonstrated various degrees of both functional independence and interdependence of certain verbal operants in similar populations (e.g., Finn, Miguel, & Ahearn, 2012; Hall & Sundberg, 1987; Kelley, Shillingsburg, Castro, Addison, & LaRue, 2007; Petursdottir, Carr, & Michael, 2005). A synthesis of this entire literature suggests that functional independence appears to be more likely in the youngest children and in individuals with language disorders, supporting the notion that typical experiences in the developmental period give rise to functional interdependence in later life. We refer the reader to Barnes-Holmes, Barnes-Holmes, and Cullinan (2000), Horne and Lowe (1996), and Petursdottir et al. (2005) for theoretical accounts of such emergent language that are consistent with or complementary to Skinner's (1957) analysis.

From a therapeutic perspective, the concept of functional independence is the foundation of language training. It is a fairly safe assumption that individuals who require explicit language training (e.g., children with developmental delays, individuals with traumatic brain injury) are likely to exhibit some degree of functional independence of their verbal operants. If this is indeed the case, then teaching such individuals a response under only one type of stimulus control (e.g., *bike* as a tact) should not be expected to lead to the emergence of other verbal operants (e.g., mand, intraverbal) without explicit training. The assumption that a learner's verbal operants are functionally interdependent could be quite risky because this assumption might lead to neglect of other verbal operants, leading to an incomplete verbal repertoire.

A more conservative position would be to assume a learner's verbal operants are functionally independent until evidence is found that some of the operants are interdependent. Even then, the directionality of interdependence—for example, whether mand training produces tacts, but not vice versa—needs to be established so that important verbal operant functions are not neglected. When the kind (e.g., mand–tact) and directionality (e.g., bidirectional vs. unidirectional) of functional independence are established, a language curriculum can be mounted more comprehensively and with confidence that all of a learner's relevant verbal operant functions will be addressed. See the Novel (Derived) Verbal Relations section for a discussion of how certain training strategies might be used to generate functional interdependence and, thus, produce emergent language without explicit training.

Assessment of Verbal Behavior

Before language intervention can begin, a learner's existing verbal repertoires must be assessed to determine the verbal responses and functions that are intact, weak, and missing. Because most standardized language assessments are developed from a structural (e.g., expressive–receptive) rather than a functional perspective, they often fail to provide information about all of a learner's relevant verbal operants (Esch, LaLonde, & Esch, 2010). For example, the Boston Assessment of Severe Aphasia (Dabul, 2000) assesses most of the verbal operants but neglects the mand relation, the Kaufman Speech Praxis Test for Children (Kaufman, 1995) assesses only the echoic relation, and the Expressive

Vocabulary Test (K. T. Williams, 1997) assesses only the tact and intraverbal relations. If language training is based on the assumption of the verbal operants' functional independence (until evidence to the contrary exists), an assessment that explicitly assesses the strength and breadth of a learner's verbal repertoire is necessary. In recent years, two function-based approaches to verbal behavior assessment have emerged.

The first approach to verbal behavior assessment is characterized by an experimental evaluation of a single verbal operant or response topography. For example, Bourret, Vollmer, and Rapp (2004) developed an experimental evaluation of the vocal mand repertoire for individuals with developmental disabilities. The assessment includes conditions that assess whether an individual displays no mands, has idiosyncratic or inarticulate mand topographies, or only mands when prompted. After using the assessment, Bourret et al. empirically demonstrated different mand profiles for three individuals with developmental disabilities. These deficiencies were then directly targeted by a prescribed intervention, resulting in more effective vocal mand repertoires.

Lerman et al. (2005) developed an experimental procedure for determining the verbal operant functions of a single existing response form. In this assessment, learners are exposed to multiple conditions in which the potential maintaining variables for specific verbal operants (e.g., mand, tact, intraverbal, echoic) are arranged for the response. Differentially elevated rates of the response in a particular condition would suggest that the response was under that particular verbal operant's control. For example, if a learner emitted the response at high rates in a condition in which a salient nonverbal stimulus was present and the experimenter delivered response-contingent praise, the evidence would support the response being characterized as a tact. Lerman et al. demonstrated at least one verbal operant function for the single vocal responses of four children with developmental disabilities. Three subsequent replications demonstrated similar differential responding in children with a variety of developmental disabilities (e.g., Kelley, Shillingsburg, Castro, Addison, LaRue, & Martins, 2007; LaFrance, Wilder, Normand, & Squires, 2009; Normand, Severtson, & Beavers, 2008).

The previously described vocal mand assessment (Bourret et al., 2004) and verbal functional analysis (Lerman et al., 2005) procedures require relatively extensive direct observation and environmental manipulation, resulting in high-quality information about a single verbal operant function or response form. Thus, these assessments are likely most relevant for research purposes and could be useful in studying normal and abnormal language development. From a therapeutic perspective, however, one often requires information about the entirety of an individual's verbal repertoire, and thus a more comprehensive approach to language assessment is needed. We describe two such assessments.

The Assessment of Basic Language and Learning Skills—Revised (ABLLS–R; Partington, 2006) is a criterion-referenced assessment that comprehensively assesses a child's learning, verbal behavior, and academic repertoires in 25 specific skill domains. These domains include visual performance (e.g., object matching), echoics, tacts, mands, intraverbals, play, social interaction, classroom routines, reading, and self-help skills, among others. Each domain is further divided into subdomains. For example, the mand domain is made up of 27 different mand skills ranging from nonverbal indicators of interest in an item or activity to fully independent mands. In addition to serving an assessment function, the detailed skill taxonomy of the ABLLS–R serves as a guide to curricular development and as a way to assess individual progress over time. During administration, each ABLLS–R skill is assessed via direct observation or the subjective evaluation of an informant. Given the comprehensive nature of the assessment and its extensive subcategorization, the ABLLS–R can be quite time-consuming to administer. Nevertheless, it appears to be quite popular in therapeutic environments. To date, however, no data on the psychometric properties of the ABLLS–R have been published.

The Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP; M. L. Sundberg, 2008) is another comprehensive verbal behavior assessment for children. As is the ABLLS–R, the VB-MAPP is a criterion-referenced assessment that can be used to document a child's existing repertoire, suggest areas for additional intervention, and track progress over time. The VB-MAPP includes four different assessments. The first, the Milestones Assessment, contains 170 learning, verbal, and academic skills that are sequenced and normed to three early childhood age ranges. The Milestones Assessment also includes the Early Echoic Skills Assessment subtest designed exclusively to assess a learner's echoic (or vocal imitation) repertoire. In addition to the Milestones Assessment, the VB-MAPP includes the Barriers Assessment, which is designed to identify characteristics of a learner that might interfere with learning (e.g., few identifiable reinforcers, dependence on prompts, lack of eye contact). The VB-MAPP also includes the Transition Assessment, which is used to determine when a learner might benefit from a less restrictive therapeutic environment (e.g., transition from a specialty clinic to kindergarten). Finally, the VB-MAPP includes a Task Analysis and Skills Tracking section in which the key milestones are further subdivided into more than 900 skills. As is the ABLLS–R, the VB-MAPP is primarily administered using direct observation supplemented with subjective evaluation. Another similarity is that the VB-MAPP also lacks published analyses of its psychometric properties.

One of the primary advantages of these verbal behavior assessments is that they provide information that is directly relevant to identifying targets for language intervention. Thus, these assessments appear to be more useful for designing interventions than traditional standardized language assessments (Esch et al., 2010). Furthermore, the inclusion of developmental norms in the VB-MAPP affords the opportunity to determine whether it is developmentally appropriate to teach certain language targets. However, until the psychometric properties, primarily interrater reliability, are established for the comprehensive verbal behavior assessments (VB-MAPP and ABLLS–R), their use and interpretation should be approached cautiously.

A Focus on the Verbal Operants

The foundation of virtually all therapeutic applications of verbal behavior is that language is taught under its defining operant controlling variables (G. Williams & Greer, 1993). For example, instead of teaching requests and labels, whose controlling variables may be unspecified, one would teach mands and tacts under their respective defining stimulus control. Although this distinction may appear semantic, it has important clinical and educational implications. Consider this example: A therapist teaches a child to request a break from instruction but does not first determine whether terminating the teaching session would actually function as a reinforcer. Instead, when the child requests the break, the therapist attempts to reinforce the request by providing access to a preferred item. According to a verbal behavior analysis, the child's request is not a mand controlled by motivation to escape from a boring or difficult instruction session. Instead, it might be a mand controlled by motivation to acquire the preferred item. If the latter is true, then when the child wishes to escape from a boring or difficult instruction session, he or she may be unable to do so because he or she has not learned that specific mand. However, if the teaching arrangement had been analyzed from a verbal behavior perspective, the child would have been taught to request a break from instruction when it was uninteresting or had been occurring for quite some time. Thus, all of the elements of the mand relation (i.e., motivation, response, specific reinforcer) would be present during training, and the child might be expected to behave similarly in future similar circumstances.

The same logic applies to the other verbal operants as well. Before a verbal operant is considered fully learned, the behavior should occur under the stimulus conditions specified by each operant. For example, Partington, Sundberg, Newhouse, and Spengler (1994) showed that the tact repertoire of a child with autism had been hindered by prior instruction in which the child was asked, "What is this?" and shown an object. The extraneous verbal stimulus "What is this?" is not a controlling variable for tacts. Thus, this stimulus blocked the ability of nonverbal stimuli (the controlling variables for tacting) to evoke new tacts. Partington et al. then showed that new tacts were acquired by eliminating the verbal stimulus from the instructional situation. Again, although this distinction may appear to be trivial, teaching an entire tact repertoire in the presence of "What is this?" will likely produce a learner who is able to talk about his or her environment only when asked to do so with this specific question. To the extent that this is not a therapist's clinical goal, teaching the tact under its proper controlling variables may eliminate such problems. Of course, if supplemental instructional stimuli are required during the early phases of language training, they can be faded over time such that the target verbal relation is left intact before the end of training (M. L. Sundberg & Partington, 1998).

Transfer of Stimulus Control Across Verbal Operants

One therapeutic strategy that has emerged from the verbal behavior literature is using existing verbal operants to teach new ones (M. L. Sundberg & Michael, 2001). Consider the case of a learner with an existing tact repertoire but almost no intraverbal skills. During baseline, the learner's therapist asks, "What animal chirps?" with the correct intraverbal response being "bird." When the appropriate intraverbal is not forthcoming, the therapist can use the existing tact repertoire to prompt the correct response. For example, the therapist could show the learner a photograph of a bird, which would be likely to evoke the tact *bird*. Over subsequent teaching trials, the photograph of the bird could be faded out by digitally reducing the intensity of the image or delaying its presentation after the verbal instruction. After the photograph is completely removed, the response *bird* may then occur solely under the control of the question and thus be considered an intraverbal response.

In one of the first investigations of this technique in the context of teaching verbal behavior, often referred to as a stimulus–control transfer procedure, Braam and Poling (1983) successfully taught intraverbal responses to two individuals with intellectual disabilities by transferring stimulus control from a temporary nonverbal stimulus to the target verbal stimulus. This tact-to-intraverbal transfer has since been replicated with children with intellectual disabilities (Luciano, 1986), children with autism (Goldsmith et al., 2007), and typically developing children (Miguel, Petursdottir, & Carr, 2005; Partington & Bailey, 1993). Intraverbal behavior has also been taught to children with autism by fading echoic prompts (Watkins et al., 1989). Stimulus control transfer has also been demonstrated to be effective in teaching other kinds of verbal behavior. For example, Barbera and Kubina (2005) and Bloh (2008) taught tacts to children with autism by fading echoic prompts. In addition, M. L. Sundberg, Endicott, and Eigenheer (2000) taught tacts to children with autism via the intraverbal repertoire, and Drash, High, and Tudor (1999) taught echoic responses to children with autism via the mand repertoire.

The generality of stimulus control transfer between various verbal operants makes the procedure quite useful in language intervention. If an individual in need of language instruction has even a small part of one of the verbal repertoires intact (e.g., mands), a therapist can use that verbal operant to teach others, which could reduce the time it would otherwise take if new verbal responses were shaped by reinforcing successive approximations.

Modes of Communication

As previously described, verbal behavior consists of any behavior whose reinforcement is mediated by a trained listener. Thus, not all verbal behavior is vocal behavior. Thus far, we have considered speaking, signing, and writing when describing the primary verbal operants; however, other effective forms of communication exist, such as symbolic systems (Mirenda & Dattilo, 1987). Michael (1985) proposed a distinction between two kinds of verbal behavior on the basis of their response forms that may serve to distinguish among different modes of communication. He referred to these kinds of verbal behavior as *topography-based* and *selection-based* verbal behavior. With topography-based verbal behavior, verbal responses differ in their form (or in the way they look or sound) as a function of their controlling variables. For instance, after not having had food for a while, a speaker might ask for food, whereas after not having had water for a while, the same speaker may ask for water. These two mands have distinct forms (i.e., they consist of different words) that vary with respect to the specific variable that influenced their occurrence. By contrast, selection-based verbal behavior involves indistinguishable verbal forms such as pointing at, touching, or selecting icons from a communication board. Using the preceding example to describe selection-based verbal behavior, the first and second variables (hunger and thirst) would cause indistinguishable selection responses directed at different icons, those depicting food and water, respectively.

Although both kinds of verbal behavior seem to be as effective in communicating with the listener, there may be some important differences in how they are acquired and maintained that could affect how one would choose the mode of communication to be taught to those who lack an effective verbal repertoire. The selection of a communication system for a nonvocal individual has important implications for that individual's life (Shafer, 1993). One important issue to consider is the additional level of conditionality present in selection-based verbal behavior. The evocative control of the visual stimulus (e.g., a picture) over the selection response is conditional on another variable. In our example, the discriminative control exerted by the water icon for selecting it over other icons is dependent on water deprivation, whereas the discriminative control exerted by the food icon is dependent on food deprivation. Conversely, topography-based responses vary in their form as a direct function of the primary controlling variable. In other words, water deprivation directly influences the vocal topography "water, please" or the manual sign for water. Despite the fact that many other variables may contribute to the emission of a specific verbal topography, selection-based verbal behavior always possesses an additional level of conditionality over topography-based verbal behavior; thus, it theoretically has more than one controlling variable. A second difference between the two forms of verbal behavior is the direct correspondence between the response form and its product. The motor movements involved in topography-based verbal behavior (e.g., signing, speaking, writing) correspond with the visual stimuli produced by it, whereas in selection-based verbal behavior, the pointing response has no correspondence with any feature of the indicated stimulus. A third difference is the assumption that a sophisticated repertoire for scanning relevant visual stimuli may be needed for the emission of selection-based, but not a topography-based, verbal behavior (Michael, 1985).

Numerous strategies for teaching topography-based (e.g., speech, sign language) and selection-based (e.g., picture exchange) language systems to children and adults with disabilities have been developed (Mirenda, 2003), but the issue of which form of verbal behavior should be used when designing language intervention programs is still debated among researchers and practitioners (Shafer, 1995; M. L. Sundberg & Michael, 2001; Tincani, 2004; Ziomek & Rehfeldt, 2008), with no clear consensus emerging.

After the publication of Michael's (1985) article, several studies compared topography-based and selection-based behavior in the form of manual signs and pointing responses with either tact or intraverbal functions (e.g., Potter, Huber, & Michael, 1997; C. T. Sundberg & Sundberg, 1990; Wraikat, Sundberg, & Michael, 1991). Reviewing the early work in this area, Potter and Brown (1997) favored topography-based verbal behavior, citing its more rapid acquisition, greater accuracy, and better emergent performance than selection-based verbal behavior. However, more recent studies (Adkins & Axelrod, 2002; Polson & Parsons, 2000; Tincani, 2004; Vignes, 2007; Ziomek & Rehfeldt, 2008) have contradicted this conclusion. With the exception of Polson and Parsons (2000), these later studies were conducted with children with autism, so it is possible that this population acquires selection-based verbal behavior more quickly and with better accuracy than topography-based verbal behavior (which may be more appropriate in typically developing adults). Other differences between studies with contradictory outcomes (e.g., targeting different verbal operants such as intraverbals or mands) will need to be explored in future studies before empirically supported decisions between topography- and selection-based language modalities can be forwarded. As suggested by Tincani (2004), acquisition of either topography-based or selection-based verbal behavior may vary as a function of individual learner characteristics. For example, the ability to imitate the motor behavior of others would be a prerequisite for sign language intervention. Thus, further research is needed to determine the optimal conditions for the selection of specific modalities for individuals with communication difficulties. Until that time, issues affecting the quality of life of the individual, such as communicative effectiveness, should be considered.

Stimulus–Stimulus Pairing and Automatic Reinforcement

Skinner (1957) noted that some responses directly produce a stimulus change that can reinforce the response that produced it. He referred to this process as *automatic reinforcement,* noting that vocal behavior may be reinforced by the sound it produces and may require no additional reinforcement from a listener. Some researchers have suggested that an infant's babbling is automatically reinforced before it is shaped into sounds similar to those produced by members of his or her verbal community (Bijou & Baer, 1965; Mowrer, 1954). Schlinger (1995) suggested that typically developing children frequently hear the vocalizations of their parents before important caregiving events (e.g., being fed and caressed). Such temporal contiguity may cause these sounds to acquire conditioned reinforcing properties. Consequently, any vocalizations that resemble these reinforcing sounds may "automatically" strengthen the vocal behavior that produced it. The result of this process is an infant who babbles more frequently and, theoretically, is better prepared to have his or her vocal repertoire shaped by others.

The concept of automatic reinforcement has influenced the development of a procedure for increasing the rate of vocal behavior in individuals whose vocalizations are too infrequent for direct reinforcement. In the procedure, which has come to be known as the stimulus–stimulus pairing procedure (SSP), the therapist says a target sound and then gives the individual a preferred item regardless of the individual's behavior. Repeated sequences of the target sound and access to the preferred item establish a contiguous relation between sound and item that may imbue the sound with conditioned reinforcing properties. When the individual subsequently produces the sound by emitting the target vocalization more frequently, the vocal response appears to be maintained by automatic reinforcement, because no other programmed consequence occurs. SSP, as a method for increasing spontaneous vocalizations among children with and without disabilities, has produced equivocal results (R. A. Carroll & Klatt, 2008; Esch, Carr, & Grow, 2009; Esch, Carr, & Michael, 2005; Miguel, Carr, & Michael, 2002; Normand & Knoll, 2006; Smith, Michael, & Sundberg, 1996; Stock, Schulze, & Mirenda, 2008; M. L. Sundberg, Michael, Partington, & Sundberg, 1996; Yoon & Bennett, 2000; Yoon & Feliciano, 2007).

Miguel et al. (2002) evaluated the effects of SSP on one-syllable utterances in three preschool-age boys diagnosed with autism. Vocal behavior was observed during 5-minute pre- and postsession periods in each condition. During baseline, target sounds were recorded in the absence of any experimenter interaction. During the control condition, the experimenter emitted the target vocalization and 20 seconds later delivered a preferred edible to the child to control for the possibility that increases in vocal behavior were a product of imitation or of a more stimulating environment. Baseline and control conditions produced no reliable increases in participants' vocal behavior. During the SSP condition, the experimenter's vocalization was preceded by a couple of seconds the delivery of the preferred edible 20 times per session. Results from postsession observations during the SSP condition showed increases in target sounds for two of three participants, suggesting that their vocalizations had acquired automatic reinforcing properties. In a reversal condition in which experimenter vocalizations were no longer correlated with the edibles, these two children's vocalizations decreased. Subsequent investigations of the SSP procedure have produced mixed or null findings (R. A. Carroll & Klatt, 2008; Esch et al., 2005; Normand & Knoll, 2006; Stock et al., 2008).

Esch et al. (2009) speculated that failures to produce an SSP effect may be the result of suboptimal conditioning procedures. To address this concern, they (a) ensured that participants were attending to the experimenter before the target vocal response was emitted; (b) presented the vocal response, immediately followed by the edible, at unpredictable intervals; and (c) intermittently presented a nontarget vocalization that was not followed by the presentation of the edible. Under these conditions, the SSP procedure increased target vocalizations in all three children with autism. These increases were subsequently maintained via direct reinforcement. Although a component analysis was not conducted on the new procedural modifications, this particular SSP treatment package should most likely be used until a more effective option is introduced in the literature.

Novel (Derived) Verbal Relations

On the surface, the functional interdependence of verbal operants or the spontaneous emission of novel verbal responses without training appears to challenge the behavioral conceptualization of language (Chomsky, 1959). However, behavioral researchers have long been interested in understanding the different mechanisms by which verbal behavior emerges without explicit training, and several theoretical accounts of and empirical findings about these phenomena exist (Hayes et al., 2001; Horne & Lowe, 1996; Sidman, 1994; Skinner, 1957). Although the initial research on the emission of novel verbal behavior has primarily focused on functional independence and the transfer between verbal operants (e.g., R. J. Carroll & Hesse, 1987; Sigafoos, Doss, & Reichle, 1989; Sigafoos, Reichle, Doss, Hall, & Pettitt, 1990; M. L. Sundberg et al., 1990; Wallace et al., 2006), the study of emergent listener and speaker relations has been gaining widespread attention, especially as it relates to teaching verbal behavior to children with disabilities (Greer & Ross, 2008; Rehfeldt & Barnes-Holmes, 2009). According to some authors (e.g., Barnes-Holmes et al., 2000; Chase & Danforth, 1991), an important characteristic of verbal behavior is its referential nature. In other words, what makes a behavior truly verbal is its symbolic relation with other events. Saying "car" as an echoic response, for instance, can only be seen as verbal if the word *car* is related to an actual car, the word *vehicle,* a picture of a car, and so forth. Without this relation to other objects or events, the vocal response "car" would lack any meaning (Horne & Lowe, 1996; Sidman, 1994) and could then be considered nonverbal (Barnes-Holmes et al., 2000). Thus, current applied behavioral research on verbal behavior has increasingly emphasized this relational property to generate novel[2] verbal relations (e.g., Rehfeldt & Barnes-Holmes, 2009).

One of these areas of research and application is the study of derived mands, or mands that have not been directly trained (e.g., Halvey & Rehfeldt, 2005; Murphy & Barnes-Holmes, 2009; Murphy, Barnes-Holmes, & Barnes-Holmes, 2005; Rehfeldt & Root, 2005; Rosales & Rehfeldt, 2007). For example, Rehfeldt and Root (2005) taught three adults with intellectual disabilities to request (mand) items using a picture of the item rather than a vocal response. In two subsequent conditional discrimination training conditions, participants learned to identify the pictures given their dictated names and then to identify the printed words corresponding to the dictated names. This procedure allowed for all stimuli involved (dictated names, pictures, and printed words) to become equivalent or substitutable for each other (Sidman, 1994). As an outcome of this substitutability, the printed words served the same function as the pictures. In other words, after training all participants were able to use printed words instead of pictures to request the items, despite this performance not being directly taught. This same conditional discrimination training has been used to teach children who used to follow picture activity schedules to read and follow written schedules (Miguel, Yang, Finn, & Ahearn, 2009). These studies have suggested that verbal behavior may occur without direct reinforcement but solely as a function of a specific history with other verbal events. Additionally, those teaching language to individuals with disabilities can greatly expand their learner's repertoire by relating specific response topographies or stimuli through the use of conditional discrimination training.[3]

Another important area of research is related to the emergence of tact (i.e., labeling) and textual (i.e., reading) responding (Sidman, 1994). For years, behavior analysts have used conditional discrimination training procedures in which individuals select pictures (B stimuli) and printed words

[2]In addition to *novel,* the terms *emergent* and *derived* are also used to refer to behavior that has not been directly reinforced. We use these terms interchangeably in this chapter.

[3]We refer the reader to Rosales and Rehfeldt (2007) for a description of the training protocol for generating derived mands.

(C stimuli) in the presence of their dictated names (A stimuli). Such training (AB, BC) often results in the emergence of both listener responses (i.e., selecting pictures in the presence of printed words: CB and, vice versa, BC) and speaker responses (i.e., tacting the pictures [AD] and reading the printed words [CD]). One of the most relevant applications of this research is in the area of writing and reading comprehension (e.g., De Rose et al., 1996; Hanna, De Souza, De Rose, & Fonseca, 2004). Reading comprehension has typically been defined as the presence of both speaker and listener repertoires (in the form of textual behavior) and reacting to textual stimuli, respectively (Greer & Longano, 2010; Horne & Lowe, 1996). In other words, comprehending a word involves emitting textual behavior (i.e., reading it) and responding conventionally to the stimuli generated by this behavior. Consider a written passage, for which textual behavior consists of reading the words. Conventional listener behavior may involve crying if the text passage is a story about something sad or seeing the scene in one's mind's eye (i.e., visual imagining). The text could also increase the current frequency of a specific verbal response (reading *sand* may increase the likelihood of saying "beach") or guide future behavior, if the text involves directions for doing something.

When studying reading comprehension, behavior analysts typically use matching-to-sample procedures (Sidman, 1994). In a study on reading and spelling by Hanna et al. (2004), seven nonreading first-grade students were taught to construct words from movable letters after being shown printed words as samples, which can be conceptualized as a form of matching to sample involving response construction. After training, children were assessed on whether they could accurately construct the responses given the dictated words as well as whether they could write with paper and pencil both the training and the novel words. Children who could not spell at the beginning of the study could do so with high accuracy with both trained and novel words after training. This specific area of research aims to establish textual control by small units (i.e., letters and groups of letters) that when recombined would evoke novel textual behavior (Matos & Hubner, 1992). It is important to note that many forms of conditional discrimination training have been used to generate novel textual behavior, tacts, mands, and intraverbals using not only vocal behavior but also sign language (e.g., Petursdottir & Haflidadóttir, 2009; Ribeiro, Elias, Goyos, & Miguel, 2010). This area of research is a vast and promising one that has direct implications for curriculum development.

When speaker behavior emerges from listener training, and vice versa, naming is said to have been acquired (Greer & Longano, 2010; Horne & Lowe, 1996). According to Horne and Lowe (1996), naming an object includes not only saying the appropriate tact in its presence (speaker behavior) but also emitting a previously conditioned response in the presence of its spoken, written, or signed name (listener behavior). Naming seems to play a role both in reading comprehension and in the spontaneous language learning described earlier (Greer & Longano, 2010; Miguel & Petursdottir, 2009). In other words, the emergence of novel verbal behavior seems to be correlated with the presence of this naming repertoire (Horne & Lowe, 1996).

Studies on naming have primarily focused on (a) specific procedures that would generate functional interdependence of speaker and listener repertoires (e.g., Fiorile & Greer, 2007; Greer, Stolfi, & Pistoljevic, 2007) and (b) the role of naming in the development of novel verbal and nonverbal behavior such as visual categorization (e.g., Lowe, Horne, Harris, & Randle, 2002; Miguel et al., 2008; Petursdottir et al., 2008). Fiorile and Greer (2007) taught four children with autism to tact three-dimensional arbitrary stimuli (speaker training), after which they could not receptively identify the stimuli (listener testing), suggesting lack of naming. Speaker and listener responses were then directly taught with multiple stimulus sets until participants could, in the presence of novel stimuli, receptively identify the stimuli when trained solely how to tact them. After this multiple-exemplar instructional procedure, speaker-to-listener transfer was demonstrated. Along with other studies, Fiorile and Greer's results suggested that multiple-exemplar instruction may be yet another teaching technique for generating novel verbal behavior in clinically relevant populations. Multiple-exemplar training might actually account for how naming develops in typically developing individuals. In Horne and Lowe's (1996) example of how listener behavior can be taught, selection responses are evoked by instructions (e.g., "Find the ball") and are modeled (e.g., pointing to the ball) and reinforced by the caregiver (e.g., "Good girl!"). Through this process, the child learns to identify the object in the presence of its name. Later, the child is taught to emit a variety of listener responses that encompass ever more specific instructions (e.g., *pick up, throw away, put, bounce, roll*). Children also learn to emit and repeat vocalizations that sound similar to those produced by the caregiver. Now, in the presence of the object (e.g., a ball), the caregiver may label it (e.g., "Ball") and model the conventional listener response (e.g., pointing to the ball) that would lead the child to repeat the caregiver's utterance in the presence of the object (e.g., "Ball"). After repeated trials, the child may now say the same verbal response in the absence of the model. That is, he or she would say "Ball" in the presence of a ball without being prompted to do so. Once a child has been explicitly taught to respond as a speaker and a listener in the presence of multiple objects, these two repertoires become part of an interconnected relation that allow for the emergence of one after training only the other.

A recent series of studies has also evaluated the role of naming in the development of visual categorization (Horne, Hughes, & Lowe, 2006; Horne, Lowe, & Harris, 2007; Horne, Lowe, & Randle, 2004; Lowe et al., 2002; Lowe, Horne, & Hughes, 2005; Mahoney, Miguel, Ahearn, & Bell, 2011; Miguel et al., 2008). For example, Miguel et al. (2008) taught typically developing preschool children either speaker behavior (tacting objects with common names) or listener behavior (pointing to objects after hearing their category names). After learning one of these two relations, children were asked to group the objects into categories by selecting one of the pictures that matched a sample. Of the four participants who had undergone tact training, two categorized correctly after the initial tact training and two other participants only categorized after additional training. Their categorization performance was correlated with their listener repertoire. In other words, those participants who could not point to the pictures given their category names could also not categorize them. Another group of participants, trained on listener behavior only, also failed to tact correctly when correct categorization did not occur. These results replicated those of previous studies in that naming seemed to be correlated with not only the emergence of verbal behavior but also nonverbal behavior such as categorization. These studies have important applied implications because the skill of grouping objects or pictures by category may develop with no direct training when children learn to tact pictures and objects with a common category name and respond as listeners when hearing the names of their categories.[4]

The convergence of multiple approaches to generating emergent verbal behavior, with substantial recent research on the topic, bodes well for (a) the continued development of procedures for efficiently producing language and (b) the refinement of behavioral theories of typical language development. Additionally, it seems clear that a behavioral approach to language development and acquisition adequately accounts for the emergence of novel (not directly taught and unreinforced) instances of language.

Verbal Behavior Approach to Autism Treatment

One of the most active areas of contemporary verbal behavior application is in the early and intensive behavioral intervention (EIBI) of childhood autism. EIBI, as spearheaded by the work of Lovaas (1987, 2003), often involves delivering dozens of hours of behavioral treatment each week over a span of several years to young children with autism. The clinical foci of EIBI are often skill acquisition (e.g., verbal behavior, social skills, preacademic skills) and, to a lesser extent, the reduction of problem behavior. More than two dozen large-*N* studies, both experimental and nonexperimental, have been published on EIBI. Collectively, these studies have demonstrated the most substantial improvements in the

[4]We refer the reader to Miguel and Petursdottir (2009) for a description of the procedures to establish derived categorization skills.

repertoires of children with autism than any therapeutic alternative (see Chapter 12, this volume; Eldevik et al., 2009). Some of these studies have even reported large numbers of children achieving normal intellectual functioning by the end of treatment (e.g., Lovaas, 1987; Perry et al., 2008). Because of the early empirical and dissemination efforts of Lovaas (1987, 2003), many EIBI programs share procedural similarities with his model (Love, Carr, Almason, & Petursdottir, 2009). However, an alternative version of EIBI has emerged (M. L. Sundberg & Michael, 2001), based on early language interventions influenced by Skinner's (1957) analysis of verbal behavior (e.g., Spradlin, 1963).

Sometimes referred to as the *verbal behavior approach* (Barbera & Rasmussen, 2007), this model appears to have increased in popularity and demand among therapists and consumers alike. In a survey of directors of EIBI programs, Love et al. (2009) reported that the most commonly used published curriculum was the M. L. Sundberg and Partington (1998) verbal behavior treatment manual. The growth of this approach has likely been facilitated by the publication of several other clinical manuals (e.g., Barbera & Rasmussen; Greer & Ross, 2008; Luckevich, 2008) and comprehensive verbal behavior assessments (Partington, 2006; M. L. Sundberg, 2008).

Although the verbal behavior approach shares several similarities with more traditional EIBI approaches (e.g., treatment intensity, hierarchically organized curricula, operant training techniques), the verbal behavior and traditional approaches differ substantially in how they address verbal behavior. Whereas more traditional approaches organize their language curricula around the concepts of receptive and expressive language (e.g., Leaf & McEachin, 1999; Lovaas, 2003), verbal behavior programs use Skinner's (1957) verbal operant taxonomy as their organizational framework for the reasons described earlier (see A Focus on the Verbal Operants section). Because the primary focus of most EIBI programs is language training, traditional and verbal behavior curricula often look quite different. On the basis of the published empirical and clinical literatures, the following features are common characteristics of verbal behavior EIBI programs: (a) a focus on the verbal operants as identified by Skinner, (b) comprehensive verbal behavior assessment, (c) SSP procedures as necessary, (d) an emphasis on transfer of stimulus control across verbal operants, (e) a preference for topography-based alternatives (e.g., signs) to vocal behavior, (f) mand training placed early in the curriculum, (g) mixed verbal operant teaching, (h) natural environment teaching, and (i) discontinuous measurement of learner progress. We described the first five characteristics earlier in the chapter; we briefly describe the remaining characteristics now.

Proponents of the verbal behavior approach have argued that the mand relation should occupy a prominent position in a language curriculum. This view is in contrast to many traditional programs that often spend considerable time teaching listener and tact relations during the early phases of intervention (e.g., Lovaas, 2003). M. L. Sundberg and Michael (2001) argued that the mand is relatively more beneficial for early learners than are other verbal operants because the mand produces specific reinforcers for which motivation is strong. In other words, mands allow an individual to satisfy his or her wants and needs better than other verbal operants that produce nonspecific reinforcement. Although empirical data have not been reported on the specific therapeutic value of early mand training, the underlying conceptual logic is sound and there do not appear to be any contraindications to the recommendation. Furthermore, establishing early mands could reduce the occurrence of socially reinforced problem behavior (Tiger, Hanley, & Bruzek, 2008).

Another common feature of the verbal behavior approach is the use of mixed verbal-operant trials during intervention. For example, instead of teaching mands and tacts in separate sessions, one might intersperse trials of each for the same response form in the same session. Although task interspersal has been proposed as a more efficient method of language training, the findings have been equivocal (Arntzen & Almås, 2002; R. J. Carroll & Hesse, 1987; Sidener et al., 2010). However, as we previously described (in the Novel [Derived] Verbal Relations section), mixed verbal operant trials are functionally similar to multiple-exemplar instruction, which has been shown to result in emergent behavior (e.g., Fiorile & Greer, 2007). Thus, although mixed verbal operant trials have not yet been shown to reliably produce more efficient skill acquisition, it is possible that such procedures might contribute to the development of the functional interdependence of the verbal operants involved. Additional research on this instructional strategy is warranted to elucidate the likelihood of such outcomes.

Mixed verbal operant trials are compatible with another common feature of the verbal behavior approach, natural environment teaching (M. L. Sundberg & Partington, 1999). Natural environment teaching is exemplified by learner-directed learning opportunities, enhanced motivation, and instruction in natural settings. Although natural environment teaching is not unique to the verbal behavior approach (Charlop-Christy & LeBlanc, 1999), it might facilitate teaching under each verbal operant's relevant stimulus conditions that might sometimes be difficult to arrange in more structured teaching arrangements. Both mixed verbal operant trials and natural environment training can pose challenges to the measurement of learner progress. Thus, proponents of the verbal behavior approach have often recommended discontinuous measurement procedures such as observing and recording behavioral data only on the first trial. Thus far, this and comparable discontinuous measurement procedures have produced outcomes that are comparable to continuous trial-by-trial measurement procedures (Cummings & Carr, 2009; Najdowski et al., 2009). However, additional research is needed to more fully determine the adequacy of discontinuous measurement procedures.

Of all the common procedures associated with the verbal behavior approach, the most important are the focus on verbal operants and comprehensive verbal behavior assessment. Although the other intervention components are commonly packaged together in the verbal behavior approach, they are secondary to the primary emphasis on the assessment and intervention of the verbal operants. Besides evaluations of several EIBI programs that appear to have contained elements of a verbal behavior curriculum (Howard, Sparkman, Cohen, Green, & Stanislaw, 2005; Perry et al., 2008; Sallows & Graupner, 2005), no long-term outcome data exist on the intensive application of the verbal behavior approach to problems associated with autism. Carr and Firth (2005) noted this research deficit and proposed several publication mechanisms for its remediation: case studies, case series, and randomized clinical trials. Although a large-*N* case series has recently been presented, showing successful outcomes (Miklos, 2010), additional published evidence on the verbal behavior approach will be necessary to determine its outcomes compared with those of more established approaches (e.g., Lovaas, 1987). In the meantime, the conceptual basis of the verbal behavior approach is sound and many of its attendant characteristics have some empirical support.

CONCLUSION

Skinner's (1957) interpretation of human language using established learning principles resulted in a functional taxonomy of verbal behavior that differed considerably from mainstream psycholinguistic theories. However, the analysis of verbal behavior has proven quite effective over the years in generating additional conceptual analysis as well as basic and applied empirical investigation (Schlinger, 2008b). As previously illustrated, the verbal operant taxonomy and concepts (e.g., functional independence) from Skinner's (1957) analysis have made an enormous impact on language assessment and intervention, both strategically (e.g., assessment and teaching of verbal operants) and tactically (e.g., transfer-of-stimulus control and SSP). The early and intensive behavioral intervention with autism has also benefitted from verbal behavior theory and empirical findings.

Regarding the impact of verbal behavior more generally, in recent years scholarly work on verbal behavior has more frequently been presented at professional conferences (Kangas & Vaidya, 2007), and similar increases have been observed in published empirical literature (Marcon-Dawson et al., 2009). Furthermore, Skinner's (1957) original text is still being cited regularly (Dymond, O'Hora, Whelan, & O'Donovan, 2006). We predict that the current lines of research on verbal operants and derived verbal relations, in addition to behavioral formulations of memory-related phenomena (Palmer, 1991), will not only result in even more successful therapeutic applications but also further our understanding of normal language acquisition and use.

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CHAPTER 14

ASSESSMENT AND TREATMENT OF SEVERE PROBLEM BEHAVIOR

Louis P. Hagopian, Claudia L. Dozier, Griffin W. Rooker, and Brooke A. Jones

Individuals with intellectual and developmental disabilities (IDD) are at increased risk for displaying problem behavior (National Institutes of Health, 1991), such as self-injurious behavior (SIB; e.g., hitting, biting, scratching oneself), aggression (e.g., hitting, pinching, kicking, pulling hair of others), destructive behavior (e.g., breaking or throwing items), pica (eating inedible objects), elopement (running away from caregivers), noncompliance, and tantrums (Condillac, 2007). Individuals often display multiple types of problem behavior, and the levels of severity can range from relatively minor and short lived to severe, chronic, and potentially life threatening.

Severe problem behavior has been defined as

> culturally abnormal behavior of such intensity, frequency, or duration that the physical safety of the person or others is likely to be placed in serious jeopardy, or behavior which is likely to seriously limit use of, or result in the person being denied access to, ordinary community facilities. (Emerson, 1995, p. 24)

Injuries secondary to SIB can include contusions and lacerations; retinal detachment and blindness; infections; and loss of tissue from self-biting, particularly of the tongue, lips, and hands (Hyman, Fisher, Mercugliano, & Cataldo, 1990; Kahng, Iwata, & Lewin, 2002). Aggressive behavior can result in tissue damage and broken bones to others and is associated with increased service costs, high rates of caregiver turnover, and placement in restrictive settings (D. A. Allen, 2000).

Epidemiological research has identified several variables that are correlated with problem behavior in individuals with IDD that can be considered risk factors, although the direction of causality is not certain. These risk factors include the diagnosis of autism, the level of intellectual disability, the degree of receptive and expressive communication deficits, and the presence of sensory impairments (Ando & Yoshimura, 1979; Holden & Gitlesen, 2006; Kieman & Alborz, 1996; Lowe et al., 2007; McClintock, Hall, & Oliver, 2003). Deficits associated with these risk factors may predispose one to a developmental trajectory in which problem behavior is more likely to occur, to be inadvertently reinforced by care providers, and to ultimately interfere with the development of adaptive behaviors.

Studies have suggested that 5% to 10% of individuals with IDD engage in highly severe and potentially life-threatening problem behavior. This prevalence rate rises to as high as 40% when less severe problem behaviors (e.g., not as frequent, injurious, unmanageable, or limiting) are included (Holden & Gitlesen, 2006; Lowe et al., 2007). Although estimates of the prevalence of severe problem behavior in individuals with IDD have varied across studies, the evidence that the presence of these behaviors is a significant health issue is clear (Crnic, Hoffman, Gaze, & Edelbrock, 2004; National Institutes of Health, 2001).

In addition to harming themselves and others, individuals who display severe problem behavior may display minimal academic, communication, and daily living skills because of the interference of

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problem behavior. They are less likely to access community activities, thus remaining isolated from potential opportunities for social interactions that are important for community inclusion (Harris & Glasberg, 2007; Kormann & Petronko, 2004). Without appropriate services and supports, individuals with severe problem behavior (a) are often rejected by their peers, (b) have difficulty obtaining educational and vocational services, (c) have poorer family interactions, (d) are at an increased risk for school or employment failure, and (e) have limited opportunities to make choices provided to the rest of society (e.g., choices regarding where they live, where they work, and where they attend school; Dunlap et al., 2006; McAtee, Carr, & Schulte, 2004; National Institutes of Health, 2001). For many individuals with developmental disabilities, problem behavior may represent the greatest barrier to integration and participation in community activities (Lowe et al., 2007).

Individuals who display severe problem behavior pose distinct challenges to caregivers, which often leads to family stress (Antonacci, Manuel, & Davis, 2008; Baker, Blacher, Crnic, & Edelbrock, 2002; Baker & Heller, 1996). Caregivers have strained relationships with the individual with problem behavior, other family members (i.e., other children and spouses), and friends as a result of the stress of providing care to an individual with problem behavior. Thus, the occurrence of severe problem behavior is a key reason for individuals with IDD being placed in care outside of the home environment (Sherman, 1988) or returning to facility- or community-based care (Sutter, Mayeda, Call, Yanagi, & Yee, 1980).

In addition to these immediate difficulties, continued problem behavior is associated with long-term difficulties. Individuals who are not provided appropriate and early intervention (i.e., assessment and treatment services) to decrease problem behavior will require more services and resources throughout their life (National Institutes of Health, 2001), with associated monetary costs to society (Jones et al., 2008). Honeycutt et al. (2003) estimated that the lifetime excess costs for the 2000 U.S. birth cohort of individuals with IDD is approximately $44 billion, a large portion of which is the result of the prevalence of problem behavior in this population. This variety of costs to individuals with intellectual disabilities, their caregivers, and society makes it clear that severe problem behavior is a health crisis that necessitates widespread use of evidence-based assessment of and intervention in severe problem behavior (New Freedom Commission on Mental Health, 2003).

Decades of research have shown that as with appropriate behavior, most problem behavior is learned and that both appropriate and problem behavior can serve common functions (Iwata, Kahng, Wallace, & Lindberg, 2000). For example, severe problem behavior has been shown to occur to (a) access socially mediated consequences such as attention or preferred items or activities, (b) escape or avoid an undesirable social situation such as academic demands, (c) gain sensory stimulation (e.g., auditory stimulation or visual stimulation, often referred to as *automatic positive reinforcement*), or (d) escape or avoid aversive sensory stimulation (e.g., noise or an earache, often repired to as *automatic negative reinforcement;* E. G. Carr & Durand, 1977; Iwata, Kahng, et al., 2000). That same body of behavior-analytic research has also shown that severe problem behavior can be effectively treated using interventions that are based on the function of the behavior (i.e., the reinforcing consequence that maintains the behavior); these interventions include eliminating the identified reinforcer (i.e., extinction), arranging the environment in a way that decreases the likelihood of problem behavior, and using operant procedures to establish and maintain alternative adaptive behavior (communication, social, and leisure skills). In this chapter, we describe these behavior-analytic assessment and treatment technologies. Although our focus is on ontogenetic learning processes, we should note that biological variables can have an impact on problem behavior and pharmacological interventions have been integrated into behavior-analytic interventions (see Hagopian & Caruso-Anderson, 2010; T. Thompson, Moore, & Symons, 2007). The scope of this chapter, however, is limited to nonpharmacological interventions.

FUNCTIONAL BEHAVIOR ASSESSMENT

Functional behavioral assessment (FBA) has become the dominant approach to identifying the variables that maintain problem behavior and to prescribing interventions on the basis of that knowledge. A variety of specific assessment procedures have been developed that can be used to help develop or test hypotheses about the antecedents and consequences controlling problem behavior (we discuss them in detail later). Identifying these variables facilitates the development of effective interventions designed to decrease problem behavior and increase appropriate behavior.

This approach has strong empirical support and is well established as best practice. Several review articles (Kahng et al., 2002; Lilienfield, 2005; Sturmey, 2002) and meta-analyses (e.g., Didden, Duker, & Korzilius, 1997; Weisz, Weiss, Han, Granger, & Morton, 1995) have summarized this literature. Many scientific, governmental, and professional organizations, including the American Association on Intellectual and Developmental Disabilities (formerly the American Association on Mental Retardation; Rush & Frances, 2000), the U.S. Surgeon General (U.S. Department of Health and Human Services, 1999), and the American Academy of Pediatrics (Myers, Plauche-Johnson, & the Council on Children with Disabilities, 2007), have characterized function-based behavioral interventions as empirically supported and as representing best practice for individuals with autism or other IDD. On the basis of the preponderance of data supporting the effectiveness of this approach, FBA has been codified in federal legislation: the Individuals With Disabilities Education Act of 1997 (IDEA). This law requires that an FBA inform behavior-intervention plans developed to ameliorate problem behavior in children with disabilities. It is an advance over previous practices, but one should recognize that the IDEA requirement does not prescribe which FBA method to use; we discuss the variety of FBA methods and their empirical base later in this chapter.

The three goals of an FBA are to understand, treat, and prevent problem behavior (Hanley, 2010; Iwata, Kahng, et al., 2000; Iwata, Vollmer, & Zarcone, 1990). First, the use of FBAs allows clinicians and researchers to gain a clear understanding of the antecedents and consequences that occasion and reinforce problem behavior. Second, knowledge of the controlling variables of problem behavior directly informs the development of effective treatment. That is, when conditions are identified that affect the momentary and long-term probability of problem behavior, this information can be used to decrease the problem behavior and to help the individual obtain functional outcomes in a socially acceptable manner. Finally, FBAs allow users to design environments to prevent problem behavior from developing (Hanley, 2010). For example, if an individual's problem behavior targeted for change is maintained by reinforcer A, then that individual's environment can be constructed to ensure that reinforcer A is either freely available or accessible only via appropriate behavior. Hanley, Heal, Tiger, and Ingvarsson (2007) used prevention techniques informed by FBAs to teach life skills to preschool children. Specifically, they programmed opportunities for children to obtain reinforcement for making appropriate requests for attention and preferred items, following instructions, and waiting for preferred items or activities.

Several FBA methods are commonly used by clinicians and have been studied by behavior analysts. These methods can be classified as follows: indirect (anecdotal) methods, which include caregiver reports during interviews or responses to questionnaires; descriptive (naturalistic) methods, which involve collecting observational data on environmental events that co-occur with problem behavior; and functional (experimental) analysis methods, which involve collecting observational data while antecedents and consequences in the environment are systematically manipulated.

Indirect Assessment

Indirect assessments typically involve gathering data about problem behavior via reports of individuals who have directly observed the individual emitting the problem behavior of concern. Although we provide an overview of the more commonly used indirect assessment methods, their use as anything other than a preliminary assessment tool cannot be endorsed because their validity has proven to be low (Barton-Arwood, Wehby, Gunter, & Lane, 2003). Examples of indirect assessments include the Functional Analysis Screening Tool (Iwata, 1995), the Motivation Assessment Scale (Durand & Crimmins, 1988), the Questions About Behavioral Function (Matson & Vollmer, 1995), the Contingency Analysis Questionnaire (Wieseler, Hanson, Chamberlain, & Thompson, 1985), and the Functional Analysis Interview Form (O'Neill, Horner, Albin, Storey, & Sprague, 1990). These assessments contain specific open-ended questions, close-ended questions, or both that are designed to solicit information regarding relevant characteristics (e.g., frequency, topography, context) of the problem behavior.

Indirect assessments are simple (Sturmey, 1994) and can be administered quickly (Reid, 1992). However, the indirect assessment has not been reliable when determining the function of a behavior for two reasons. First, reporters on behavior tend to differ on the likelihood of behavior given different antecedent and consequent events. For example, Sigafoos, Kerr, and Roberts (1994) and Zarcone, Rodgers, Iwata, Rourke, and Dorsey (1991) both found that the reliability between reports was low (agreement = 44.4% on aggression and 29.1% on SIB) on the Motivation Assessment Scale. This finding is not particularly surprising because indirect assessments are often conducted with reporters who may have observed the response in different settings and situations (Floyd, Phaneuf, & Wilczynski, 2005). That is, indirect assessments rely on informant responses that are subjective and may be affected by a host of variables (Lennox & Miltenberger, 1989; Sturmey, 1994). For example, the informant may respond with what he or she thinks is an appropriate response rather than with what actually occurred. Second, correspondence between indirect assessments and a more stringent test of the maintaining variables (e.g., a functional analysis [FA], the standard for demonstrating a causal relation between environmental events and problem behavior, described in the section Functional [Experimental] Analysis later in this chapter) do not always correspond (e.g., Alter, Conroy, Mancil, & Haydon, 2008). Similarly, this finding is not particularly surprising because indirect assessments provide information only on the correlation between an event before and after a response.

Despite the limited usefulness of the indirect assessment in determining the function of behavior, this assessment method may still be useful in identifying environmental variables that are important to consider. The most useful of these assessments are those that include open-ended questions allowing for elaboration about variables or circumstances that may affect the problem behavior (Hanley, 2010). Thus, these methods are well suited for use as preliminary guides such that clinicians have access to information about a target behavior and potential environmental determinants before conducting a functional (experimental) analysis. Because of this, indirect assessments may be necessary (e.g., to identify events to assess) but are not sufficient for the development of effective treatment.

Descriptive Assessment

Descriptive assessment (DA) involves direct observation of the behavior of concern in the environment in which it occurs while recording the antecedent and consequent events surrounding that behavior. When conducting a DA, the clinician does not manipulate antecedents or consequences. Instead, the purpose of a DA is to provide a qualitative or quantitative account of the target behavior and its temporal relation with environmental events.

Numerous DA methods have been developed. *Narrative recording* is an open-ended form of DA in which an observer records details about events happening before and after the problem behavior (Bijou, Peterson, & Ault, 1968). This method can be inaccurate, because responses can be difficult for observers to record in the moment and later quantify. That is, writing down all of the possible events that surround problem behavior and later determining how to categorize these events for purposes of quantifying their occurrence may be difficult. These difficulties may lead to problems with determining accurate and reliable levels and types of behavior and environmental events. Another DA method, *antecedent–behavior–consequence recording* (Lalli, Browder, Mace, & Brown, 1993; Mace & Belfiore, 1990; Repp, Singh, Karsh, & Deitz, 1991) often involves an observer recording the target problem behavior and the antecedent and consequent events immediately surrounding that behavior. When this recording is done in a closed-ended fashion, the observer is limited to recording antecedent and consequent events from a predetermined list. Such a practice is only as good as the list. Antecedent–behavior–consequence data must be collected in a manner that permits one to identify each of the various antecedents that are encountered (both with and without problem behavior), which will allow one to determine the probability of problem behavior in the context of each antecedent relative to how often it is encountered.

Finally, *scatterplot recording* (Touchette, MacDonald, & Langer, 1985) involves recording when an instance of problem behavior occurs and plotting these occurrences over time. Such a plot allows clinicians to observe temporal distributions of problem behavior before, during, and after regularly scheduled events such as meals, medication delivery, and bedtime. Although this method is simple to implement, its correlational nature is limiting. For example, many antecedent and consequent events that are functionally related to behavior are not fixed to particular time periods; thus, the correlation may be weak. Even strong correlations provide only tentative hypotheses about the specific events that may be effectively manipulated to reduce problem behavior (e.g., problem behavior that occurs around bedtime may be linked to access to attention; however, additional analysis is required to verify this finding).

Although DAs provide information about the correlation between problem behavior and environmental events, they do not determine functional (cause–effect) relations in the way that FAs do; the FA is described in the next section. Numerous studies comparing the outcomes of DAs and the more definitive FAs have suggested that the correspondence between these assessments is poor, suggesting that the DA can incorrectly identify the function of the problem behavior (e.g., J. C. Borrero & Vollmer, 2002; Lerman & Iwata, 1993; Mace & Lalli, 1991; St. Peter et al., 2005; R. H. Thompson & Iwata, 2001). For example, in the St. Peter et al. (2005) study, DAs of the problem behavior of three individuals suggested that attention was the most common consequence of problem behavior; however, the FAs failed to demonstrate a cause–effect relationship between problem behavior and attention. This outcome is less surprising when one considers that severe problem behavior often leads caregivers to attend to the client (e.g., to ensure the safety of the client and other individuals or to suppress the behavior through restraint or blocking). The DA documents the correlation between problem behavior and attention, but the function of the behavior may lie elsewhere. Thus, the clinician using the DA must be careful to recall that correlation does not imply causation. To ignore this fact increases the probability that DA-informed interventions will fail to reduce problem behavior.

Given these limitations, the most useful role for the DA is to refine operational definitions of problem behavior, obtain information about the context in which problem behavior occurs, and ultimately formulate tentative hypotheses about the environmental determinants of the problem behavior, hypotheses that may then be evaluated in an FA. Indeed, some studies have demonstrated the usefulness of DA in identifying idiosyncratic variables not often assessed in a typical FA (e.g., Fisher, Adelinis, Thompson, Worsdell, & Zarcone, 1998). This information may be most useful when the DA is conducted by an experienced observer using an open-ended DA (Hanley, 2010).

Functional (Experimental) Analysis

FA (Iwata, Dorsey, Slifer, Bauman, & Richman, 1982/1994) is an FBA methodology in which antecedents and consequences are experimentally manipulated and their effects on problem behavior are directly examined. The approach is characterized as experimental in the sense that the FA permits a direct test of hypotheses and can identify causal relations (see Hanley, Iwata, & McCord, 2003); it does not mean that the method is still in a testing or development phase.

The first comprehensive and standardized model for conducting an FA was described by Iwata, Dorsey, et al. (1982/1994) and involved direct observation of participants during brief, repeated exposure to three test conditions and one control condition. The test conditions assessed sensitivity of problem behavior to social positive reinforcement (attention), social negative reinforcement (escape from age-appropriate demands), and sensory stimulation (typically termed *automatic reinforcement* because the behavior produces its own reinforcement). The level of problem behavior (e.g., frequency) during each of these test conditions was compared with a control condition in which these consequences were absent. If problem behavior occurred predominantly during a single condition, and if this pattern was observed repeatedly, then Iwata, Dorsey, et al. concluded that they had identified the function of the problem behavior.

Since the seminal study by Iwata, Dorsey, et al. (1982/1994), numerous modifications and extensions of the FA have been described, which include (a) additional test conditions used to evaluate additional antecedents and consequences that may be functionally related to problem behavior, (b) the use of different experimental designs, and (c) the use of more specific control conditions (see Hanley et al., 2003, for a review). FAs have been conducted with various topographies of severe problem behavior, including aggression (e.g., Fisher, Ninness, & Piazza, 1996; R. H. Thompson, Fisher, Piazza, & Kuhn, 1998), disruption (e.g., Broussard & Northup, 1995; Hanley, Piazza, & Fisher, 1997), self-injury (e.g., Iwata, Dorsey, et al., 1982/1994; Kennedy & Souza, 1995; Mazaleski, Iwata, Vollmer, Zarcone, & Smith, 1993; Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993), and pica (e.g., Mace & Knight, 1986; Piazza et al., 1998). In their review of the FA literature through 2000, Hanley et al. (2003) reported that more than 300 FA studies had been conducted across many different populations and behaviors and that in 96% of the cases evaluated, the FA method proved reliable in identifying the function of the problem behavior. Recent research has supported the ecological validity of the FA because the variables commonly manipulated in FAs frequently occur in the natural environment (Camp, Iwata, Hammond, & Bloom, 2009; McKerchar & Thompson, 2004; R. H. Thompson & Iwata, 2001).

Although the FA is the most rigorous method for determining variables responsible for problem behavior, it is not without weakness. FA results were undifferentiated (i.e., failed to identify a cause of the problem behavior) in 4.1% of cases in a review of published studies (Hanley et al., 2003) and in 12.5% (Kurtz et al., 2003) and 15% (Vollmer, Marcus, Ringdahl, & Roane, 1995) of research studies.

Common FA conditions. To create conditions analogous to those present in the natural environment, FAs involve several conditions in which relevant antecedent and consequent events are manipulated. Antecedent events include establishing operations (EOs) and discriminative stimuli (S^Ds). EOs are events (e.g., deprivation from attention or the presence of aversive demands) that increase the reinforcing efficacy of a particular stimulus (e.g., attention or escape from demands) and the likelihood that behavior will occur to access that stimulus (see Michael, 1982, 1993, 2000, for an extended discussion of EOs and Iwata, Smith, & Michael, 2000, for a specific discussion on EOs and problem behavior). An S^D is a stimulus that increases the momentary probability of behavior on the basis of a history of that stimulus being correlated with a reinforcement contingency (Skinner, 1953). For example, the presence of a family member could function as an S^D for problem behavior if that family member frequently reinforces problem behavior.

In the control condition of the FA, highly preferred tangible items and attention are freely available, and no programmed consequences occur for problem behavior. This condition serves as the control condition because the EOs and programmed consequences essential to the test conditions are not present. Thus, when interpreting the findings of the FA, the levels of problem behavior in all other conditions are compared relative to those observed in the control condition.

The attention condition of the FA is conducted to determine whether problem behavior is maintained by social positive reinforcement in the form of attention. In the attention condition, the antecedent event is a period of minimal social interaction (i.e., the therapist ignores the client). The consequent event is the provision of physical and social attention (e.g., social disapproval, statements of concern) contingent on problem behavior. Other behaviors emitted in this condition (e.g., appropriate requests for attention) have no programmed consequences. If problem behavior is reliably higher during the attention condition relative to the control condition, then one may conclude that at least one function of the problem behavior is acquisition of attention.

The escape condition of the FA is conducted to determine whether problem behavior is maintained by social negative reinforcement in the form of escape from demands. In the escape condition, the therapist presents a task for the client to complete (e.g., interacting with instructional materials) and uses a three-step prompting procedure to ensure that the task is completed. These three sequentially presented steps are (a) verbal instruction, (b) model the desired behavior, and (c) physically guide the client as he or she completes the desired behavior. If the client engages in problem behavior at any time during the prompting sequence, the therapist removes the demands (e.g., takes away the instructional materials and ceases the prompting sequence) for a brief period (e.g., 30 seconds) of escape. As before, if problem behavior is reliably higher in this condition relative to the control condition, then one may conclude that at least one function of problem behavior is escape from task demands.

The alone condition is conducted to determine whether the behavior is maintained by consequences that do not require social mediation, such as sensory stimulation, so-called automatic reinforcement. In this condition, the therapist is absent, and no programmed consequences occur for problem behavior. If the problem behavior of interest is aggression or the client cannot be left alone, an ignore condition may be conducted in lieu of the alone condition. In the ignore condition, the therapist is present but ignores the client. If problem behavior is reliably higher in the alone (or ignore) condition relative to the control condition, then one may conclude that behavior is maintained by automatic or sensory reinforcement. The therapist may also conclude that problem behavior is maintained by automatic reinforcement when problem behavior is higher in all conditions relative to the control condition, because this pattern indicates that behavior occurs less in conditions with more external stimulation. An automatic function can also be posited when problem behavior is high in all conditions (including the control condition) because this patterning indicates that behavior persists independent of environmental conditions (see Hagopian et al., 1997).

Other FA conditions. Informed by anecdotal information, indirect or descriptive assessments, or inconclusive initial FA results, additional FA conditions have been designed to test for idiosyncratic functions of problem behavior (or more specific conditions under which problem behavior might occur). Examples include a tangible condition, divided-attention condition, and escape from social interaction condition.

A tangible condition is conducted to determine whether problem behavior is maintained by access to social positive reinforcement in the form of preferred tangible items (R. M. Day, Rea, Schussler, Larsen, & Johnson, 1988; Mace & West, 1986). Before this condition, the client is given 2 minutes of access to highly preferred items. These items are removed at the start of the session and briefly returned to the client when problem behavior is emitted. If problem behavior occurs reliably in this condition, then one may conclude that the function of problem behavior is contingent access to tangibles.

A divided-attention condition is conducted when the therapist suspects that attention functions as a reinforcer only when attention is directed toward someone other than the client. For example, problem behavior may occur when a parent is talking to the client's sibling and thereby directs attention away from the client. In these cases, problem behavior is not observed in the standard attention condition described earlier, and a divided-attention condition is necessitated (Fisher, Kuhn, & Thompson, 1998; Mace, Page, Ivancic, & O'Brien, 1986; O'Reilly, Lancioni, King, Lally, & Dhomhnaill, 2000). In the divided-attention condition, the therapist ignores the client but engages in social interaction with another person. Contingent on problem behavior, the therapist provides attention to the client. If this antecedent and consequent arrangement reliably increases the probability of problem behavior, an important function of the behavior has been identified.

A social-escape condition is conducted to determine whether escape from social interaction functions as a negative reinforcer for the problem behavior (Hagopian, Wilson, & Wilder, 2001; Taylor & Carr, 1992; Taylor, Ekdahl, Romanczyk, & Miller, 1994). In this escape condition, the therapist provides continuous attention to the client except when problem behavior occurs. Contingent on problem behavior, the therapist terminates social interaction for a brief period of time (e.g., 30 seconds). If the problem behavior occurs reliably in this condition, then one can conclude that the problem behavior occurs to escape from social interaction with others.

Conducting an FA. When an FA is conducted, multiple conditions are typically completed in a single day. Each condition is of a brief duration (e.g., 10 minutes), and conditions alternate between all those to be included in the FA. This alternation between conditions is referred to as a *multielement design* (see Volume 1, Chapter 5, this handbook), which allows efficient implementation of the FA. As conditions change, and are repeated, and differences in responding are observed relative to the control condition, hypotheses about the function of the problem behavior may be evaluated. If the problem behavior is well differentiated across conditions, the multielement design allows one to rule out a host of alternative explanations of the behavior (reactivity, the passage of time, etc.).

Problem behavior is typically recorded as a response rate during each component of an FA. As these data are collected, they are graphed across conditions using different symbols depicting rates of problem behavior in each condition. If the rate of problem behavior is visually higher in one condition relative to the control condition, then evidence is provided that the antecedents and consequences arranged in that condition are important determinants of the problem behavior. This evidence will be strengthened if the problem behavior is differentiated from control levels every time the client was exposed to that condition (i.e., the effect is replicable). For a more in-depth overview of visual analysis of behavioral data, we refer the reader to Volume 1, Chapter 9, this handbook; Hagopian et al. (1997); Hersen and Barlow (1976); and Kazdin (1982).

Special Considerations in FA

Although some FAs may be relatively straightforward and produce clear results, others may require modification or additional manipulations because of the pattern of responding or risk associated with the occurrence of problem behavior. In the following paragraphs we describe some of these modifications or manipulations that may be conducted to increase the clarity of FA outcomes or ensure safety of the client and therapist.

Undifferentiated high-rate responding. In some instances, problem behavior will occur at a high, undifferentiated rate across conditions of the FA. We consider five reasons why this may occur and how this problem may be ameliorated.

First, and as noted earlier, high, undifferentiated rates may occur when the problem behavior is maintained by automatic reinforcement. One way to further evaluate the automatic reinforcement hypothesis is to conduct consecutive or extended-duration alone or ignore sessions (Vollmer, Marcus, Ringdahl, & Roane, 1995). If problem behavior persists, the case for automatic reinforcement is further supported. However, if the problem behavior decreases or stops, then other hypotheses will need to be evaluated (see the section Undifferentiated Low-Rate Problem Behavior).

When problem behavior is undifferentiated across conditions, a second possibility is that stimulus control has not been established. That is, the problem behavior does not come under control of the changes in antecedent conditions or consequent arrangements across conditions. Discrimination may sometimes be improved by conducting the different conditions in different rooms, with different therapists, or by conspicuously presenting different colored poster boards in each condition (Conners et al., 2000). The same improvement in discriminated responding can sometimes be achieved by extending session duration, thereby increasing experience with the antecedents and consequences before moving on to another condition (Wallace & Iwata, 1999).

A third possible cause of undifferentiated responding is between-condition interaction or carry-over effects. That is, responding in one condition may be affected by recent experience with the previous condition. When between-condition interactions are the suspected cause of undifferentiated high rates, the clinician may consider reducing the number of conditions presented between control sessions (Iwata, Duncan, Zarcone, Lerman, & Shore, 1994). Vollmer, Iwata, Duncan, and Lerman (1993) reported that conducting repeated sessions within a particular condition before initiating the next condition was also effective in producing differentiated responding across conditions.

The fourth reason that responding may occur in all FA conditions is that the problem behavior is maintained by several different types of reinforcement (e.g., C. S. W. Borrero & Vollmer, 2006; H. M. Day, Horner, & O'Neill, 1994; Neidert, Iwata, & Dozier, 2005; Smith, Iwata, Vollmer, & Zarcone, 1993). For example, Smith et al. (1993) showed that three participants' problem behavior occurred in more than one FA condition. To determine whether problem behavior was maintained by each of these reinforcers, different function-based treatments were implemented in each condition. For two of three participants, all of the different treatments reduced problem behavior, suggesting that for these participants, problem behavior was controlled by several different contingencies.

A final reason that responding may occur across multiple FA conditions is if several types of problem behavior are assessed simultaneously, but some are maintained by different types of reinforcement (Derby et al., 1994). For example, visual analysis of combined problem behavior may suggest one function for all those behaviors in the aggregate, when in fact one form of problem behavior (e.g., self-injury) is maintained by one type of reinforcement, whereas another (e.g., aggression) is maintained by another type of reinforcement. One way to address this problem is to collect data and graph each form of problem behavior separately or conduct a separate FA for each problem behavior.

Undifferentiated low-rate problem behavior. FA is very effective for determining the function of high-rate problem behavior; however, its utility may be more limited if the problem behavior occurs at a low rate (or not at all) during the assessment. Three modifications of the FA have been developed that may aid in determining the function of low-rate problem behavior. First, Kahng, Abt, and Schonbachler (2001) suggested that this problem could be solved by increasing the session duration. They developed the "all-day FA" in which conditions remain in effect for an extended period of time (e.g., throughout an entire class period or "all day"). In their study, Kahng et al. showed that the extended FA was effective for determining the function of low-rate problem behavior. Moreover, treatments based on FA results were effective in reducing problem behavior. A second method involves conducting FA sessions contingent on an episode of problem behavior (Tarbox, Wallace, Tarbox, Landaburu, & Williams, 2004). Two test conditions and one control condition are conducted, with conditions continuing if problem behavior persists. Tarbox et al. (2004) found that more problem behavior occurred during the response-contingent FA. For two of three clients, the function identified in the FA proved useful in designing effective treatments.

Cyclical patterns of problem behavior. Problem behavior may occur in what appears to be a cyclical fashion with both high and low levels of problem behavior observed at various times during the FA. This pattern of responding has been shown to depict maintenance by social reinforcers (e.g., social negative reinforcement), but only when certain EOs (e.g., biological events such as pain associated with an earache) are present. For example, the presence of task demands when an individual has an ear infection (O'Reilly, 1997) or is deprived of sleep (Kennedy & Meyer, 1996; O'Reilly, 1995) has been shown to result in cyclical problem behavior maintained by escape. To effectively assess behavior that is cyclical, first determining the source of this variability is necessary. That is, biological factors that could contribute to the cyclical nature of SIB should be ameliorated before assessing the function of problem behavior.

Other exceptions to the rule. Several idiosyncratic variables have been shown to affect the occurrence of problem behavior, including task novelty (Mace, Browder, & Lin, 1987; Smith, Iwata, Goh, & Shore, 1995), task difficulty (Call, Pabico, & Lomas, 2009; Roscoe, Rooker, Pence, & Longworth, 2009), rate of task presentation (Smith et al., 1995), prompting style (Asmus et al., 2000; Crockett & Hagopian, 2006; Smith, Iwata, Goh, & Shore, 1995), presence or absence of particular people (Broussard &

Northup, 1995; Flood, Wilder, Flood, & Masuda, 2002; Northup et al., 1995; Ringdahl & Sellers, 2000), type or content of attention (Britton, Carr, Kellum, Dozier, & Weil, 2000; Fisher, Ninness, Piazza, & Owen-DeSchryver, 1996; LeBlanc, Hagopian, Marhefka, & Wilke, 2001; Piazza et al., 1999; Richman & Hagopian, 1999), and parental compliance with child requests (Bowman, Fisher, Thompson, & Piazza, 1997). Data from these studies have suggested the utility of open-ended indirect and direct analyses for identifying idiosyncratic antecedent and consequent events that could be included in an FA.

FA of high-risk problem behavior. Permitting problem behavior to occur freely is generally necessary when conducting an FA. This necessity must be balanced with safety when the problem behavior involves risk to the client or others (e.g., aggression, self-injurious behavior, elopement, property destruction). These cases underscore the importance of conducting FAs under the direct supervision of a qualified professional. At least three modifications have been made to FA methodology to accommodate effective and safe assessment of high-risk behavior.

One option is to reduce the frequency of problem behavior by measuring latency to the first instance of problem behavior in the session rather than the frequency or rate measure typically used (Thomason-Sassi, Iwata, Neidert, & Roscoe, 2011). Consistently shorter latencies in one condition than in the control and other conditions suggest the function of the problem behavior. Thomason-Sassi et al. (2011) compared latency and rate measures from 38 previously conducted FAs and showed correspondence between the outcomes (i.e., same functions) using the latency measure and the rate measure for 33 of 38 cases. In an experiment conducted by the same investigators, the results of separate latency and standard FAs were in accordance among nine of 10 participants. This procedure is safer because a condition is terminated once problem behavior occurs, thereby reducing the overall amount of behavior.

A second option for minimizing risks associated with FA of high-risk behavior is derived from research on response class hierarchies (Harding et al., 2000; Lalli & Mace, 1995; Richman, Wacker, Asmus, Casey, & Andelman, 1999). This literature has demonstrated that precursor behaviors (e.g., yelling, laughing, crying, smiling, grimacing, fidgeting) often precede high-risk problem behavior. When contingencies are applied to these precursors, high-risk problem behavior often decreases. On the basis of this information, a safer assessment involves conducting an FA of precursor behavior (Najdowski, Wallace, Ellsworth, MacAleese, & Cleveland, 2008; Smith & Churchill, 2002). Before an FA of precursor behavior, either an indirect assessment (Smith & Churchill, 2002) or a DA of the precursor behaviors is conducted (C. S. W. Borrero & Borrero, 2008; Langdon, Carr, & Owen-DeSchryver, 2008). Then, an FA of these precursor behaviors rather than of the severe problem behavior is conducted. The assumption is that the function of the precursor is the same as the target problem behavior and is based on the fact that these behaviors usually co-occur under the same conditions.

A third option for decreasing the risk associated with FA of severe problem behavior involves the use of protective equipment (e.g., helmets for self-injurious head banging) during FA. The use of protective equipment should be considered carefully because these devices can affect FA outcomes (J. C. Borrero, Vollmer, Wright, Lerman, & Kelley, 2002; Le & Smith, 2002; Moore, Fisher, & Pennington, 2004). Specifically, protective equipment has been shown to reduce rates of problem behavior (possibly through punishment or sensory extinction; i.e., blocking the sensory consequences produced by the behavior) during an FA, resulting in inconclusive FA results. However, other studies have shown that the use of protective equipment can help clarify ambiguous FA outcomes—permitting either identification of a previously masked social function (Contrucci Kuhn & Triggs, 2009) or confirming an automatic function (Moore et al., 2004).

IDENTIFYING ALTERNATIVE REINFORCERS

Once the function of the problem behavior has been identified, the clinician is in a better position to develop an effective behavioral intervention designed to reduce this behavior. One strategy is to extinguish the problem behavior (i.e., prevent the delivery of the reinforcer identified by the FA) while teaching the client to engage in alternative behavior. To establish and maintain these alternative behaviors, effective reinforcers other than those maintaining the problem behavior can be useful. Techniques for identifying these alternative reinforcers include preference assessments and competing stimulus assessments.

Preference Assessments

Conducting a systematic preference assessment should be a routine part of the assessment and treatment development process. Generally, preference assessment procedures involve systematically exposing an individual to putative reinforcing stimuli for a brief period of time and recording the individual's approach responses or levels of engagement with each stimulus over multiple trials. The levels of approach or engagement are then summarized across trials, and a preference hierarchy is derived. *Preference* therefore refers to the extent to which a stimulus will be approached or consumed when freely available, whereas *reinforcing efficacy* refers to the extent to which a stimulus will increase behavior when provided contingently. Although preference assessments do not directly assess the reinforcing efficacy of a particular stimulus, ample evidence has suggested that preference indices are good predictors of reinforcing efficacy (e.g., Hagopian, Rush, Lewin, & Long, 2001; Piazza, Fisher, Hagopian, Bowman, & Toole, 1996). Once highly preferred stimuli are identified, they can be used in the treatment of problem behavior (see Arbitrary Reinforcers section later in this chapter).

Preference assessment procedures that expose clients to two or more stimuli simultaneously include the paired stimulus (Fisher et al., 1992), multiple stimulus without replacement (DeLeon & Iwata, 1996), and free operant (Roane, Vollmer, Ringdahl, & Marcus, 1998) preference assessments. These assessments provide a measure of relative preference in that during each trial, the individual must choose one stimulus to the exclusion of others that are available. Data on approach of stimuli and consumption of stimuli allow for a hierarchy of most to least preferred stimuli to be established.

Preference assessment procedures that involve presenting stimuli singly provide measures of absolute preference in that approach or engagement with each stimulus is measured independently of other stimuli (DeLeon & Iwata, 1996; Pace, Ivancic, Edwards, Iwata, & Page, 1985). Measures of relative preference are generally preferred because some individuals tend to approach or engage with any stimulus presented to them, which can lead to inflated indices of preference (e.g., Roscoe, Iwata, & Kahng, 1999).

Competing Stimulus Assessments

Competing stimulus assessments are designed to examine the extent to which access to various items displaces problem behavior, relative to a control condition in which the reinforcer responsible for maintaining problem behavior continues to be presented. Items associated with decreases in problem behavior produce reinforcement that competes with reinforcement maintaining problem behavior. This assessment has direct implications for the treatment of behavior maintained by automatic reinforcement. For example, noncontingent access to competing items can effectively reduce problem behavior maintained by automatic reinforcement (Piazza, Fisher, Hanley, Hilker, & Derby, 1996; Ringdahl, Vollmer, Marcus, & Roane, 1997; Roane, Vollmer, Ringdahl, & Marcus, 1998; Shore, Iwata, DeLeon, Kahng, & Smith, 1997; Zhou, Goff, & Iwata, 2000). Similarly, items that displace problem behavior can enhance treatments for attention-maintained behavior as well (Fisher, DeLeon, Rodriguez-Catter, & Keeney, 2004; Fisher, O'Connor, Kurtz, DeLeon, & Gotjen, 2000; Hagopian, Bruzek, & Bowman, 2007). That is, attention is less reinforcing when items that compete with attention are available; therefore, problem behavior is less likely to occur.

FUNCTION-BASED TREATMENT

FA methodology has not only resulted in an increase in the understanding of the conditions under which problem behavior is likely to occur but has also resulted in a more principled approach to treatment development. In contrast to earlier behavioral interventions that relied on reinforcement and punishment technologies to override existing contingencies, contemporary function-based interventions are designed to change problem behavior by directly altering its controlling variables (Mace, 1994). An outcome of this conceptual and technological shift was an increase in the implementation and study of more effective antecedent- and reinforcement-based interventions and less reliance on punishment-based interventions (Iwata, Kahng, et al., 2000). Research on the treatment of problem behavior has demonstrated that function-based interventions (i.e., interventions based on the function rather than the form of the behavior) are superior to non–function-based interventions (E. G. Carr et al., 1999; Newcomer & Lewis, 2004).

Function-based interventions designed to reduce the occurrence of problem behavior may include (a) elimination of the functional reinforcer for the occurrence of the problem behavior (extinction [EXT]), (b) modifications of the antecedent conditions that occasion problem behavior that are designed to decrease motivation to engage in the problem behavior, and (c) provision of the functional reinforcer for the absence of problem behavior (differential reinforcement of other behavior [DRO]) or the occurrence of a replacement or alternative response (differential reinforcement of alternative behavior [DRA]; J. E. Carr, Coriaty, & Dozier, 2000; Iwata & Dozier, 2008). These classes of interventions vary procedurally depending on the function of problem behavior and are typically used in some combination as treatment components of a behavioral intervention. In addition to interventions that specifically target controlling antecedent and consequent variables of problem behavior, other treatment components are often included with an eye toward facilitating the shift from inappropriate to appropriate behavior. These components include the use of arbitrary reinforcers and response reduction procedures.

Extinction

EXT involves the discontinuation of the contingency between a response (e.g., problem behavior) and a reinforcer (e.g., Iwata, Pace, Cowdery, & Miltenberger, 1994). Successful implementation of EXT requires both knowledge of the reinforcer responsible for maintaining problem behavior and the ability to withhold that reinforcer contingent on problem behavior. Identifying the function of behavior is necessary before the implementation of EXT, because some forms of EXT will be irrelevant or contraindicated depending on the function of behavior. For example, Iwata, Pace, et al. (1994) compared procedural (i.e., planned ignoring) and functional (i.e., based on the function of the problem behavior) EXT, and results showed that functional EXT was more effective at decreasing problem behavior than procedural EXT. Few studies have been done on the effects of EXT alone, possibly because (a) side effects have been reported, which include EXT bursts (i.e., initial increases in the frequency, intensity, or duration of problem behavior that previously resulted in the functional reinforcer), emotional responding (e.g., crying), and spontaneous recovery (i.e., an increase in responding after initial treatment effects are observed; see Lerman, Iwata, & Wallace, 1999, for a review) and (b) EXT alone does not reinforce adaptive behavior or provide a means by which reinforcement can be obtained. Although much research has demonstrated that EXT is a necessary component of treatment for problem behavior (e.g., Hagopian, Fisher, Sullivan, Acquisto, & LeBlanc, 1998), it is rarely used in isolation but rather in conjunction with reinforcement-based procedures, such as DRA or noncontingent reinforcement (NCR).

Extinction: Social positive and negative reinforcement. EXT of behavior maintained by social positive reinforcement involves no longer providing that reinforcer contingent on problem behavior (Iwata, Pace, et al., 1994; see Chapter 4, this volume). For example, if an individual's problem behavior is maintained by attention, EXT involves the removal or withholding of attention contingent on problem behavior (i.e., planned ignoring). EXT of behavior maintained by social negative reinforcement (escape EXT) involves no longer removing the stimulus (e.g., instructions) that was previously terminated contingent on problem behavior (Iwata, Pace, Kalsher, Cowdery, & Cataldo, 1990). Common procedures for implementing escape EXT include contingent physical guidance so that escape cannot occur (e.g., Iwata, Pace, et al., 1990; Zarcone, Iwata, Hughes, & Vollmer, 1993), delivering demands on a predetermined schedule independent of problem behavior (e.g., Repp, Felce, & Barton, 1988), or nonremoval of aversive stimuli (e.g., Mueller, Piazza, Patel, Kelley, & Pruett, 2004).

Extinction: Automatic reinforcement. As noted earlier, when an FA indicates that the problem behavior is maintained by automatic reinforcement, the reinforcing consequence is not explicitly identified. Educated guesses, however, may be made and evaluated through extinction interventions. Interventions designed to disrupt the contingent relation between problem behavior and the putative reinforcer have produced EXT-like effects (Rapp & Vollmer, 2005). For example, mechanical devices designed to attenuate the sensory consequences produced by self-injury frequently reduce problem behavior maintained by automatic reinforcement (Dorsey, Iwata, Reid, & Davis, 1982; Kennedy & Souza, 1995; Moore et al., 2004; Rincover, 1978; Roscoe, Iwata, & Goh, 1998). Moore et al. (2004) showed that the application of protective equipment reduced three different topographies of SIB displayed by a girl diagnosed with autism. In addition, when protective equipment was removed from specific areas, the rate of SIB associated with that area increased, whereas the other topographies of SIB remained at low levels. Although protective equipment is sometimes necessary, it is inherently restrictive. Therefore, efforts to systematically fade protective equipment should be used when protective equipment is necessary (e.g., Magnusson & Gould, 2007).

Another intervention sometimes used to interrupt the contingency between problem behavior and the automatic reinforcer is response blocking (Hagopian & Adelinis, 2001; Lerman & Iwata, 1996; McCord, Grosser, Iwata, & Powers, 2005; Reid, Parsons, Phillips, & Green, 1993; Smith, Russo, & Le, 1999). Response blocking generally involves momentarily physically preventing or interrupting engagement in problem behavior. For example, response blocking for eye poking might involve the therapist placing his or her arm between the individual's hand and face when the individual initiates eye poking. Although response blocking can reduce problem behavior in some cases via sensory EXT, the reduction in behavior associated with response blocking can also possibly be the result of punishment (Lerman, Kelley, Vorndran, & Van Camp, 2003). Recent studies have shown that response blocking can be highly effective in reducing stereotypies when combined with redirection to an alternative response (response interruption and redirection; Ahearn, Clark, DeBar, & Florentino, 2005; Miguel, Clark, Tereshko, & Ahearn, 2009).

Problem behavior maintained by automatic negative reinforcement may occur to remove or avoid physiological pain or discomfort (Iwata, Kahng, et al., 2000). In these cases, EXT is contraindicated. Instead, interventions should involve medical interventions designed to reduce discomfort or pain that occasions self-injury. For example, an individual who might engage in self-injurious ear poking when he or she has an ear infection (see Cataldo & Harris, 1982) might be prescribed medication to alleviate the pain and infection, thereby reducing the occurrence of self-injury (Smith & Iwata, 1997).

Noncontingent Reinforcement

NCR involves providing free access to either the functional reinforcer (e.g., Hagopian, Crockett, VanStone, DeLeon, & Bowman, 2000; Hanley, Piazza, & Fisher, 1997; Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993) or reinforcers that compete with the functional reinforcer (e.g., Fischer, Iwata, & Mazaleski, 1997; Lindberg, Iwata, Roscoe, Worsdell, & Hanley, 2003). The implementation details of these procedures are considered in the sections that follow. Here we note three mechanisms by which NCR may reduce problem behavior. First, by providing free and frequent access to the functional reinforcer, motivation to obtain more of the reinforcer by emitting problem behavior may decrease. Second, behaviors other than problem behavior that occur when NCR reinforcers are delivered may be reinforced by the NCR events (e.g., Madden & Perone, 2003). Third, the individual may learn that problem behavior is no longer required to obtain the functional reinforcer and adjust the rate of problem behavior accordingly (Hagopian, Toole, Long, Bowman, & Lieving, 2004).

NCR events are delivered at regular (fixed-time) or irregular (variable-time) intervals independent of the behavior occurring when the NCR event is scheduled to be delivered (Zeiler, 1968). When NCR is a function-based intervention, the reinforcer responsible for maintaining problem behavior is scheduled for fixed-time or variable-time delivery (Lalli, Casey, & Kates, 1997; Vollmer, Iwata, Zarcone, et al., 1993). NCR typically begins with a dense schedule of reinforcement (e.g., continuous noncontingent access) and is progressively thinned to achieve an interreinforcer interval that is sustainable throughout the course of a day (Hagopian, Fisher, & Legacy, 1994; Vollmer, Iwata, Zarcone, et al., 1993).

NCR may be preferable to other behavior reduction strategies because (a) its ease of implementation yields higher treatment integrity, (b) it results in higher rates of reinforcement than other behavior reduction procedures such as EXT and DRO, and (c) it reduces the likelihood of EXT-induced emotional responding (Vollmer, Iwata, Zarcone, et al., 1993). We should, however, note three limitations of NCR. First, because the NCR event is delivered regardless of ongoing behavior, adventitious reinforcement of problem behavior may occur (e.g., Vollmer, Ringdahl, Roane, & Marcus, 1997). One way to prevent this is to use a DRO schedule in which NCR events are canceled if problem behavior occurs within 10 seconds of the scheduled delivery time (Britton et al., 2000; Lalli, Mace, Livezey, & Kates, 1998; Vollmer et al., 1997). Britton et al. (2000) showed that this modified NCR procedure was effective in reducing problem behavior to low levels for all three individuals even when the NCR schedule was thinned.

A second limitation of NCR is that it does not directly teach replacement behaviors that can allow the client a socially acceptable way in which to obtain the functional reinforcer (Tucker, Sigafoos, & Bushell, 1998); indeed, free and frequent access to reinforcers may decrease motivation to engage in adaptive replacement behavior (Goh, Iwata, & DeLeon, 2000). A few studies have combined NCR with DRA (a procedure for increasing a specific replacement behavior while extinguishing problem behavior; e.g., Goh et al., 2000; Marcus & Vollmer, 1996; Mildon, Moore, & Dixon, 2004). Marcus and Vollmer (1996) showed that relatively dense NCR schedules (i.e., fixed-time 20 seconds) did not interfere with the acquisition of replacement behavior (i.e., requesting the functional reinforcer), and requests continued when the NCR schedule was thinned. In a similar evaluation, Goh et al. (2000) showed that continuous NCR (i.e., the client was given continuous noncontingent access to the functional reinforcer) interfered with the acquisition of replacement behaviors via DRA; however, as the NCR schedule was thinned, DRA with NCR increased replacement behaviors and maintained low levels of problem behavior.

Finally, NCR may not be effective over long periods of time if the reinforcers provided are not identical (i.e., they do not perfectly substitute for the reinforcer that maintained problem behavior; see Chapter 8, this volume). For example, Lindberg, Iwata, Roscoe, Worsdell, and Hanley (2003) found that when a substitute item was provided during 10-minute sessions, SIB did not occur; however, when the same item was provided over 120-minute sessions, SIB reemerged.

Noncontingent reinforcement: Social positive reinforcement. When problem behavior is maintained by social positive reinforcement, NCR involves providing access to the functional reinforcer on a response-independent schedule. NCR has proven effective for reducing many forms of problem behavior maintained by attention or access to tangible items (Marcus & Vollmer, 1996; Van Camp, Lerman, Kelley, Contrucci, & Vorndran, 2000; Vollmer, Iwata, Zarcone, et al., 1993).

When problem behavior is maintained by social negative reinforcement (e.g., escape), NCR involves providing the negative reinforcer on a response-independent schedule, which abolishes the motivation to engage in negatively reinforced problem behavior. One NCR procedure, noncontingent escape (NCE), involves providing escape (the functional reinforcer) from the aversive situation (e.g., instructional situation) on a time-based schedule (Vollmer, Marcus, & Ringdahl, 1995). NCE has proven effective in decreasing escape-maintained problem behavior in instructional situations (Kahng, Iwata, DeLeon, & Worsdell, 1997; Kodak, Miltenberger, & Romaniuk, 2003; Vollmer, Marcus, & Ringdahl, 1995) and other aversive contexts (e.g., medical examinations; O'Callaghan, Allen, Powell, & Salama, 2006). Vollmer, Marcus, and Ringdahl (1995) showed that NCE plus EXT maintained low levels of problem behavior even when the NCE schedule was thinned to every 10 minutes.

A variation of NCE involves removing all demands initially and gradually increasing the number demands across sessions (Pace, Ivancic, & Jefferson, 1994; Pace, Iwata, Cowdery, Andree, & McIntyre, 1993; Zarcone, Iwata, Smith, Mazaleski, & Lerman, 1994). Evidence suggests that this procedure (*demand fading*) can be more effective when combined with EXT (Zarcone, Iwata, Smith, Mazaleski, & Lerman, 1994) and DRA for compliance (Piazza, Moes, & Fisher, 1996).

Another NCR procedure for escape-maintained behavior involves providing access to preferred positive reinforcers (nonfunctional reinforcers) in the demand context (e.g., Durand & Mapstone, 1998; Lomas, Fisher, & Kelley, 2010; Long, Hagopian, DeLeon, Marhefka, & Resau, 2005). For example, Lomas et al. (2010) showed that the delivery of preferred edibles and praise on a variable-time schedule of reinforcement (i.e., aperiodic noncontingent reinforcers) decreased problem behavior even though it continued to result in escape. The provision of these items would appear to have decreased the aversiveness of the demand context, thereby reducing the motivation to escape.

Noncontingent reinforcement: Automatic reinforcement. When problem behavior is maintained by automatic reinforcement, NCR involves providing free access to stimuli that are likely to compete with (or substitute for) the sensory reinforcer produced by the problem behavior (e.g., Favell, McGimsey, & Schell, 1982; Fisher, Lindauer, Alterson, & Thompson, 1998; Piazza, Adelinis, Hanley, Goh, & Delia, 2000; Rapp, 2006). Favell et al. (1982) showed that an NCR procedure using competing reinforcers decreased the SIB of all participants. A competing stimulus assessment can aid in identifying effective competing reinforcers (e.g., Piazza, Fisher, Hanley, Hilker, & Derby, 1996; Ringdahl et al., 1997; Roane et al., 1998; Shore et al., 1997; Zhou et al., 2000), that is, reinforcers that result in high levels of engagement and low levels of problem behavior.

Antecedent Interventions for Escape-Maintained Behavior

As noted earlier, escape-maintained behavior is occasioned by stimuli that are correlated with a transition from a more- to a less-preferred activity. For example, a therapist may initiate an academic or life skills activity that occasions problem behavior. An approach to decreasing escape-maintained problem behavior is to decrease the difficulty of the task or other aversive qualities of the situation to which the client will transition (Geiger, Carr, & LeBlanc, 2010; Smith & Iwata, 1997). One approach to decreasing task difficulty is to use teaching or prompting procedures that make it more likely that the client's behavior will be reinforced (e.g., errorless learning, extrastimulus prompts, modeling, physical prompts, gestural prompts; Ebanks & Fisher, 2003; McComas, Hoch, Paone, & El-Roy, 2000; Weeks & Gaylord-Ross, 1981). For example, McComas et al. (2000) showed that problem behavior decreased when a client was provided with checkers to aid in completing math problems. As with instructional fading, prompts should be gradually faded while maintaining low levels of problem behavior.

Other strategies include interspersing easy tasks with difficult tasks (Horner, Day, Sprague, O'Brien, & Heathfield, 1991; Mace & Belfiore, 1990) or embedding demands into positive contexts, such as a play setting (E. G. Carr, Newsom, & Binkoff, 1976; Pace et al., 1994). These procedures may increase reinforcement and novelty, but EXT clearly plays a critical role in their efficacy (e.g., Zarcone et al., 1993; Zarcone, Iwata, Mazaleski, & Smith, 1994).

Giving clients choices about the situations in which they are asked to complete tasks also appears to decrease problem behavior (e.g., Dunlap, Kern-Dunlap, Clarke, & Robbins, 1991; Dunlap et al., 1994; Dyer, Dunlap, & Winterling, 1990; McComas et al., 2000; Romaniuk et al., 2002). For example, McComas et al. (2000) showed that a young boy's escape-maintained SIB decreased when he was allowed to choose the order in which he completed tasks. As noted by Kern et al. (1998), choice interventions are easy to implement, interfere minimally with instructional activities, have high social acceptability, and effectively reduce problem behavior while increasing compliance. As with interspersing procedures, the mechanism by which the introduction of choice decreases problem behavior is not well understood.

Differential Reinforcement

Differential reinforcement interventions are the most common treatment for reducing problem behavior (Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993). The two differential reinforcement procedures most commonly applied to problem behavior are DRO and DRA. Both procedures typically involve EXT of the problem behavior and reinforcing appropriate behavior (Vollmer & Iwata, 1992).

Differential reinforcement of other behavior. DRO is one of the most commonly used interventions and is often effective (Whitaker, 1996). Under a DRO procedure, reinforcers are provided after an interval of time has elapsed without an instance of the problem behavior. In the initial stages of DRO, this interval is usually shorter than the mean interval between instances of the problem behavior during baseline, which increases the likelihood that the client's behavior will contact reinforcement. DRO can be implemented using a resetting or a nonresetting procedure (Vollmer & Iwata, 1992). If a resetting DRO is used, each instance of problem behavior resets the inter-reinforcement interval that would be used if no problem behavior occurred. In a nonresetting DRO procedure, reinforcement is provided at the end of any interval in which no problem behavior occurs; however, instances of problem behavior do not restart the DRO interval. That is, intervals in which problem behavior occurs time out before a new interval in which the opportunity for reinforcement is available.

Few studies have been conducted on the effects of DRO when the reinforcer responsible for maintaining problem behavior (i.e., the functional reinforcer) is delivered. Mazaleski et al. (1993) compared the effects of three DRO procedures for decreasing problem behavior maintained by attention. The DRO procedures differed in the type of stimuli delivered (i.e., preferred arbitrary stimuli, nonpreferred arbitrary stimuli, and the functional reinforcer) and were compared with EXT alone. The results suggested that all three of the DRO procedures were effective for decreasing problem behavior (regardless of the type of reinforcer delivered) and EXT alone was equally as effective. Limitations of DRO have been noted and include (a) aggressive or emotional responding when reinforcement criteria are not met, (b) continuous observation of the client by the person implementing the treatment (see Hammond, Iwata, Fritz, & Dempsey, 2011, for a more feasible DRO procedure), (c) possible low rates of reinforcer delivery, and (d) the absence of a contingency for directly teaching appropriate replacement behaviors (Vollmer, Iwata, Zarcone, et al., 1993).

Differential reinforcement of alternative behavior. DRA involves the delivery of a reinforcer for the occurrence of an alternative or replacement behavior while no longer delivering the reinforcer for the problem behavior. Numerous studies have shown that DRA is effective for decreasing problem behavior (Vollmer & Iwata, 1992). An advantage of DRA over NCR or DRO is that it involves teaching and directly reinforcing a replacement behavior. Such behavior may allow the client to access the functional reinforcer in a socially appropriate way. The acquisition of replacement behavior also allows the client to control the amount and time of reinforcement delivery (Hanley, Piazza, Fisher, Contrucci, & Maglieri, 1997; Mace & Lalli, 1991).

Several studies have shown that DRA is less effective when the EXT component of DRA is omitted (Fisher et al., 1993; Hagopian et al., 1998; Mazaleski et al., 1993). For example, Fisher et al. (1993) and Hagopian et al. (1998) showed that a specific form of DRA, functional communication training (FCT; E. G. Carr & Durand, 1985), which involves teaching an individual to request access to the functional reinforcer, is more effective when problem behavior is extinguished. In addition, several studies (DeLeon, Arnold, Rodriguez-Catter, & Uy, 2003; Piazza et al.,

1999) have shown that EXT of attention-maintained problem behavior increases the reinforcing efficacy of attention provided for appropriate replacement behavior. A more detailed discussion of differential reinforcement procedures based on the function of problem behavior follows.

Differential reinforcement: Social positive reinforcement. When problem behavior is maintained by social positive reinforcement, DRO involves delivering the functional reinforcer contingent on the absence of problem behavior. By contrast, DRA involves extinguishing the problem behavior while concurrently teaching a replacement behavior so the client may access the functional reinforcer.

FCT is a common DRA procedure used to decrease problem behavior maintained by social positive reinforcement (e.g., Bailey, McComas, Benavides, & Lovascz, 2002; E. G. Carr & Durand, 1985; Fisher et al., 1993; Hagopian et al., 1998; Kurtz et al., 2003; Shirley, Iwata, Kahng, Mazaleski, & Lerman, 1997; Tiger, Hanley, & Bruzek, 2008). Several procedural variations have been used to both select (Grow, Kelley, Roane, & Shillingsburg, 2008) and establish requests for the functional reinforcer (Gutierrez et al., 2007). Ideally, the request should be a low-effort response and be easily understood by nontrained people such that it will produce reinforcement in the typical environment (Durand & Carr, 1991). FCT is often ineffective if the EXT component of this DRA procedure is omitted (Hagopian et al., 1998).

Differential reinforcement: Social negative reinforcement. In general, when DRO is applied to escape-maintained problem behavior, escape is delivered when a criterion period of time has elapsed without the emission of the problem behavior (Vollmer & Iwata, 1992). Two variations on this DRO procedure are to provide either escape (e.g., K. D. Allen, Loiben, Allen, & Stanley, 1992; Kodak et al., 2003; Vollmer, Marcus, & Ringdahl, 1995) or a positive reinforcer contingent on the absence of escape-maintained problem behavior (e.g., Iwata, Pace, et al., 1990).

Using DRA (e.g., FCT) to reduce escape-maintained problem behavior involves teaching a replacement behavior to access escape (or a competing reinforcer) and ensuring that escape is no longer provided for engaging in problem behavior. Differential negative reinforcement involves teaching a replacement behavior (e.g., communicative response or compliance with demands) to access escape (in the form of a break from work; e.g., E. G. Carr, Newsom, & Binkoff, 1980; Durand & Carr, 1991; Marcus & Vollmer, 1995) or to access help with a difficult task (e.g., E. G. Carr & Durand, 1985). Differential positive reinforcement involves providing positive reinforcers for compliance while implementing escape EXT for problem behavior (e.g., DeLeon, Neidert, Anders, & Rodriguez-Catter, 2001; Ellison, 2007; Marcus & Vollmer, 1995).

Treating Problem Behavior Without EXT

Although EXT can be combined with other treatments to enhance their effectiveness, determining whether treatment will be effective in the absence of EXT is important for several reasons (Athens & Vollmer, 2010; Hagopian et al., 1998). First, implementing EXT with high treatment integrity can be difficult. Care providers sometimes inadvertently reinforce (e.g., provide attention to) or are simply unwilling to not react to socially unacceptable problem behavior, even if they are aware that their response may be reinforcing. When this happens, the behavior is reinforced on an intermittent schedule of reinforcement, which may increase the rate of problem behavior. The utility of EXT may therefore be limited because it is relatively prone to treatment integrity failures. However, some research has shown that occasional lapses of the EXT component of DRA do not compromise the efficacy of the procedure as long as reinforcement for alternative behavior is greater than reinforcement for problem behavior. For example, Worsdell, Iwata, Conners, Kahng, and Thompson (2000) found that four of five participants allocated more responding to alternative behavior only after problem behavior was reinforced more intermittently. These results suggest that a functional alternative response may be acquired and maintained even when extinction is not implemented at the highest possible integrity.

A second reason for determining whether the intervention will work without EXT is that for some problem behavior, implementation of EXT would be dangerous for either the individual or others. For example, not providing some form of attention (including response interruption) for attention-maintained aggression toward others may be dangerous or result in other problems (e.g., injuries to others, suspension from school). In addition, implementing escape EXT in the form of continued presentation of demands may be dangerous for the caregiver or the teacher. Thus, determining whether and under what conditions reinforcement might be effective in the absence of EXT is important.

Several studies have shown that DRA in the absence of EXT (i.e., reinforcing an alternative response) might be effective when reinforcement parameters favor appropriate rather than problem behavior (Athens & Vollmer, 2010). That is, when alternative behavior leads to (a) longer durations of reinforcement (Athens & Vollmer, 2010), (b) higher rates of reinforcement (Athens & Vollmer, 2010; Horner & Day, 1991; Worsdell, Iwata, Hanley, Thompson, & Kahng, 2000), (c) higher quality reinforcers (Lalli et al., 1999; Piazza et al., 1997), or (d) more immediate reinforcers (Athens & Vollmer, 2010), appropriate behavior may come to replace problem behavior. For example, Athens and Vollmer (2010) showed that DRA without EXT reduced problem behavior and increased appropriate behavior when appropriate behavior led to higher quality, longer duration, or less delayed reinforcement. Furthermore, large and lasting effects were found when these dimensions of reinforcement were combined. These outcomes are in accord with several quantitative models of choice, including Herrnstein's matching law (see Volume 1, Chapter 14, this handbook, and Chapter 7, this volume).

ADDITIONAL TREATMENT COMPONENTS

The previous sections have discussed how the maintaining reinforcers for problem behavior can be used to increase appropriate behavior and how extinction is used to decrease inappropriate behaviors. However, in some cases this combination of procedures is not effective at decreasing problem behavior to sufficiently low levels. In these cases additional treatment strategies are necessary, including the use of arbitrary reinforcers to increase appropriate behavior and the addition of punishment to further reduce problem behavior.

Arbitrary Reinforcers

As noted previously, arbitrary reinforcers may be used as a treatment component even when the function of behavior is known. Arbitrary reinforcers are not the reinforcers that maintain problem behavior (i.e., those identified in the FA); instead, they are identified during preference assessments or competing stimulus assessments. There are three reasons to use arbitrary reinforcers. First, for some skills, arbitrary reinforcers are more effective or convenient to deliver than the functional reinforcer. For example, Carter (2010) found that for one individual with escape-maintained destructive behavior, edible and leisure items more effectively reinforced compliance than did access to escape. This result replicates previous studies reporting that edible reinforcers are effective at increasing compliance and decreasing problem behavior (DeLeon et al., 2001; Kodak, Lerman, Volkert, & Trosclair, 2007). Indeed, some evidence has suggested that individuals with escape-maintained problem behavior prefer edible items (the arbitrary reinforcer) over a break from tasks (the functional reinforcer; DeLeon et al., 2001; Lalli et al., 1999).

A second reason for using arbitrary reinforcers is that sometimes the therapist may not have identified or have access to the reinforcer that maintains problem behavior (e.g., automatic reinforcement). Repp, Deitz, and Deitz (1976) implemented DRO in which food and attention were delivered for the absence of stereotypy and showed a decrease in stereotypic behavior; however, this result may be the exception—DRO is typically not very effective in treating behaviors maintained by automatic positive reinforcement (Piazza, Fisher, Hanley, Hilker, & Derby, 1996), perhaps because the EXT component of DRO cannot be implemented. In addition, DRO does not teach a specific alternative behavior that the individual can use to obtain the arbitrary reinforcers that might compete with automatic reinforcement. Thus, when treating automatically reinforced problem behavior, most researchers have used artificial reinforcers to teach appropriate behavior. These reinforcers might include appropriate toy play or other leisure activities or, in the case of escape-maintained behavior, teaching the individual an adaptive escape behavior (e.g., asking for and taking medication).

Third, some arbitrary reinforcers may mitigate ongoing aversive events that establish escape as a reinforcer (e.g., providing video or music at the dentist or providing a magazine while waiting). As noted earlier, applications of NCR sometimes involve the use of arbitrary reinforcers. For problem behavior maintained by attention, NCR with arbitrary reinforcers involves providing free access to highly preferred items or activities that compete with attention (e.g., Fischer et al., 1997, 2004; Hanley, Piazza, & Fisher, 1997). For example, Fischer et al. (1997) showed that the noncontingent delivery of edibles was effective for decreasing problem behavior maintained by other positive reinforcers (e.g., attention). Thus, the availability of the edibles likely reduced the motivation to engage in problem behavior to access attention.

We should note one caution in the use of arbitrary reinforcers. When additional reinforcers are added to contexts in which problem behavior is already occurring, these reinforcers may increase the future probability of that behavior (Nevin, 2009). Specifically, response contingent (Mace et al., 2009) and noncontingent (e.g., Ahearn, Clark, Gardenier, Chung, & Dube, 2003) reinforcers may produce reductions in problem behavior in the short run, but in so doing, these events may make problem behavior more difficult to extinguish or disrupt through other therapeutic means, a process known as *behavioral momentum* (see Chapter 5, this volume). This may have particularly important implications for the use of NCR in the treatment of problem behavior because the programmed rate of reinforcement in NCR interventions is so high, and higher rates of reinforcement engender the problem behavior with more behavioral momentum. Although this potential risk warrants consideration and further investigation, most published studies on NCR have not reported such effects.

Punishment Procedures

In some cases, the interventions we have described do not reduce problem behavior to clinically acceptable levels. In these cases, additional consequence-based interventions are required to achieve meaningful outcomes. We discuss several of these common procedures here.

Time out. Time out is a negative punishment procedure that effectively decreases problem behavior maintained by social positive reinforcement, particularly when it is combined with procedures to increase appropriate replacement behavior (Bean & Roberts, 1981). *Time out* refers to a class of procedures involving the loss (or prevention) of access to reinforcement for a period of time contingent on the occurrence of problem behavior. To be maximally effective, time out (a) must be applied in the context of a highly reinforcing environment (time in), (b) must involve removing other sources of reinforcement during time out (i.e., a child should not be permitted to play during time out; Solnick, Rincover, & Peterson, 1977), and (c) should not be used for problem behavior maintained by escape (time out would operate as a reinforcer in this case). Time out has been effective in the treatment of attention-maintained problem behavior (e.g., Durand & Carr, 1992). Time out can also be effective when it involves removal of preferred stimuli that are not functionally related to the problem behavior (Falcomata, Roane, Hovanetz, Kettering, & Keeney, 2004; Keeney, Fisher, Adelinis, & Wilder, 2000).

Time out is particularly useful when attention cannot be withheld (i.e., EXT). For example, if problem behavior is maintained by peer attention and peers are unlikely to implement EXT, then time out may be used to ensure that the child does not receive additional peer attention (i.e., removal of the child from the room will ensure that peer attention is not delivered; Sachs, 1973). Similarly, if problem behavior is too dangerous to ignore, then a time-out procedure may be preferred.

Time out has been associated with several limitations (see Brantner & Doherty, 1983). One limitation is that time out may not be feasible with large individuals. That is, if the individual refuses to go to the time-out area, then a struggle may ensue, resulting in a dangerous or reinforcing situation. Another limitation is that time out usually involves removing the individual from an environment in which desirable behavior is being taught. Finally, the procedural aspects of time out have not been thoroughly investigated. For example, how to determine the most efficient length of time out or whether to gain compliance before reentry into the time-in context is not clear.

Response cost. Response cost is another negative punishment procedure that can be used to reduce problem behavior. Procedurally, response cost involves removal of a specific amount of a reinforcer after problem behavior (Jostad, Miltenberger, Kelso, & Knudson, 2008). Most studies on response cost are embedded in a context in which tokens or points are awarded either noncontingently (e.g., Iwata & Bailey, 1974) or contingent on some appropriate behavior (e.g., Reisinger, 1972). In this context, problem behavior occasions response cost (i.e., removal of tokens or points). One advantage of response cost using tokens is that it does not require that the client be removed from the learning environment. For attention-maintained problem behavior, however, response cost involving the removing of tokens or points may result in a small degree of attention delivery, which may function as a reinforcer for problem behavior (McLaughlin & Malaby, 1972). For a review of response cost, we refer the reader to Kazdin (1972); Pazulinec, Meyerrose, and Sajwaj (1983); and Walker (1983).

Brief contingent holds. Contingent holds involve brief (e.g., 30–60 seconds) constraint of the individual (or part of his or her body) contingent on problem behavior. Use of brief contingent holds (e.g., hands down, baskethold, facial screen) has been used to treat SIB, aggression, and other forms of problem behavior that pose a risk to the individual or others. These procedures can be a highly effective treatment component for severe problem behavior (e.g., Fisher et al., 1993; Hagopian et al., 1998; Hanley, Piazza, Fisher, & Maglieri, 2005; Perry & Fisher, 2001; Lerman, Iwata, Shore, & DeLeon, 1997; Vorndran & Lerman, 2006; Wacker et al., 1990). Brief contingent holds are often characterized as positive punishment procedures, although they may also exert their effects through negative punishment via time out (Lerman & Vordran, 2002).

PROGRAMMING FOR GENERALIZATION AND TREATMENT SUSTAINABILITY

Interventions to decrease problem behavior and increase appropriate behavior are effective when implemented with high treatment integrity. However, as noted earlier, maintaining treatment integrity is difficult when the intervention involves EXT or dense reinforcement schedules or requires that reinforcers be delivered immediately after adaptive (replacement) behavior. Because none of these procedures can be maintained for very long outside of the treatment context, it is important to determine how to (a) effectively thin the schedule of reinforcement, (b) teach clients to discriminate situations in which the adaptive behavior will and will not be reinforced (i.e., stimulus control), and (c) train clients to better tolerate delays to therapeutic reinforcers.

Schedule Thinning

Although NCR is most effective when the functional reinforcer is delivered on a dense schedule (Derby, Fisher, & Piazza, 1996; Kahng, Iwata, DeLeon, & Wallace, 2000; Lalli et al., 1997), maintaining this rate of reinforcement is not always feasible. Therefore, thinning the schedule of reinforcement (e.g., Hagopian, Fisher, & Legacy, 1994) is necessary. In the case of NCE, schedule thinning may be needed to increase instructional time to acceptable levels (Vollmer, Marcus, & Ringdahl, 1995). Thinning of NCE has been conducted in two ways. First, in demand (or instructional) fading, initially no demands are presented. Next, the number of demands is systematically increased, so that the amount of time without instruction is reduced over the course of a session. This type of schedule thinning is not successful unless problem behavior never leads to escape (Zarcone, Iwata, Smith, Mazaleski, & Lerman, 1994). Alternatively, the duration of NCE periods may be decreased over the course of sessions (Vollmer, Marcus, & Ringdahl, 1995). No general rules apply to the rate of schedule thinning. Instead, the therapist should let the rate of problem behavior determine when another step in the schedule-thinning process may be taken. The field may profit if more systematic research were to examine standard procedures for schedule thinning (e.g., percentile schedules of reinforcement; see Galbicka, 1994).

When a DRA procedure succeeds in teaching a more adaptive behavior, the client is obtaining reinforcers at a high rate that probably cannot be maintained outside the therapeutic context. For example, FCT may have taught the client to request the functional reinforcer instead of engaging in problem behavior, but now the frequency of requests is too high for caregivers to attend to each time (i.e., implement the treatment at a high level of integrity; Hanley et al., 2003; Tiger & Hanley, 2004). Delay fading involves gradually increasing the amount of time between the request for a reinforcer and access to that reinforcer. Hagopian, Fisher, Sullivan, Acquisto, and LeBlanc (1998) summarized the results of delay-fading studies and found that it was effective in fewer than half of the cases (five of 12). Clearly, more research is needed.

Stimulus Control

A second technique for increasing the practicality of behavioral interventions is to teach the individual to discriminate situations in which his or her adaptive behavior is more or less likely to result in reinforcement, that is, establish stimulus control. This technique is most often used in conjunction with schedule thinning (e.g., Hanley, Iwata, & Thompson, 2001; Tiger & Hanley, 2004). Briefly, the technique involves enforcing the reinforcement contingency in the presence of stimulus A (colored card, timer, presence of a communication device) and an EXT contingency in the presence of stimulus B. When stimulus control develops, the adaptive behavior is emitted only in the presence of stimulus A. Combining this stimulus control technique with schedule thinning appears to increase the efficacy of schedule thinning (Fisher, Kuhn, & Thompson, 1998; Hagopian et al., 1998; Hanley et al., 2001; Vollmer, Borrero, Lalli, & Daniel, 1999) because the individual makes fewer errors.

Because caregivers are likely to reinforce adaptive behavior aperiodically, there may be utility in using stimuli that signal unpredictable interreinforcer intervals (i.e., variable-interval schedules). Once stimulus control has been established, these stimuli might be given to the caregiver with better generalization outcomes. Future researchers might also investigate whether more naturalistic signals could serve as S^Ds, thereby obviating the need for the use of artificial S^Ds in the natural environment.

Increasing Tolerance to Reinforcer Delay

Numerous studies have shown that treatments such as DRA can reduce problem behavior when reinforcers are delivered immediately. Because immediate delivery is not always feasible outside of the treatment context, it is important to teach clients to tolerate delays to reinforcement. One technique that has proven ineffective is gradually increasing the delay between appropriate behavior and the delivery of reinforcement (e.g., Hagopian et al., 1998; Hanley et al., 2001). The efficacy of this technique can be somewhat improved if the client is taught to engage in delay-mediating activities (Fisher et al., 2000; Hanley et al., 2001). However, Fisher et al. (2000) reported that this technique failed (resurgence of problem behavior) once delays were increased to 30 seconds. A third method is to present a signal immediately after the appropriate behavior and throughout the delay to reinforcement (e.g., a countdown timer). Vollmer et al. (1999) found that this technique worked better than not signaling the delay, but the delay duration tested was quite brief (10 seconds).

Clearly, more research is needed on effective ways to teach clients to tolerate those delays to reinforcement that are inherent to nontherapeutic environments. A seemingly important issue to consider in this research is the immediacy of reinforcement for engaging in problem behavior. If the alternative reinforcer cannot practically be delivered immediately, then perhaps this reinforcer will need to be superior to that which may be obtained via problem behavior (see Vollmer et al., 1999). In addition, determining whether more naturalistic delay-bridging stimuli (e.g., “You need to wait,” “In a few minutes,” “Not right now”) will improve the maintenance of treatment effects in nontherapeutic settings will be important.

CONCLUSIONS

Although much research has been conducted on the use of FAs for the assessment of problem behavior, several questions and areas for extension remain.

First, the generality of the model is relatively limited in terms of population and target behavior. That is, most studies have shown the usefulness of FAs for individuals with developmental disabilities and for problem behaviors that are typical to this population (e.g., SIB, aggression, property destruction, elopement, inappropriate sexual behavior). Thus, more studies are needed with individuals who are typically developing and for the assessment of behaviors and disorders that are displayed by this population (e.g., depression, eating disorders, substance use disorders, pathological behaviors). Finally, continued research needs to be conducted on the treatment validity of FAs, especially as it relates to extended periods and long-term outcomes.

Many function-based interventions that involve directly manipulating the controlling antecedents of and consequences for problem behavior have been shown to be effective for reducing problem behavior. One area for future research is establishing a repertoire of adaptive skills that enable the individual to recruit more reinforcers. Currently, skills targeted for treatment have included communication skills (Tiger & Hanley, 2004), play or leisure skills (Lang et al., 2009; Stahmer & Schreibman, 1992), and social skills (Frea & Hughes, 1997; Hagopian, Kuhn, & Strother, 2009; Hanley et al., 2007). As mentioned previously, Hanley et al. (2007) showed that teaching preschool children to engage in a series of appropriate social skills (e.g., waiting your turn, saying "thank you," comforting others in distress, sharing with others) resulted in an increase in these social skills and an overall decrease in the occurrence of problem behavior (i.e., vocal disruptions and aggression). Finally, additional research should address the external and social validity of our function-based interventions, that is, determination of interventions that are more likely to be implemented with high integrity and those that are more likely to show maintained effects in natural and more complex environments.

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CHAPTER 15

UNDERSTANDING AND TREATING ATTENTION-DEFICIT/ HYPERACTIVITY DISORDER

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Attention-deficit/hyperactivity disorder (ADHD) is one of the most frequent diagnoses among school-age populations. Recent studies have estimated the prevalence at approximately 7% of children ages 3 to 17 years in the United States (Centers for Disease Control and Prevention, 2005). Boys are twice as likely as girls to be diagnosed with ADHD (Bloom & Cohen, 2007). Data have suggested that children who are of poor or fair health status are 3 times more likely to be diagnosed with ADHD than children with better health (Bloom & Cohen, 2007). ADHD is associated with several comorbid disorders; the most common are oppositional defiant disorder (estimated in 40%–65% of individuals with ADHD) and learning disabilities (approximately 31% of individuals with ADHD; DuPaul & Stoner, 1994).

Several poor outcomes have been correlated with childhood diagnoses of ADHD. For instance, 12-year-old-children diagnosed with ADHD were found to have significantly lower reading achievement scores, higher rates of absenteeism, increased occurrence of grade retention, and greater incidence of dropping out of school than those without the diagnosis (Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2007). Children with ADHD are more likely to have social difficulties that interfere with friendships, family interactions, leisure activities, and occupational performance than peers without ADHD (Mannuzza, Klein, Bessler, Malloy, & Hynes, 1997; Strine et al., 2006). Furthermore, children with disabilities including ADHD have been found to have a higher prevalence of nonfatal injuries (Schubiner et al., 2000; Xiang, Stallones, Chen, Hostetler, & Kelleher, 2005) as well as higher rates of substance abuse (Levin & Kleber, 1995). Collectively, these statistics suggest that early diagnosis and intervention for children with ADHD is paramount in improving their quality of life.

DIAGNOSIS AND ASSESSMENT

The *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text revision; *DSM–IV–TR;* American Psychiatric Association, 2000) describes ADHD as an ongoing pattern of inattention, hyperactivity, or both that occurs more often or to a greater extent than is developmentally typical. ADHD is divided into three subtypes: predominantly inattentive type, predominantly hyperactive–impulsive type, and combined type. Diagnosis and classification into one of these subtypes is usually made by matching observed behaviors to symptoms listed as diagnostic criteria in the *DSM–IV–TR*. Because the symptoms of ADHD occur periodically in most people, the symptoms must have been present for at least 6 months and occur at a level that is both disruptive and developmentally inappropriate.

Structural Approaches

The process of diagnosing ADHD using *DSM–IV–TR* criteria is a topographical, or structural, assessment. That is, diagnosis is made based on what an individual's behavior looks like (its topography). Unfortunately, there is no commonly accepted measure for diagnosing ADHD. Diagnosis is usually based on indirect measures such as behavior rating scales,

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which have several shortcomings. For example, the descriptors used in these rating scales typically do not have objective anchors, are not operationally defined, and involve subjective judgments subject to informant bias, often resulting in inconsistent and imprecise application (Atkins & Pelham, 1991; Gulley & Northup, 1997; Kollins, Ehrhardt, & Poling, 2000; Stoner, Carey, Ikeda, & Shinn, 1994). Virtually all widely used neuropsychological tests for assessing ADHD have low predictive validity when used at the level of individual assessment (Barkley, 2008).

Another limitation of a topographical assessment is that it does not provide information about the purpose or functional properties of behaviors of concern, and therefore it has limited utility in guiding treatment. Although many behaviors look alike, they may occur for different reasons. For example, one child might scoot in his chair to within kicking distance of the girl seated in front of him. The girl might scoot her chair forward in the same manner, out of kicking distance of the boy behind her. The chair scooting of both children might look the same, but they serve different purposes (gaining the attention of the girl vs. escaping the chair kicks of the boy). An alternative seating arrangement would eliminate the need for the girl to scoot her chair, but it would likely result in the boy engaging in other inappropriate bids for the girl's attention (e.g., throwing paper wads at her). Interventions for problem behavior that are based on a behavior's form without considering its function often fail, thus increasing reliance on more intrusive interventions such as punishment.

Functional Approaches

An alternative approach to using topographical descriptions is to define behavior according to its function (see Chapter 14, this volume). This approach has several advantages. From a diagnostic standpoint, a functional definition of a disability such as ADHD is likely more precise, resulting in a more homogeneous group and better prediction of treatment effects.

More important, identifying the function of a behavior informs treatment. That is, when the function of the behavior is known, it is possible to then develop interventions to match that function, increasing the likelihood of treatment success (see, e.g., Pelios, Morren, Tesch, & Axelrod, 1999). In addition, because behaviors that look different can produce similar outcomes, an intervention that addresses the function should successfully treat both behaviors. For instance, kicking a student's chair and grabbing a book from her, although different behaviors, likely produce similar outcomes (immediate attention from the peer). An intervention that teaches and reinforces an appropriate alternative that achieves the same outcome (e.g., offering to share something that is desired) has the potential to replace and reduce both of the inappropriate behaviors.

The trend toward emphasizing function rather than form has largely been an outgrowth of the development of functional analysis methodologies (see Volume 1, Chapter 4, this handbook). This approach has been developed with other populations, principally severe problem behavior of individuals with developmental disabilities, but has since been applied to individuals with a diagnosis of ADHD (e.g., Boyajian, DuPaul, Handler, Eckert, & McGoey, 2001; Broussard & Northup, 1995; Dicesare, McAdam, Toner, & Varrell, 2005; Ervin, DuPaul, Kern, & Friman, 1998; Gunter, Jack, Shores, Carrell, & Flowers, 1993; Kodak, Grow, & Northup, 2004; Northup et al., 1995; Northup & Gulley, 2001; Northup, Kodak, Grow, Lee, & Coyne, 2004; Umbreit, 1995). For instance, Flood, Wilder, Flood, and Masuda (2002) conducted functional analyses of the off-task behavior exhibited by three children diagnosed with ADHD. The results of those analyses suggested that peer attention served as a reinforcer for each participant's off-task behavior. An intervention that consisted of peer-delivered redirection back to task and peer attention for on-task behavior successfully reduced all participants' off-task behavior.

CORE SYMPTOMS OF ADHD

The diagnostic criteria for ADHD are based on symptoms of inattention, hyperactivity, and impulsivity.

Inattentiveness

Attention deficits are viewed by many as "the major symptom construct that forms the essential nature of this disorder" (Barkley, 2006, p. 77). They are multifaceted (e.g., encompassing sensory as well as motivation processes) and are often characterized as distractibility, lack of persistence, failure to sustain attention, or all of these. Attention deficits are not clearly operationalized (Sagvolden, Johansen, Aase, & Russell, 2005), and identifying and measuring attention or inattention presents difficulties. As with thinking, attention cannot be directly observed by anyone other than the person engaged in attending activities, and its occurrence or nonoccurrence must therefore be inferred from other behavior. Topographical definitions are often used, such as head and eyes oriented toward materials relevant to the assigned task (e.g., Jurbergs, Palcic, & Kelley, 2007). Such definitions can be misleading or inadequate. One can be daydreaming while looking at a math problem or, conversely, compute a math problem while not looking at it, for example.

A functional definition of *attention*, however, is "discriminative responding based on some stimulus or stimulus property. An organism is said to *attend* to a stimulus or property when variations in that stimulus or property change behavior" (Catania, 2007, pp. 378–379; for a more thorough treatment of the topic of attention, see Volume 1, Chapter 17, this handbook). If ADHD is characterized as a problem with sustained attention, then a functional approach would indicate that ADHD is characterized by the inability of stimuli to control behavior over time. Inattention is inferred from this outcome.

Conceptualization. From a behavioral perspective, attention deficits as well as other symptoms of ADHD might usefully be conceptualized as anomalies of delay-of-reinforcement gradients (Catania, 2005; Sagvolden et al., 2005) or temporal discounting (Critchfield & Kollins, 2001). That the response-strengthening effect of a reinforcer is largest when it is delivered immediately after a response has been long established. Delaying the delivery of a response-contingent reinforcer weakens this ability, with delay duration inversely related to reinforcer efficacy. Basic researchers studying choice (e.g., Mazur, 1987) have mapped out how the value of a reinforcer is discounted as the delay to reinforcer delivery increases. This is illustrated by the discounting curves in Figure 15.1. We are less concerned with the shape of the curve and more concerned with the potential implications of this curve on attention.

If a discriminative stimulus (S^D) signals the availability of an immediate reinforcer, the onset of this stimulus will increase the probability of two behaviors—attending to the stimulus and engaging in the operant response that has, in the past, produced the reinforcer. However, if the S^D signals the availability of a delayed reinforcer, then the value of that reinforcer is discounted below its objective value. When the value (efficacy) of the reinforcer is discounted, the individual may not attend to the S^D, and therefore, the probability of the appropriate operant responding is less likely to increase (see Volume 1, Chapter 17, this handbook, for a discussion of behavioral approaches to attention).

An extralaboratory example may help in seeing the relevance of this conceptual analysis of ADHD-related inattention. Assume a teacher gives the student a sheet of mathematics problems. The sheet can serve as an S^D signaling that reinforcement is available for problem solving. After the student correctly writes the answer to the first problem, the teacher immediately indicates that the response is correct, perhaps by revealing the correct answer or by

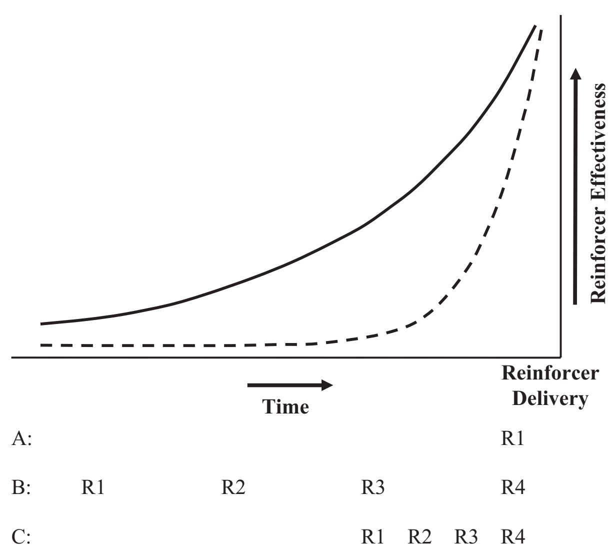

FIGURE 15.1. Hypothetical delay-of-reinforcement gradients that are steep (dashed line) and shallow (solid line). A, B, and C represent different patterns of responses occurring across time in relation to the point of reinforcer delivery. R = reinforcer.

putting a star or a plus sign on the student's paper (consequence). This is illustrated in row A of Figure 15.1. The reinforcer (R1) occurs immediately after the operant response, and the reinforcer retains its full efficacy. In addition, repeated pairing of the S^D (math problem) with a reinforcer (star or plus sign) can establish the S^D as a conditioned reinforcer (e.g., the presentation of the problem signals a reduction in the delay to the reinforcer relative to the background rate of reinforcement).

Suppose, however, that as is more typical of classroom situations, the teacher's practice is to wait until the students have had sufficient time to complete all of the problems before announcing the correct answers (row B). In this classroom, the worksheet signals the availability of a delayed consequence—a consequence that may have very little reinforcing efficacy depending on the degree to which delayed reinforcers are discounted. For students with steep delay-of-reinforcement gradients (dashed curve in Figure 15.1), the presentation of a worksheet signals the availability of a reinforcer with almost no value. As such, very little responding may be initiated, and very little attention may be directed to the math problems, which characterizes the performance of many children with ADHD. By contrast, children who discount delayed consequences less steeply (solid curve) would be expected to respond more diligently under this delayed reinforcement scenario. That is, for these children, each problem is an opportunity to obtain a delayed but valuable consequence.

Evidence informing this conceptual analysis of inattention comes from three sources. First, a growing number of studies have suggested that the inbred spontaneously hypertensive rat is a valid animal model of ADHD (e.g., Sagvolden et al., 2009) compared with the Wistar Kyoto rat. The behavior of spontaneously hypertensive rats is characterized by inattention and hyperactivity, and recent evidence has suggested that these rats show learning deficits when reinforcers are delayed (e.g., Hand, Fox, & Reilly, 2006; Johansen, Killeen, & Sagvolden, 2007). Important for the present analysis, spontaneously hypertensive rats more steeply discount the value of delayed food reinforcers than do Wistar Kyoto rats (Fox, Hand, & Reilly, 2008; Wooters & Bardo, 2011). To date, no experiments have compared spontaneously hypertensive rats and Wistar Kyoto rats using a procedure, such as the five-choice serial reaction-time task, that assesses rodent attention and other forms of impulsivity (see Robbins, 2002, for a review).

Second, children diagnosed with ADHD appear to pay less attention to stimuli that signal less frequent reinforcement. For example, Aase and Sagvolden (2006) asked 28 boys diagnosed with ADHD and 28 control participants to complete a pair of tasks requiring sustained attention. In both tasks, when participants used a computer mouse to click colored squares on a screen, clicking was reinforced at unpredictable time intervals. When the square color signaled that clicks would be reinforced frequently (on average every 2 seconds), the ADHD and control children performed comparably. However, the younger children diagnosed with ADHD demonstrated sustained attention deficits relative to control participants when the square color signaled infrequent reinforcement (an average of 20 seconds between reinforcers). Similar results were reported by Sagvolden, Aase, Zeiner, and Berger (1998) when the time interval between reinforcers was predictable. This tendency toward ignoring stimuli that signal infrequent reinforcement is predicted from a discounting perspective: If the delayed reinforcer is steeply discounted and retains little value, the stimulus signaling the availability of this low-value reinforcer should garner little attention relative to other stimuli in the environment.

Third, some evidence has been found that children diagnosed with ADHD more steeply discount the value of delayed rewards. An early study suggested that children with ADHD prefer smaller–sooner over larger–later rewards if this pattern of choice leads to more immediate escape from the attention-demanding experimental session (Sonuga-Barke, Taylor, Sembi, & Smith, 1992), a finding systematically replicated in college students (Scheres, Lee, & Sumiya, 2008). However, mixed results characterize two studies in which choosing the smaller–sooner reward (a pattern of choice consistent with steep delay discounting) did not end the session more quickly. Although Schweitzer and Sulzer-Azaroff (1995) reported that children with ADHD were more likely to make impulsive choices, Sonuga-Barke et al. (1992) reported no difference between ADHD and control participants.

Studies measuring the steepness of delay-discounting curves (Figure 15.1) among children diagnosed with ADHD and control participants have generally supported the position that individuals with ADHD more steeply discount the value of delayed rewards than do control participants (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001; Scheres et al., 2008; Scheres, Tontsch, Thoeny, & Kaczkurkin, 2010; Wilson, Mitchell, Musser, Schmitt, & Nigg, 2011; although see Scheres et al., 2006). However, the relation between delay discounting and attention, when assessed in these studies, has been mixed (see Scheres et al., 2008, 2010; Wilson et al., 2011).

In sum, the case for steeper discounting of delayed reinforcers among individuals with ADHD (and an animal model of ADHD) appears to be supported by the available literature; however, a smaller and less consistent literature has informed the question of delay discounting as a mediator of inattention. Many procedural differences separate studies exploring this relation (e.g., delay durations, real vs. hypothetical rewards, dependent measures), and they make it difficult to interpret disparate findings (see Wilson et al., 2011). Thus, conclusions regarding the role that delayed reinforcers and steep temporal discounting may play in inattention in ADHD remain tentative.

Intervention strategies. Because individuals with ADHD appear to discount delayed consequences more steeply than individuals without this diagnosis, the long-standing recommendation to arrange more immediate reinforcers appears well founded and has often been followed. Neef and Northup (2009) described a case that illustrates this strategy, which appeared to improve attention.[1] The 10-year-old student with ADHD was referred by his fourth-grade teacher and the principal of an urban public elementary school because of problems during independent seatwork. Typically during this time, the teacher distributed a worksheet containing items from math and language arts workbooks, collected the worksheets at the end of the period, and reviewed the correct answers. The student frequently engaged in disruptive behavior and rarely attempted to answer any of the questions, and few answers were correct (M = 5%). The worksheet was then modified by inserting the correct answers with Invisible Changeable Crayola Markers. In this way, the student could reveal the correct answer by coloring over the space immediately after completing the problem. With this reduction in the delay to reinforcement, the student began to attend to the worksheet and enter answers, many of which were correct (M = 41%). To promote further improvements, immediate conditioned reinforcers were added. One fourth of the answers were randomly designated with a star that was also revealed by coloring over the space (a random-ratio 4 schedule of reinforcement). If the student's answer to a worksheet problem matched the correct answer, and it was designated with a star, he earned a point. Four points could be exchanged for a reward at the end of the period. Indicative of attending, the student entered answers to 100% (142 of 142) of the worksheet questions, 84% of which were correct. Similar findings were obtained in replications with other students.

Other interventions that bring reinforcer presentation within reach of the time period of reinforcer impact may be similarly effective. In fact, many of the behavioral treatment programs that have been found to be effective for children with ADHD have involved increased frequency and immediacy of reinforcement (e.g., Barkley, 2006; DuPaul & Stoner, 1994). Catania (2005) suggested that very short delays to reinforcement might be intermixed with progressively longer delays in an effort to maintain attention to a stimulus predictive of immediate and, at least occasionally, delayed reinforcers. Such an intervention may help to establish the stimulus as a conditional reinforcer that will maintain attention over progressively longer delays to reinforcement.

Well-designed computer-based instruction may be especially well suited to this purpose (Clarfield & Stoner, 2005; Ota & DuPaul, 2002). Its potential to automatically provide immediate or precisely

[1]The case is a representative participant in a dissertation conducted by Summer J. Ferreri.

arranged consequences for responses or defined behavior sequences relieves teachers of a burden they cannot practically execute given the number of students to whom they must concurrently attend. An example is Headsprout Reading Basics, which, in comparison with teacher-directed instruction, was found to produce educationally significant gains in oral reading fluency and increased task engagement in kindergarten and first-grade students with ADHD:

> The student works sequentially through 40 animated lessons, each lasting approximately 20 minutes. The program is highly interactive as the students engage in over 180 active learner interactions per lesson. The lessons are individualized and adapt to a child's pace. The program is designed so that the student's success rate in each lesson is at least 90%. A majority of the Headsprout activities involve the child completing tasks, which in turn results in the moving of an animated character to a desired destination. The students keep track of their progress through the use of a colorful progress map. After students complete a set of episodes, they receive a Headsprout reader, which is a colorful story booklet containing the sounds and words that the students have learned throughout the program. The Headsprout readers also are intended to motivate students to progress through the program, as they are distributed at regular intervals in the sequence of lessons and indicate improvement in reading skill development. Feedback is interspersed within the Headsprout program, as every student response is acknowledged with feedback, encouragement, and corrections if necessary. For example, after each correct response, the computer tells the child, "yeah" or "you did it." Also, the program provides 10–30-second humorous movies to entertain the students in between activities. (Clarfield & Stoner, 2005, p. 249)

The advantages of such approaches in enhancing attention in individuals with ADHD are at present more theoretical than empirical. Most applied studies of interventions to increase attention in children with ADHD have used topographical definitions that, as described earlier, may not necessarily capture the actual phenomena of attention. Perhaps as a result, interventions designed to increase attending or on-task behavior of children with ADHD have not always produced concomitant changes in academic performance (e.g., Ferritor, Buckholdt, Hamblin, & Smith, 1972).

Basic behavioral research has elucidated a great deal about attending behaviors by focusing on functionally defined observing responses (e.g., Dinsmoor, 1985; Nevin, Davison, & Shahan, 2005). An observing response produces stimuli correlated with the availability or nonavailability of reinforcement (but does not have any effect on the rate or distribution of scheduled primary reinforcers). Because an individual must attend to a stimulus for it to affect behavior, observing responses are considered a measurable accompaniment of attention and are subject to the same principles that affect other operants. Several studies have extended investigations of observing responses to applied problems with stimulus control (e.g., Dube & McIlvane, 1999; Walpole, Roscoe, & Dube, 2007). Differential observing responses require differential responding to stimuli to verify that critical features have been observed (see Chapter 6, this volume). For example, Walpole et al. (2007) reported the use of differential observing responses with an individual with autism who had difficulty discriminating printed words that had letters in common (e.g., *cat, can, car*). The differential observing responses consisted of matching letters that differentiated the words (e.g., *t, n, r*), which improved accuracy on the immediately following task of matching whole words. Extending the generality of such research findings to ADHD is likely to produce promising practices.

Hyperactivity

Unlike attention, which must be inferred from its outcome, hyperactivity is a public event. It is often described as persistent heightened activity expressed topographically as pervasive fidgeting, frequent activity changes, squirming in seat, restlessness, leaving seat, or excessive talking and motor movements. Definitions of *hyperactivity* are not always operationally defined or consistent and often overlap with those for *impulsivity*. Applied studies often focus on problematic behavior presumed to be a byproduct or correlate of hyperactivity (e.g., aggression, elopement) rather than on hyperactivity itself.

Conceptualization. Similar to inattentiveness, hyperactivity can be linked to the more limited temporal range in which consequences affect individuals' behavior with steep delay-of-reinforcement gradients (Catania, 2005; Sagvolden et al., 2005). Specifically, for many individuals with ADHD, it is likely that only those behaviors and stimuli that occur close to the time of reinforcer delivery are effectively reinforced or assume conditioned reinforcer properties, such that rapid response sequences are strengthened. This is illustrated in row C of Figure 15.1. Longer and slower sequences of behavior are more temporally distant from reinforcer delivery and are therefore more likely to occur outside the range of reinforcer effectiveness (as in row B of Figure 15.1). When rapid response sequences are differentially strengthened in this way, a behavioral pattern that can be described as hyperactive emerges. Consistent with this hypothesis, Darcheville, Riviere, and Wearden (1992) reported that children who appeared to steeply discount the value of delayed reinforcers (i.e., they preferred a smaller–sooner over a larger–later reward) tended to respond at high rates under fixed-interval schedules of reinforcement. This pattern of responding is most inefficient because the fixed-interval schedule will deliver the same rate of reinforcement for low-rate responding. Children who demonstrated less steep delay discounting (by choosing the larger–later reward) were more likely to emit this efficient response pattern, beginning their responding as the time of reinforcer availability approached.

Intervention strategies. Several approaches have been used to decrease the occurrence of hyperactivity. Often, interventions consist of delivering reinforcement after successively longer and slower sequences of behavior. Initial response requirements are easily met, thereby increasing the likelihood that the reinforcer will be contacted and low-rate responding reinforced. Initial success may establish the task as a conditioned reinforcer, which later operates as the response requirements are increased.

Azrin, Ehle, and Beaumont (2006), for example, used an intervention based on the Premack principle to treat the hyperactive behavior of a 4-year-old boy diagnosed with ADHD. The Premack principle (Premack, 1962) states that behavior that occurs at a high probability in baseline can be used to reinforce and thus increase the occurrence of low probability behavior. In its application to the treatment of hyperactivity, access to physical activity such as running and jumping (behavior that occurs frequently) would be made contingent on completing an academic task while seated (behavior that occurs infrequently). In this example, Azrin et al. targeted high levels of jumping out of seat and nonacademic behavior for reduction. Using a shaping procedure and access to the playground as a reinforcer, they differentially reinforced progressively longer durations of sitting calmly (which was incompatible with high levels of jumping and nonacademic behavior). Initially, the time the child was required to sit calmly was brief (1 second); however, as he demonstrated success, the time requirement was slowly increased by approximately 50% until a terminal duration of 60 seconds was met. Of course, longer periods of behaving calmly are required to integrate well into classroom settings, so the Azrin et al. study might be regarded as a proof of concept, with future research addressing the continued utility and practicality of this intervention.

Reinforcement has also been delivered via self-management interventions. Several studies have shown that self-management strategies in combination with reinforcement for accurate self-monitoring are effective in reducing hyperactive behaviors (e.g., Ardoin & Martens, 2004; Kern, Marder, Boyajian, Elliot, & McElhattan, 1997). Ardoin and Martens (2004) taught students how to accurately record whether target behaviors (looking around, playing with objects, inappropriate peer interaction, out of seat) occurred during an observation period. When accurate self-monitoring was reinforced, targeted hyperactive behavior was reduced.

One classroom modification often made for students with ADHD is to provide time-based opportunities for the students to take a break and engage in active play. The arrangement of scheduled recess periods can be conceptualized as a noncontingent reinforcement schedule in that access to preferred activities, such as those that might occur during recess, is provided independent of the type of behavior observed in the classroom. By making those activities freely available for a period of time, the reinforcing efficacy of the consequences of these activities may temporarily be reduced, which may result in reduced in-class physical activity and increased academic activity after the noncontingent period of play. As the time from the last recess period increases, access to this activity increases in value. This analysis is supported by a study of the effects of recess on the classroom behavior of boys with and without a diagnosis of ADHD (Ridgway, Northup, Pellegrin, LaRue, & Hightshoe, 2003). Recess (10 minutes of midmorning outdoor free play with items such as balls, jump ropes, and hula hoops) was alternated with no recess across days. During the baseline and no-recess conditions, levels of inappropriate behavior (off task, inappropriate vocalizations, out of seat, fidgeting, and playing with objects) increased for both groups as the morning progressed. Levels of inappropriate behavior during observations late in the morning were lower on days with recess than on days without recess. Although similar effects were observed for both groups of students, the effect was greater for those students with ADHD.

In another example of noncontingent reinforcement, Jones, Drew, and Weber (2000) used peer attention delivered noncontingently to reduce high levels of talking out, getting out of seat, and playing with unrelated objects by a young boy diagnosed with ADHD during independent math assignments. In comparison with contingent peer attention for disruptive behavior, noncontingent peer attention reduced disruptive behavior to near-zero levels. As with self-management techniques, peer-delivered consequences are advantageous in that they decrease the demand on teachers to monitor behavior and deliver intervention components.

Impulsivity

Impulsivity is a construct often defined topographically by describing various forms of behavior considered to be impulsive. For example, the *DSM–IV–TR* lists symptoms such as blurting out answers before the questions have been finished, interrupting, and not waiting for one's turn as indicative of impulsivity.

Impulsivity appears to be multifactorial and reflects more than one behavioral process (see Evenden, 1999, for a review). Impulsivity may be demonstrated by premature responding (responding that is not under the control of available information but that occurs as soon as the opportunity is presented), a failure of response inhibition, or frequent switching between response alternatives, for instance. As noted earlier, another aspect of impulsivity is the steep devaluation of delayed reinforcers. For example, the child who calls out in class for the teacher's attention appears to demonstrate steep devaluation of a better consequence that could be had at a later time if he had raised his hand and waited for the teacher to call his name. That is, the child has chosen a smaller–sooner (negative attention now) over a larger–later (positive attention in a minute or two) reinforcer, a choice suggestive of the steep discounting curve shown in Figure 15.1. In behavioral research, impulsive behavior is often defined as choosing a smaller or less preferred reward that is immediate over a larger or more preferred reward that is delayed (Ainslie, 1975). In contrast, self-control is exemplified by the opposite choice. This functional account of impulsivity lends itself to objective and precise measurement.

Research using these measures of impulsivity has indicated that the choices of children with ADHD are especially likely to be governed by reductions in delay to reinforcement (e.g., relative to their peers, children diagnosed with ADHD are more likely to choose smaller–sooner over larger–later reinforcers; Hoerger & Mace, 2006; Neef, Bicard, & Endo, 2001; Neef, Marckel, et al., 2005; Schweitzer & Sulzer-Azaroff, 1988; Sonuga-Barke et al., 1992). For example, Neef, Marckel, et al. (2005) conducted a functional assessment of impulsivity by objectively measuring sensitivity to different dimensions of reinforcement contingencies and outcomes (e.g., quality, effort, rate). *Quality* referred to the relative preference for an item or activity. High- and low-quality items were identified by a preference assessment before each session during which children chose from an array of 10 rewards (e.g., a piece of candy, a coupon for 5 minutes of a preferred activity, extra attention). The first five items selected were considered to be high-quality items, and the last five items selected were considered to be low-quality items. *Effort* referred to the relative difficulty level of the two academic tasks and was determined by performance on sample problems before the experiment. *Rate* referred to the schedule of reinforcement in effect for each academic task. A high rate of reinforcement was a variable-interval 30-second schedule, medium rate was a variable-interval 60-second schedule, and low rate was a variable-interval 90-second schedule. Computer-based assessments were conducted with 58 children (including 32 children with a diagnosis of ADHD) by arranging choices between academic tasks (math problems that participants were able to complete). Throughout each assessment, two math problems were presented on the computer screen at a time. Students could choose to complete a problem that resulted in an immediate consequence that was less favorable with respect to another dimension (e.g., low-preference reward delivered soon) or a problem that resulted in a delayed consequence that was more favorable with respect to that same dimension (e.g., a highly preferred reward delivered the next day). Examination of response patterns as well as of the percentage of choices that were made to the respective alternatives indicated the extent to which each student's behavior was influenced by immediacy of reinforcement or by another dimension. On one hand, for example, the behavior of a student who consistently selected the response alternative that produced immediate reinforcement even when it resulted in less preferred rewards, fewer rewards, or required more effort relative to the alternative would be characterized as impulsive. On the other hand, favoring the response option that resulted in a more preferred reinforcer even when it was delayed, or allocating responding in a way that produced the most reinforcement from each alternative, would be indicative of self-control. The results revealed consistent choice patterns that could be used to identify relative sensitivities to reinforcer dimensions for each individual. Reinforcer immediacy was the most influential dimension for most of the participants with ADHD, for example, whereas rate and effort affected their choices least often.

Hoerger and Mace (2006) also conducted a computerized functional assessment of impulsivity in which 30 children (15 of whom had ADHD features) participated. Similar to Neef, Marckel, et al. (2005), children chose between two math problems, and the consequences for those choices varied along one dimension. For instance, in the delay assessment, one alternative produced a single immediate reinforcer (e.g., edible item, pencil, money) and the other produced three reinforcers after a 60-second delay. During the effort assessment, the two math problems differed in difficulty. Completing easy problems produced one reinforcer, and completing difficult problems produced three reinforcers. Hoerger and Mace found that impulsiveness (greater sensitivity to reinforcer delay and effort than to amount) characterized the choices of more children with ADHD features than of children in the control group. In addition, impulsive choices on the functional assessment correlated with direct measures of classroom behavior (gross motor activity) characteristic of ADHD.

As described previously, several studies have systematically varied the delay and size (or other dimension) of the reward (Scheres et al., 2008, 2010; Wilson et al., 2011). By systematically examining how variations in values (duration of delay in relation to a competing dimension) affect choice, a more precise temporal discounting function can be obtained. Scheres et al. (2010), for example, compared responding of ADHD combined type, ADHD inattentive type, and matched typically developing participants on three versions of a task in which the magnitude of the delayed reward, session length, and maximum total gain were varied. They found that discounting was positively associated with symptoms of hyperactivity and impulsivity.

Conceptualization. According to the delay-of-reinforcement model, immediate reinforcers are more likely to fall within the range of reinforcer effectiveness than delayed reinforcers, with the resultant selection or strengthening of impulsive behavior (Catania, 2005; Sagvolden et al., 2005).

Intervention strategies. One of the simplest techniques designed for decreasing impulsive behavior is the use of a progressive delay to reinforcement. Initially, a choice between small and large reinforcers is provided when the delay to both reinforcers is equivalent. Under these conditions, choice favors the larger reinforcer. For example, a parent might initially ask a child to choose between one cookie available immediately and three cookies available immediately. Once consistent choice of the larger reinforcer is established, a delay is introduced and then systematically increased as long as choice continues to favor the larger–later reinforcer. In our example, the single cookie is still available immediately; however, choosing the three cookies will require a brief wait before the cookies are delivered. Through repeated success at contacting delayed reinforcement, progressive delays may slowly strengthen self-control.

Basic laboratory evidence for this analysis comes from a study in which pigeons were given extensive training under this self-control paradigm and subsequently made considerably fewer impulsive choices than a control group of pigeons (Mazur & Logue, 1978). A translational extension of this paradigm was conducted by Schweitzer and Sulzer-Azaroff (1988), who used a progressive delay to the larger–later reinforcer to increase the self-control of six young children who were described as impulsive and hyperactive. Throughout training, almost all participants chose exclusively the larger–later reinforcer. Subsequent testing revealed greater delay tolerance than demonstrated at a pretraining baseline.

The results of this study demonstrate one way of increasing self-control for children with ADHD. When attempting to teach self-control, the delay to the larger reinforcer should initially be brief. Once a child is repeatedly choosing the larger reinforcer, small increases in the wait time should be introduced, provided that preference for the larger–later reinforcer is maintained. This preference-contingent shaping of delay tolerance can be continued until the desired delay has been met.

Progressive delays are often used in combination with other interventions such as intervening activities (e.g., Binder, Dixon, & Ghezzi, 2000) or *competing reinforcer dimensions* (Neef et al., 2001). For instance, Neef et al. (2001) conducted a functional assessment of impulsivity (as described in Neef, Marckel, et al., 2005) with three students diagnosed with ADHD. The analysis showed that choices were principally governed by reinforcer immediacy. The next most influential dimension as indicated by the assessment (reinforcer quality for two of the students and reinforcer rate for one student) was then arranged to compete with reinforcer immediacy. Thus, for example, the two students for whom reinforcer quality was an influential dimension were allowed to choose between math problems associated with immediate low-quality reinforcers and delayed high-quality reinforcers. Initially, the delay to the high-quality reinforcers was set at a minimal duration; once this alternative was selected consistently, the delay was increased gradually. When combined with a progressive delay, the competing reinforcer dimensions promoted self-control for delays lasting as much as 24 hours. Another finding of this study was that the self-control developed with one reinforcer dimension (e.g., quality) persisted when other reinforcer dimensions (e.g., rate, effort) were retested. That is, after self-control training, the participants continued to demonstrate self-control in situations different from those in which the training occurred.

Intervening activities are often used as a means of filling the gap between a response and later delivery of the reinforcer. From a procedural standpoint, once the initial choice for a delayed reinforcer has been made, the individual is then provided access to an activity in which to engage during that delay. The intervening activity may serve several functions. First, engaging in the intervening activity may serve as a competing response that interferes with attending to the delay. For example, airport terminals provide access to televisions as a means of bridging the delay to boarding the airplane. An intervening activity may also serve the opposite purpose, increasing attending to the impending delivery of the delayed reinforcer. For instance, when exercising for a specific duration of time, some individuals frequently check the stopwatch on the exercise machine. Seeing progress toward meeting their exercise goal for that day may help to bridge the delay to the end of the workout.

Intervening activities have been examined with respect to their efficacy in increasing tolerance for delay and whether preference for an activity or the type of activity has a bearing on its effectiveness. For example, Mischel and colleagues conducted a series of studies that focused on the delay tolerance of typically developing preschoolers. In one study Mischel, Ebbesen, and Raskoff Zeiss (1972) examined the effects of various intervening activities on the length of delay that the preschoolers could tolerate before consuming a preferred edible item. The procedures for these experiments were fairly simple. The experimenter provided an initial choice between two small edibles. Once the child made a selection, he or she was instructed that (a) the experimenter had to leave the room to complete a task; (b) if the child could wait until the experimenter returned, he or she could consume the high-preference item; and (c) if the child was unable to wait, the child could ring a bell and the experimenter would return and provide access to the low-preference item. If the child did not ring the bell, the experimenter returned to the room after 15 minutes and provided access to the high-preference treat. Intervening activities included access to a toy and various instructions such as "Think fun thoughts," "Think sad thoughts," and "Think about the reward." Children who were provided with an intervening activity waited longer than those who were not given one. In addition, instructions to "Think fun thoughts" produced a longer mean duration of waiting than did access to a toy, whereas instructions to "Think sad thoughts" or "Think about the reward" produced shorter durations of waiting.

Research conducted by Dixon and colleagues with populations other than children with ADHD (Dixon & Cummings, 2001; Dixon & Holcomb, 2000; Dixon et al., 1998; Dixon, Horner, & Guercio, 2003; Dixon, Rehfeldt, & Randich, 2003) has shown intervening activities to be an effective means of treating impulsive behavior. Their procedures were different than those of Mischel et al. (1972), which may explain why they reported benefits of a wide range of intervening activities, regardless of whether those activities involved rules or preferred activities. Gordon (1979) observed that 90% of participants diagnosed as hyperactive engaged independently in behavior such as counting, swinging legs, singing, or foot or finger tapping during a task that required them to withhold button presses for a set interval to receive a reward. He speculated that such intervening activities might resemble hyperactivity but serve to mediate self-control.

Another potential means of promoting self-control over impulsivity is through the use of a *commitment response*. Specifically, a commitment binds one to selecting a large delayed reward at a later time when one might be tempted by a smaller–sooner reward. For example, committing to have a small portion of your paycheck withheld and placed into a savings account (larger–later retirement benefits) decreases the probability that had the amount been available at the end of the month, you would have spent it on something frivolous (smaller–sooner reward). Rachlin and Green (1972) demonstrated that when the environment was properly constructed, pigeons (a notoriously impulsive species) were capable of making commitments and, thereby, demonstrating self-control (see also Siegel & Rachlin, 1995).

Commitments are best made when the benefits of the smaller–sooner and larger–later rewards are both remote. The reason for this recommendation are beyond the scope of this chapter (see Chapter 7, this volume), but one way of intuitively understanding it is to consider that self-control choices are easier to make when the benefits of the larger–later reward are not immediately available (see Chapter 8, this volume, for an overview of the neuroscience of this phenomenon). The potential of the commitment strategy to enhance self-control in individuals with ADHD remains to be investigated.

Reinforcer bundling consists of linking multiple reinforcer deliveries to a single choice response. For instance, at the start of the school day, a student could be asked to choose between earning small reinforcers immediately after work completion or the same number of larger reinforcers at the end of the school day. The choice would then determine reinforcer delivery for the entire day. In other words, a single choice determines which consequence will be delivered for multiple reinforcer deliveries. At the time the choice is made, most of the reinforcer deliveries are remote and therefore less valued. As such, if these deliveries are linked, the likelihood of impulsive behavior for the first delivery is offset by the likelihood of self-control on all subsequent deliveries. As with commitment strategies, the effectiveness of reinforcer bundling in increasing the self-control of individuals with ADHD is unknown; however, basic research involving both nonhuman (Ainslie & Monterosso, 2003; Mitchell & Rosenthall, 2003) and human participants (Kirby, 2006; Kirby & Guastello, 2001) has suggested that bundled reinforcers may be an effective intervention.

MEDICATION MANAGEMENT

Stimulant medication, including methylphenidate (MPH; Ritalin), dextroamphetamine (Dexedrine), and magnesium pemoline (Cylert), is the most common treatment for ADHD, and its use has ample support (MTA Cooperative Group, 1999). The Multimodal Treatment Study of Children With ADHD found medication management to be particularly effective in attenuating core ADHD symptoms (inattention and hyperactivity). Medication management has been supported by within-subject studies as well. For example, Mace et al. (2009) showed higher levels of task engagement and fewer activity changes during medication (Concerta XL) than during placebo conditions in an adolescent with ADHD. In an investigation involving 48 children with ADHD that corrected for some of the limitations of the Multimodal Treatment Study of Children with ADHD study, Fabiano et al. (2007) found that MPH and behavioral intervention alone and in combination had substantial effects on classroom behavior, productivity, and teacher ratings of functioning.

Although little question exists regarding whether pharmacological treatment can be beneficial for people with ADHD, it is not a panacea. First, the improvements achieved with medication have not always been sufficient. For example, Mace et al. (2009) showed that problem behavior (e.g., aggression) was reduced with stimulant medication relative to placebo, but not, according to them, to acceptable levels.

Second, medication interacts with environmental conditions to affect behavior; if the behavioral mechanisms of drug action are unknown or uncontrolled, medication is likely to have inconsistent or seemingly idiosyncratic effects. This result was illustrated clearly by Northup et al. (1999). They examined the effects of different conditions and contingencies commonly observed in classrooms on the disruptive and off-task behaviors of children diagnosed with ADHD under MPH versus placebo conditions. When the students were asked to work by themselves (alone condition), high levels of disruption and off-task behavior occurred under placebo as well as medication conditions. However, medication reduced the target behaviors relative to placebo for each student in at least one of the other classroom conditions (noninteractive teacher present, contingent teacher reprimands, contingent brief time out). Thus, medication reduced problem behavior under some environmental conditions but under not others, and the effects differed across students.

Finally, as noted by DuPaul and Stoner (1994), “It appears as though problems with inattention, impulsivity, and overactivity predispose children to other difficulties that are, in some cases, more severe than the core deficits of ADHD” (p. 4). ADHD places individuals at risk for academic underachievement, disturbances in peer relationships, and difficulties in several areas of functioning. Stimulant medication alone has not typically been sufficient to address these concerns. For example, unless combined with psychosocial treatment, medication was not found to produce significant improvements on measures of classroom behavior or ratings of social skills (MTA Cooperative Group, 1999), and its effectiveness in improving academic performance or learning has been questioned (Purdie, Hattie, & Carroll, 2002). Indeed, considering that as many as 80% of children with ADHD have been found to exhibit academic performance problems (Cantwell & Baker, 1991) despite stimulant medication’s being the most commonly used treatment, it seems an unrealistic expectation for medication to shoulder sole responsibility for addressing these children’s needs.

The issue of medication is a continuing controversy (Fabiano et al., 2007; Pelham & Fabiano, 2008). We believe that the relevant question is not whether medication is better than behavioral intervention overall but (a) how, and the conditions under which, each operates to produce the desired outcomes (such that effects can be better predicted) and (b) what are the most efficacious treatment components for each individual. The former will require continued research (e.g., Neef, Bicard, Endo, Coury, & Aman, 2005). The latter can be best addressed through systematic assessment, and several approaches for this purpose have been examined. Cooper et al. (1993) presented a model for efficiently assessing the relative effects of medication and function-based treatment on target behaviors. The assessment model, incorporating brief functional analyses, was illustrated with two cases, and Kayser et al. (1997) applied it to another study. Assessment results in one Cooper et al. case indicated improved behavior with a combination of MPH and alteration of environmental variables. For the other, alteration of environmental variables improved behavior regardless of medication usage. Assessment results in the Kayser et al. case indicated that inappropriate behavior, which functioned primarily to escape demands, was reduced to near-zero levels with behavioral intervention regardless of MPH and that sleep improved without MPH.

Gulley et al. (2003) similarly described a practical and relatively efficient method of evaluating the separate, relative, and combined effects of varying dosages of stimulant medication and different behavioral interventions to determine the most effective treatments for individual children. Illustrative cases were presented in which MPH and differential reinforcement of other behavior were each used separately and then in combination. Thereafter, an increase in MPH dosage, a change in behavioral treatment (differential reinforcement of other behavior plus either response cost or time out contingent on disruptions), or both were implemented in sequential phases. The behavioral treatment was presented during only one of two daily observation sessions, and MPH and placebo were alternated as well. Both behavioral treatment and MPH alone reduced disruptive behavior to near-zero levels for all participants.

Curriculum-based measurement offers a promising means of assessing the relative effects of treatments on academic performance. Data are derived from brief fluency measures of student performance in basic academic skill areas, using material samples from the student's curriculum. Extensive research has supported its technical adequacy from both behavioral and traditional psychometric perspectives and its sensitivity to changes resulting from educational interventions (Fuchs & Deno, 1991). Stoner et al. (1994) examined the utility of curriculum-based measurement of reading and math for evaluating student response to three dosages of MPH. The results provided preliminary support for its use as a sensitive measure of medication effects on academic performance and for making decisions regarding stimulant medication.

CONCLUDING REMARKS

Functional definitions of the main clinical symptoms of ADHD provide useful information about how environmental variables may affect these behaviors and guide treatment. To date, function-based interventions have received varying degrees of coverage in the applied literature. As a private event, inattentiveness may be the most difficult symptom to address. Although further applied behavioral research is needed in this area, a theoretical foundation for attending can be found in the basic behavioral research. Interventions that establish stimuli as conditional reinforcers may be effective in increasing and maintaining sustained periods of attention.

Hyperactivity and impulsivity, however, have been studied to a greater extent than inattention in applied settings. Treatments for hyperactivity that differentially reinforce longer and slower sequences of behavior have been shown to be effective. In addition, impulsivity has been decreased via procedures that establish success in obtaining delayed reinforcement, such as providing alternative activities during delays.

Several intervention studies have targeted presumed by-products of core ADHD symptoms. Collectively, the success of these interventions demonstrates the utility of functional approaches to the treatment of ADHD. Stimulant medication can affect behavior by altering sensitivity to antecedents or consequences, but effects appear to vary on the basis of environmental conditions and individuals. Optimal treatment requires systematic assessment for prediction of treatments most likely to be efficacious for an individual as well as monitoring and evaluation of outcomes.

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CHAPTER 16

TEACHING READING

Edward J. Daly III and Sara Kupzyk

> We shouldn't teach great books; we should teach a love of reading.
>
> —B. F. Skinner

The very fact that you are reading this chapter strongly suggests that reading has become highly instrumental in your life: It allows you to accomplish tasks that produce reinforcing consequences. The marvelous advantage of the skill is that for the proficient, it becomes such a natural process that they can focus on what needs to be done without giving a second thought to the process that prepares them for achieving their greater ends. Readers rarely pause to think about what they are actually doing until they stumble into difficult terrain; that is, when the markings on the page (or screen) fail to occasion an effective response. For example, a competent reader learning a new language struggles with unfamiliar letter combinations or, in some cases, even an alphabet or character system that is different from anything encountered before. Another reader may struggle to follow unclear or improperly translated directions about how to assemble an object. In another scenario, a bibliophile may tackle a novel with foreign names that slow his or her progress.

Under these conditions, the otherwise competent reader gives conscious, deliberate attention to what is on the page. The reader generally attempts to sound out the word syllable by syllable or even sound by sound and will then probably attempt to blend the syllables or sounds together to form a single word. The momentarily struggling reader may then reread the sentence containing the newly conquered, troublesome word until he or she feels certain of having comprehended the meaning of the text. Usually, competent readers fall back on skills that may have been learned many years ago. Even so, they will probably give little or no thought to, and may not even be aware of, the intentionally sequenced reinforcement history with text that now allows them to read naturally in most contexts and figure out a difficult text when confronted with it.

The fact that you are reading this chapter also suggests that you are interested in the highly complex process that allows characters on a page to influence a nonproficient reader's actions in beneficial ways. You are giving conscious, deliberate attention to the process, presumably to help someone else with acquiring this skill. As such, you are a part of a community of students of reading. Fortunately, this community has agreed on three things about reading instruction. First, the reader should comprehend or derive meaning from text (Adams, 1990; National Institute of Child Health and Human Development [NICHD], 2000; Snow, Burns, & Griffin, 1998). The intended effect of texts is to have an impact on readers' behavior; when the reader responds predictably and competently, one infers that he or she has understood what was read. Second, learning to read to comprehend is a highly complex process, and a long and carefully sequenced series of interactions with text is necessary for comprehension to occur. Finally, everyone agrees that the ultimate goal is for the learner to love

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to read and choose to read when he or she wants to efficiently accomplish a task or solve a complex problem. The crowning achievement of teaching reading is when the reader chooses to read when alternative leisure-time activities are available.

Despite these agreements, various opinions exist about (a) how to teach so that a love of reading results, (b) what comprehension—the highest level of reading activity—is exactly, and (c) how to conceptualize the process of learning to read in such a way that it improves educators' ability to teach children how to read. In other words, the unanimous agreement on the goals does not extend to the methods used for achieving them.

Explanations abound for how learning to read takes place and, depending on the explanation favored, the pedagogical practices that will best teach reading. Those explanations that ensure a speedier learning process through prescribed teaching methods will have the most beneficial impact on aspiring readers. Currently, most reading research has explained the emergence and development of reading as occurring through unobservable processes that mediate the effect of written text on reading. For example, in a seminal text summarizing reading research to date, Snow et al. (1998) accounted (in part) for critical developmental events in the first 5 years of life that will subsequently relate to reading acquisition in the following manner:

> The interplay between elaboration and reorganization of children's mental models has been well documented in the domain of orthographic development. . . . Visual word recognition can flourish only when children displace the belief that print is like pictures with the insight that written words are comprised of letters that, in turn, map to speech sounds. (p. 45)

In elaborating on changes in children's use of language, Snow et al. (1998) stated, "Each such change must be guided by the metalinguistic insight that language invites inspection and reflection" (p. 45). Explanations such as these turn the reading community's attention to studying children's mental models, visual word recognition, insights about written words, displacing beliefs, and metalinguistic insights about language, all of which are held to be mediating processes that cannot be directly observed. These constructs place the cause of reading activities inside the aspiring reader. Such constructs are not amenable to experimental analysis and direct empirical verification in the way that reinforcement, punishment, and stimulus control are. The behavior analyst is not very comfortable operating within a conceptual model whose causal processes cannot be observed and manipulated directly.

Applied behavior analysts hold a different standard for the explanations and constructs they embrace, taking the middle man out of the explanatory picture. For the behavior analyst, constructs must (a) be tied to environmental events that can be manipulated, (b) produce reproducible and directly observable effects on behavior, and (c) be clearly related to empirically derived principles of behavior (Baer, Wolf, & Risley, 1968). Therefore, a behavior-analytic account of reading, and the teaching of reading, is fundamentally different from common conceptions of this process in the broader field of education. A behavior-analytic account will be built on the principles of operant behavior that have served the field well in understanding and intervening in many important spheres of human and animal functioning (Catania, 2007). Although a behavior-analytic conceptualization of the reading process is not widely known, its contributions to teaching reading are well established. In this chapter, we present an opportunity to explore how behavior analysis has contributed to successful programs of reading instruction and how future research in a behavior-analytic tradition may continue to advance this technology.

Our purpose in this chapter is to outline how to teach reading on the basis of principles of operant behavior and to summarize the empirical findings regarding the efficacy of this approach. We begin with a description of how learning to read and teaching reading are currently characterized in the education literature. We argue that some of the research findings in this literature lend indirect support to a behavior-analytic approach to teaching reading. Next, we analyze reading and the teaching of reading from the perspective of basic behavioral processes. Finally, we describe behavior-analytic instructional principles to show how principles of behavior can be translated into strong and valid instructional practices.

HOW LEARNING TO READ AND READING INSTRUCTION ARE CONCEPTUALIZED IN EDUCATION

Historical and Contemporary Trends in Reading Instruction

Debate over how reading should be taught has long permeated the field of education and has been shaped by the social and environmental factors of the times (see Adams, 1990, for a detailed historical review). Jeanne Chall (1967) stands out as perhaps the most important historical figure for clarifying the two views that have come to dominate the discussion of how to teach reading. In her influential book *Learning to Read: The Great Debate,* Chall provided an extensive and articulate description of the differences between what have come to be referred to as the code-emphasis and meaning-emphasis approaches. *Code-emphasis programs,* on one hand, are those that place initial focus on mastery of the alphabetic code and introduce words on the basis of mastery of letter–sound correspondences. In other words, students are first taught letter sounds and then taught how to combine the sounds to read words. *Meaning-emphasis programs,* on the other hand, are those that place initial focus on meaning and introduce words that appear frequently in text without regard to letter–sound correspondences or spelling patterns (Carnine, Silbert, Kame'enui, & Tarver, 2010; Chall, 1967). If, or when, letter–sound correspondences are taught, meaning-emphasis–based instruction involves the analysis of whole sight words by parts (Chall, 1967). Chall's review concluded that phonics instruction is an essential component of reading instruction because the empirical evidence suggested that it produced better word analysis, reading speed, and comprehension than meaning-emphasis instruction. Despite these findings, Chall noted in 1967 that most schools used meaning-emphasis programs to teach reading.

As the debate surrounding code-based versus meaning-based instruction continued, Marilyn Adams (1990) was commissioned to write a comprehensive review of the reading research collected in the 20 years after Chall's (1967) review. Adams's highly influential book *Beginning to Read* spawned further integrative scientific reports, the two most prominent of which are the National Research Council's report, *Preventing Reading Difficulties in Young Children* (Snow et al., 1998) and the National Reading Panel's report, *Teaching Children to Read* (NICHD, 2000). These reports summarized the extant literature on the development of literacy and effective instructional practices.

The National Research Council report (Snow et al., 1998) concluded that most reading difficulties can be prevented through the implementation of high-quality, research-based instruction. The committee provided information about critical skills, early developmental interactions, and environments that play an instrumental role in the development of reading. Specifically, the report highlighted the need for explicit (rather than natural) reading instruction. This instruction should build phonemic awareness (i.e., an ability to discriminate individual sounds within words), teach letter–sound relationships, and promote fluency and comprehension—recommendations in accordance with Chall's (1967) review and analysis some 30 years earlier. Additionally, the National Research Council report recommended that early intervention should begin in preschool to promote language and literacy skills and increase the number of students entering school with necessary prerequisite skills. After the National Research Council report was published, a panel of prominent reading scholars was commissioned to provide a systematic, quantitative report of instructional methods, materials, and approaches to teaching reading in five basic areas of literacy: phonemic awareness, the alphabetic principle, fluency, vocabulary, and comprehension (see Table 16.1 for a brief explanation of each). Detailed research supporting specific instructional practices for each of these five literacy components can be found in the National Reading Panel report (NICHD, 2000).

Although the topography of instruction will obviously vary according to the area being targeted (e.g., phonics, fluency, comprehension), the National Research Council report (Snow et al.,

TABLE 16.1

Five Components of Reading Described in the Report of the National Reading Panel (Snow, Burns, & Griffin, 1998)

Component	Definition	Importance
Phonemic awareness	The ability to manipulate phonemes in words	■ Aids in decomposing multiphonemic words into constituent phonemes (Adams, 1990) ■ Strong predictor of how well students will learn to read (Foorman et al., 2003)
Alphabetic principle (i.e., phonics)	The ability to associate letters and letter combinations with individual phonemes (i.e., letter–sound correspondence) in written words. Advanced phonics skills include knowledge of prefixes, suffixes, and roots and strategies for decoding multisyllabic words.	■ Fundamental to reading because of the alphabetic nature of English (Adams, 1990) ■ A prerequisite to word reading (Juel, 1988)
Fluency	The ability to read text accurately and quickly	■ Facilitates and supports unassisted comprehension (Snow, Burns, & Griffin, 1998)
Vocabulary	Words one must know and understand to communicate effectively	■ Aids in comprehension; as students understand word meanings they read to learn from the text (Nagy & Scott, 2000)
Comprehension	The ability to understand what one is reading	■ Allows one to understand text, remember it, and put it into use (National Institute of Child Health and Human Development, 2000)

1998), the National Reading Panel report (NICHD, 2000), and other reviews of the research (Adams, 1990; Linan-Thompson & Vaughn, 2010; Torgesen, 2002) are in agreement that reading instruction should include concurrent, explicit, and systematic instruction in all five literacy components with multiple, repeated opportunities to respond across a range of exemplars with suitable materials that are appropriately controlled for content. *Explicit instruction* refers to the direct and overt teaching of specific skills through explanations, modeling, and prompting. After the skill is introduced and modeled, students should be given opportunities to practice the skill with guidance and feedback. A teacher can use many well-validated strategies to provide guided practice, including choral responding, response cards, unison responding, pacing, signaling, small-group instruction, and peer-assisted learning activities (D. Fuchs, Fuchs, Mathes, & Simmons, 1997; Torgesen, 2002; Touchette & Howard, 1984). Linan-Thompson and Vaughn (2010) concluded, "Programs that include principles of direct instruction such as these in their design and delivery are most effective for beginning readers, particularly those at risk for reading failure due to lack of opportunity to learn" (p. 278).

As a result of the National Reading Panel report (NICHD, 2000), many reading publishers have revised their materials to address instruction in all five literacy components. Consumers of these materials (e.g., educators and school board members who make material-adoption decisions) must be careful to look for more than a listing of the five components. A careful analysis of curriculum is warranted because programs differ in the amount of emphasis placed on each component, what skills are taught when (i.e., the scope and sequence of skills), and how instruction is delivered. To assist educators in reviewing and evaluating core reading programs, supplemental programs, and interventions programs, organizations such as the Florida Center for Reading Research (http://www.fcrr.org) and the University of Oregon Center for Teaching and Learning (http://reading.uoregon.edu) have published guides outlining critical components of curricular and instructional programs. For example, the

Consumer's Guide to Analyzing a Core Reading Program (Simmons & Kame'enui, 2003) guides consumers in scrutinizing the research evidence for a program, whether it targets critical skills, how effective its lessons are, and whether the instructional progression of lessons is appropriate.

Teaching All Students to Read Through Flexible, Responsive, and Differentiated Instruction

With the vast amount of research on the teaching of reading to date and multiple consensus documents on the topic, it is unfortunate that instruction provided in schools is often not aligned with best practices, and thus many students fail to progress adequately in their reading skills (Chard & Kame'enui, 2000; Simmons, Kuykendall, King, Cornachione, & Kame'enui, 2000). The many challenges to the implementation of evidence-based reading practices in schools include instructional methods, resources, teacher education, and reluctance to change (Kamps et al., 2008). However, recent laws and governmental recommendations appear to be causing schools to place greater emphasis on early intervention and the use of scientifically based instruction to meet the needs of all students (Individuals With Disabilities Education Improvement Act of 2004; No Child Left Behind Act of 2001).

Until recently, students who had difficulty learning to read were dependent on an exceptionally skilled and devoted teacher, Title I programs, and special education services. For a struggling reader to qualify for special education services, he or she had to be identified as having a learning disability, evidenced by a severe discrepancy between IQ and norm-referenced achievement scores (referred to as the *discrepancy model*). The discrepancy model grew out of a tradition of psychometric models of assessment that relied on individualized, norm-referenced assessments of cognitive and academic skills that were generally conducted by school psychologists as a basis for identifying students with learning disabilities. Over the years, educators have become aware of problems with the discrepancy model. These problems include (a) not providing services until a severe discrepancy emerges (because of floor effects on norm-referenced tests), (b) assessments with poor diagnostic accuracy, (c) a disconnect between what was assessed and how the curriculum could be changed to address the child's reading difficulties, (d) overrepresentation of minorities in special education, (e) variable to poor outcomes in special education, and (f) use of assessments that do not control for students' educational history (Fletcher, Coulter, Reschly, & Vaughn, 2004; Gresham, 2001; Heller, Holtzman, & Messick, 1982; Kavale & Forness, 1999; Macmann & Barnett, 1999; No Child Left Behind Act of 2001; President's Commission on Excellence in Special Education, 2002; Vellutino et al., 1996). Vellutino and colleagues (Vellutino, Fletcher, Snowling, & Scanlon, 2004; Vellutino, Scanlon, & Lyon, 2000; Vellutino et al., 1996; Vellutino, Scanlon, & Tanzman, 1998) have presented a large and convincing body of evidence that diagnosing reading problems is better done by directly and explicitly evaluating critical literacy skills (e.g., word identification skill, phonological skill) than by attempting to diagnose cognitive factors (e.g., visual deficits, syntactic deficits, sensory deficits), as is characteristic of the traditional psychometric approach to diagnosing reading problems. Research to date has established a stronger causal basis for experiential deficits (i.e., lack of prerequisite literacy skills and inadequate instruction) than for diagnosing cognitive profiles (e.g., evaluating visuospatial skills) in the development of later reading problems (Vellutino et al., 2004). Furthermore, direct assessment of critical skills also provides a stronger basis for skill remediation than do psychometric approaches (Vellutino et al., 1996). The implication is that determining instructional need on the basis of reliable and valid indicators of critical skills that should be taught in the classroom is superior to relying on cognitive profiles of skills derived from norm-referenced assessments.

The nature and scope of these problems came to the attention of the U.S. federal government as it was preparing to reauthorize special education law (President's Commission on Excellence in Special Education, 2002). These research findings about the inadequacy of the discrepancy model ultimately shaped federal law (Individuals With Disabilities Education Act of 2004; No Child Left Behind Act of 2001), which has given rise to response to intervention (RtI) as a comprehensive, multitiered, preventive, and responsive instructional model. The origins of RtI can, interestingly, be found in applied behavior analysis (Daly, Martens, Barnett, Witt, & Olson, 2007). As a result of national concern regarding students' reading proficiency, RtI practices have most often been applied to schoolwide reading instruction (McCardle, Chhabra, & Kapinus, 2008). With RtI, high-quality instruction should be matched to student need on the basis of the results of periodic progress monitoring (Batsche et al., 2008). If classroom instruction in the regular curriculum does not result in adequate growth in reading skills, educators are responsible for intensifying instruction through high-quality, research-based intervention programs. In sum, to prevent reading difficulties, the RtI mandate calls for schools to use flexible, responsive, and differentiated instruction based on student assessment data (Linan-Thompson & Vaughn, 2010).

RtI models in reading typically include three or four tiers of intervention, with greater intensity of instruction as students move up the tiers. Students' response to instruction is assessed over time using sensitive, reliable, and valid indicators of reading proficiency. These results provide the database for decisions about moving students from one tier to another. Across all of the tiers, an emphasis is placed on the use of scientifically based instruction delivered with high fidelity. The first tier—universal intervention—serves a preventive function because it is designed to address and meet the needs of most students through the implementation of a scientifically based core curriculum. The core curriculum is the primary tool teachers use to teach reading, and it is therefore a critical component of the system for preventing reading difficulties. For students whose needs are not sufficiently met by the first tier, additional small-group instruction is generally provided in a second tier of intervention. More intensive, explicit, comprehensive, and individualized instruction is provided in the third tier for students who fail to make progress at the second tier. Students' movement through the tiers (i.e., increasing and decreasing intensity of intervention) is based on their responsiveness to instruction and proficiency with basic reading skills. Therefore, a major goal of RtI is to improve student reading skills by measuring student performance, analyzing student data, and delivering the type and intensity of instruction that every child needs. This approach is consistent with a behavior-analytic framework for teaching (e.g., Daly et al., 2007), as we show in the following sections.

TEACHING READING FROM A BEHAVIOR-ANALYTIC PERSPECTIVE

Basic Behavioral Processes Related to Learning to Read

B. F. Skinner's (1957) *Verbal Behavior* has provided a starting point from which behavior analysts have studied reading. Skinner suggested that reading is a verbal operant, where *operant* is defined as a class of behavior whose members are affected by characteristic antecedent stimuli and consequences. Skinner suggested that verbal operants are controlled by the same types of environmental contingencies that affect nonverbal operants. Therefore, according to Skinner, reading is explainable within an operant paradigm, as the following analysis demonstrates.

B. F. Skinner (1957) termed reading *textual behavior,* a response class in which a written or printed stimulus controls vocal (reading aloud), subvocal (reading under one's breath), or covert behavior (reading silently). According to Skinner's analysis, among fluent readers a single irreducible response class is controlled by each textual unit (e.g., the letter *t* controls one response—saying "t"—and *th* controls a different response—uttering "th," referred to as *point-to-point correspondence*). However, no direct correspondence exists between the antecedent stimulus properties (which are textual) and the verbal responses (which are auditory; referred to as a *lack of formal similarity*; Cooper, Heron, & Heward, 2007). Learning to emit verbal responses under the control of antecedent stimuli is crucial to becoming a fluent reader, and it is accomplished through a process of discrimination training. Briefly, this training involves reinforcing a target response (e.g., making the sound corresponding to the letter *d*) in the presence of a target stimulus (e.g., the letter *d*) and withholding reinforcement if the response occurs in the presence of other stimuli (e.g., the letter *t*).

Thus, for letters and letter combinations to control verbal responding, the effective use of reinforcement is required. (The interested reader should consult Chapter 3, this volume, which outlines procedures for arranging effective reinforcement contingencies.) The conceptual kinship between the behavior analyst's perspective and the code-emphasis instructional approach that is so well supported by the reading research reviewed earlier (e.g., Linan-Thompson & Vaughn, 2010) should be clear.

As the learner becomes an increasingly proficient reader, several natural sources of reinforcement can be derived from reading. For example, the history buff may get a job teaching history and thereby be at his or her leisure to pursue a passion with like-minded history enthusiasts. Reading may also allow the reader to avoid or escape an aversive situation, as when a teenager receives and reacts to a text message from a sibling to stay out of the way of their father, who is in a bad mood. Before natural sources of reinforcement such as these can control the probability of reading, the teacher must explicitly program contingencies to build appropriate reading responses.

In describing textual behavior as a form of verbal operant, B. F. Skinner (1957) was referring only to reading text, not to comprehending it. Although a complete account of comprehension and meaning is beyond the scope of this chapter, we briefly examine how text influences the reader's behavior beyond giving a textual response to illustrate some of the other basic functional relations that are developed. Textual behavior (i.e., uttering a vocal or subvocal response) is the most conspicuous form of reading. Textual stimuli, however, do more than simply occasion a vocal or subvocal utterance. Textual stimuli must control other verbal (i.e., responses that do not share point-to-point correspondence with the text) and nonverbal response classes before comprehension is said to occur. Additional verbal operants come in to play at this point. A text may tell the reader what to do (referred to as a *mand*). When the mand produces the appropriate form of behavior in the reader, one infers that the reader has understood the text, such as when a bank teller reads a withdrawal slip and gives the customer money from his or her account. A text may describe a state of affairs (referred to as a *tact*), such as when a book recounts the dates of a particular historical event. The history buff who reads a book is said to have understood the text if he or she can describe both the event and the date correctly. A text may occasion a nonechoic, intraverbal response from a reader. An *intraverbal response* is a response that lacks point-to-point correspondence but is functionally related to the speaker's utterance. For example, a posting on a blogger's website criticizing his or her political views may evoke a response from the blogger that gives further justification for a previously described position. The blogger's response is not just a repetition of the previous response; rather, it is an elaboration of the previous response that shares properties with the original posting. Another characteristic of verbal behavior is that one stimulus often exerts multiple control (Cooper et al., 2007; Michael, 2004). Therefore, effective reading instruction will establish textual stimuli's effectiveness in occasioning both textual (i.e., vocal or covert) responses conjointly with verbal responses (i.e., intraverbal), nonverbal responses (i.e., reaction to a mand), or both. In other words, for the proficient reader, textual stimuli occasion no fewer than two operant responses—a discriminated vocal (or covert) operant response and at least one other form of either nonverbal response (e.g., following a recipe) or verbal response that lacks both point-to-point correspondence and formal similarities but that is judged to be appropriate to the circumstances (e.g., being asked to give a good title for a story after just reading it). When the vocal response displays point-to-point correspondence with the textual arrangement of letters, spaces, and punctuation, and it also evokes one or more responses that are suitable to the functional properties of the text (e.g., the student gives a correct answer on a test; an adult correctly builds a toy from instructions as a gift for a child; the history buff describes historical conditions that permitted Napoleon Bonaparte to become emperor), then comprehension is said to have occurred. Essentially, the text has influenced the reader's behavior in multiple ways.

Along with being the purpose of reading, comprehension is the highest and most sophisticated level of control that text can exert over the reader.

Comprehending text is the result of several coordinated response classes that contribute to behavioral control through text. Unassisted reading comprehension (the ultimate goal of instruction) cannot occur unless more elemental response classes (e.g., segmenting and blending phonemes) are brought under control of the text through differential reinforcement. If the correct forms of stimulus control relative to the text itself are not developed appropriately, then the text will not be able to produce the other verbal operants that put the reader in contact with extratextual sources of reinforcement. The job of the reading teacher is to program the learner's reinforcement history with text to bring the behavior under the control of textual stimuli and ultimately strengthen responding to the point at which reading becomes a high-probability behavior to access other types of reinforcement (e.g., a good lab grade from conducting a chemistry experiment properly). Extensive interpretive analyses of the nontextual verbal and nonverbal operants that are referred to as *comprehension* are presented elsewhere (Catania, 2007; Cooper et al., 2007; B. F. Skinner, 1957; see also Chapter 1, this volume), and we do not discuss them further. In the remainder of this analysis, we examine how teaching establishes functional relations for textual responding.

Applying Principles of Behavior to Teaching Reading Skills

Although applied behavior analysis has a solid conceptual and methodological framework that has proven to be robust across species and spheres of human activity (Catania, 2007), behavior analysts have expended considerably less effort examining the components of effective reading instruction with the type of methodological rigor they have applied to areas such as developmental disabilities, behavior management, and early childhood education, which may have to do with the methodology behavior analysts typically use in their research. Because they are interested in identifying variables that control the behavior of individuals, behavior analysts rely on single-case experimental designs that rule out threats to internal validity by exposing the participant to all stimulus conditions (see Volume 1, Chapter 5, this handbook). This methodology has produced sophisticated forms of behavioral analysis that are generalizable to clinical settings in which treatments can be selected on an individual basis (Barlow, Nock, & Hersen, 2009).

Behavior analysts have successfully operationalized important instructional variables, drawing on principles of behavior derived from years of laboratory research. The variables identified are observable, reproducible, and manipulable. Researchers have devised methods to carefully control stimulus conditions (e.g., reducing content overlap between conditions while ensuring equal difficulty level) so that intrasubject variability across conditions can be mined, inspected, and interpreted. We describe the results in this section in the natural progression of the reading teacher's activities: The reading teacher must (a) select skills to be taught, (b) select appropriate instructional materials, and (c) deliver instruction.

Selecting skills to be taught. Alessi (1987) pointed out that a teacher cannot directly teach all possible stimulus combinations that a learner might encounter in the future. Extending this point to reading, a teacher cannot possibly teach appropriate verbal responses to all letters, letter combinations, and words. Effective instruction efficiently sequences instructional tasks to build strong prerequisite response classes (referred to colloquially as *skills*) that themselves are generalizable within the skill (e.g., after learning to read words with a short *a*, the student may be able to learn to read words with a short *e* more quickly) and to more complex skills (e.g., after learning to phonetically decode, the student's reading fluency may progress more quickly). Effective reading instruction promotes generative responding (Alessi, 1987) in that skills targeted for instruction should contribute to correct responding when faced with novel stimuli. For example, a child who successfully decodes *tab* after having first learned to decode *bat* has generalized responding of the same phonemes (i.e., /*b*/, /*a*/, /*t*/) to a novel combination of those phonemes. Successful discrimination training is used to teach skills that are generalizable within (e.g., other phoneme combinations) and across (e.g., harder skills such as reading text) response classes. Therefore, the selection of skills and the sequence in which they are taught are crucial to the success of reading instruction.

The five components of early literacy presented in Table 16.1 outline a well-established and agreed-on hierarchy of reading skills necessary for the non-reader to become a reader. Lower order skills (e.g., phonemic responding) are significant contributors to the development of proficiency with higher order skills (e.g., phonetic word analysis and reading accuracy and fluency in connected text). As such, strongly established phonemic responding (an irreducible response class for reading) contributes to the strengthening of responding to phonetic regularities of text, which contributes to fluent text reading. The development of fluency allows the mands, tacts, and intraverbals communicated by textual stimuli to influence the reader's behavior, at which point comprehension—the most complex response class—is said to have occurred.

This analysis is not intended to suggest that reading teachers should teach only one thing at a time. The research literature is clear that teachers should work on all five areas concurrently (Linan-Thompson & Vaughn, 2010). The point is that some prerequisite skills make higher order skills (e.g., comprehension) harder if not impossible to develop and that any effective reading program must sequence skill instruction appropriately. For the behavior analyst, this task involves the development of strong curricular and instructional sequences based on an accurate behavioral analysis of relevant response classes (Twyman, Layng, Stikeleather, & Hobbins, 2004). We examine this area in more detail later in the chapter when we discuss behavior-analytic reading programs.

Although plenty of evidence exists that teaching prerequisite reading skills is critical to developing proficiency with higher order reading skills (Adams, 1990; NICHD, 2000; Snow et al., 1998), few studies in the area of reading have directly examined the question of why some response classes may be generative (i.e., helpful for responding to novel reading material). For example, what are the controlling variables that make phoneme segmenting and blending so essential to the development of later reading skills? Behavior analysts have devoted little attention to this issue, but some intriguing data have emerged from studies that have examined the operant mechanisms involved. A study by Daly, Chafouleas, Persampieri, Bonfiglio, and LaFleur (2004) demonstrated experimentally that the size of the textual response (phonemes vs. words) brought under stimulus control affects the degree to which the textual response generalizes to novel words. While controlling for response opportunities, reinforcement frequency and type, and the amount of overlap between phonemes in trained words and phonemes in novel words across conditions, Daly et al. found that responding brought under the control of phonemes produced better reading of novel words than responding brought under the control of words. Learning to read a word without bringing the phonemes under proper stimulus control does not help the reader confronted with a novel word that has similar phonemic or phonetic properties.

Several other studies have found similar results for letters, syllables, and words; after training, participants combined letters, syllables, and words (orally and in print) to form new words that had not been previously taught (Matos, Avanzi, & McIlvane, 2006; Melchiori, De Souza, & De Rose, 2000; Mueller, Olmi, & Saunders, 2000). For example, Matos et al. (2006) found that teaching nonreaders to construct words from syllable blocks in response to printed models and experimenter-dictated words improved their ability to combine syllables to form previously untaught combinations in response to verbal presentation of words, to read novel words, and to demonstrate comprehension of novel words by selecting correct pictures (i.e., correct tacting). Teachers' efforts to establish generative skills enable students to respond to novel and increasingly complex reading demands. Studies such as these demonstrate that the analysis of stimulus control and equivalence class formation at the most minute levels of textual responding may shed light on how best to select and sequence skills taught to maximize generalization of effects to more complex forms of reading.

Selecting appropriate instructional materials. Just as the skill sequence chosen by the teacher influences a student's progress, so too do the materials for instructing reading. Text difficulty level is one salient variable that would appear to affect the appropriateness of instructional materials. Materials that are too hard or too easy may attenuate the potential impact of instruction: Students will not progress at the desired pace after instruction. The role of text difficulty level in the success of reading fluency instruction (one of the five major components of reading instruction discussed earlier) is a topic on which opinions abound (e.g., Howell & Nolet, 1990; Shapiro, 2004) but for which few data have been gathered using rigorous experimental designs. The absence of adequate data substantiating these recommended instructional ranges should cause educators to proceed with caution when consulting them (Binder, 1996). Virtually all recommendations to date have been based on average fluency levels gathered from large samples of behavior (e.g., L. S. Fuchs, Fuchs, Hamlett, Walz, & Germann, 1993). Although these data may be helpful for gauging where a student stands relative to other students on similar passages of similar difficulty level, they do not permit conclusions regarding the degree to which difficulty level may influence instruction for a particular student. For that, one or more analytic studies need to be done (Baer et al., 1968).

Few behavior-analytic studies have directly examined the effects of text difficulty level on students' ability to generalize newly acquired reading skills to noninstructed reading materials. Daly, Martens, Kilmer, and Massie (1996) examined the effects of difficulty level of instructional passages on the oral reading fluency (operationalized as correctly read words per minute) of four elementary-age students with mild disabilities (i.e., learning disability, emotional disability, mild mental retardation) using a single-case, multielement experimental design. Reading fluency instruction consisting of modeling and practice, and error correction was provided at two different difficulty levels: instructional match (easy) and instructional mismatch (difficult). Correctly read words per minute (fluency) and the percentage of correctly read words (accuracy) were measured at each difficulty level in two sets of passages—passages that shared a lot of the same words as those taught previously (i.e., 77%–98% word overlap) and passages that shared few of the same words as those used for instruction (i.e., 18%–46% word overlap). Daly, Martens, et al. found main effects of instructional match and word overlap; they observed higher levels of fluency and accuracy when easier materials were used (instructional match) and when the new materials overlapped more extensively with previously learned words. They also found an interaction between these variables; the effect of word overlap was more pronounced when the instructional materials were easier than when they were more difficult. Daly, Martens, et al. interpreted the results as suggesting that reading accuracy and fluency generalized more from instruction in easier rather than harder materials.

The results of the Daly, Martens, et al. (1996) study point to the potential importance of text difficulty level in mediating instructional effects. The participants in that study, however, displayed poor reading accuracy and fluency in very simple, phonetically regular texts, reading in most cases between 10 and 20 correctly read words per minute, which raises the obvious question of whether text difficulty level has similar effects on fluency and accuracy in students reading at higher difficulty levels. To answer this question, Daly, Bonfiglio, Mattson, Persampieri, and Yates (2005) conducted a similar study with students who read second- and third-grade materials at the rates of 50 and 30 words per minute, respectively. They found that the effects of text difficulty level (easy or hard) on the ability to read novel words (generalization) varied by participant. Two of the participants improved more in the easier texts, and the third improved more in the harder texts. These results suggest that individual analysis of the effects of text difficulty level (as can be accomplished through a single-case experimental analysis of the type conducted in this study) may help to guide educators to select instructional materials that improve generalized oral reading fluency outcomes.

More recently, Martens et al. (2007) selected a small set of instructional texts in which second- and third-grade students could read correctly at a rate of at least 50 words per minute. One group of students completed fluency training with these same texts until they could correctly read 100 words per minute for two consecutive sessions. A matched control group did not complete fluency training, proceeding instead with their regular classroom instruction. In the next phase, both groups were given progressively more difficult texts. Relative to the control group, fluency training students progressed more rapidly to reading texts of greater difficulty for which their reading fluency skills were found to generalize to untrained passages. These fluency training students also demonstrated greater phonological awareness and passage comprehension relative to the control group. Martens et al., therefore, demonstrated that the generalized, positive effects of selecting materials at an appropriate difficulty level may extend to other reading repertoires such as phonological processing and comprehension.

Although the research to date has not clearly pointed to an appropriate reading fluency range for text difficulty level, it should motivate behavior analysts to use their unique research methodology to investigate the role of text difficulty level more carefully as a possible variable influencing the degree to which students benefit from instruction. This research agenda is all the more urgent for students who are struggling to master reading skills. The appropriate standard for determining benefit to the student should be the degree to which he or she can improve reading when presented with novel reading materials or tasks. Questions for future research abound. For example, how much generalization can be expected at different difficulty levels (i.e., fluency ranges) for a skill such as oral reading fluency? Are the ranges normative in that they apply equally to all learners, or are they idiosyncratic, meaning they vary by learner? If the latter is the case, then educators will need ways to investigate those ranges on a case-by-case basis. Finally, how do instructional components such as modeling, practice, error correction, and reinforcement interact with difficulty level? Behavior analysts are in a good position to provide the technology for this type of analysis. Single-case experimental designs are appropriate for investigating questions such as these because they can detect interaction effects within subjects and therefore yield results that are both scientifically relevant and clinically important even when results vary across individuals.

Delivering instruction. Selection of target skills and sequencing of instructional tasks are followed in the natural progression of events by instructional delivery. From a behavior-analytic perspective, teaching reading is a question of programming contingencies of reinforcement to establish functional response classes that allow the individual to ultimately come into contact with extratextual sources of reinforcement in the natural environment. Heward (1994) and others (Greer & McDonough, 1999; C. H. Skinner, Fletcher, & Henington, 1996) have argued for the utility of conceptualizing skill instruction in terms of the three-term contingency of differential reinforcement—the presentation of an antecedent stimulus (the instructional task), behavior (the academic response), and a consequence (reinforcement or corrective feedback), otherwise referred to in educational research as the *learning trial*. Increasing the overall number of complete learning trials has been shown to reduce off-task behavior, improve academic engagement, increase active responding and learning rates, and promote generalization to untaught instructional material (Belfiore, Skinner, & Ferkis, 1995; Greer & McDonough; Heward, 1994; C. H. Skinner et al., 1996). Stimulus control can therefore be useful for explaining how to teach reading. As we show later, instruction can be organized in terms of complete learning trials whose end goal is for student responding to come under the control of the text. (The only caveat to use of the three-term contingency for explanatory purposes is that it does not include the role of antecedent motivational variables that momentarily alter response probability without changing existing contingencies [Michael, 1982], but we use it here to simplify the explanation.)

Although the consequence (reinforcement or corrective feedback) happens last in the learning trial, it is what causes behavior change (Miltenberger, 2008), and therefore it occupies the most important place in the learning trial. A learning trial is not complete without effective consequences. The antecedents to reading (i.e., the text) only become effective at controlling behavior if the consequences produce behavior change. This reason is probably why consequences in the form of positive reinforcement were historically examined first in behavior-analytic reading research. Positive reinforcement has been shown to improve reading comprehension, completion of reading exercises, and sight-word vocabulary as well as reducing disruptive behavior (Ayllon & Roberts, 1974; Lahey & Drabman, 1974; Lahey, McNees, & Brown, 1973). These early studies emphasized conditioned reinforcers such as tokens and money and socially mediated reinforcement such as praise. More recent investigations have examined the effects of performance feedback on oral reading fluency (Eckert, Ardoin, Daly, & Martens, 2002; Eckert, Dunn, & Ardoin, 2006), finding that systematically informing learners of their rate of responding and errors may further improve reading performance. Because reading behavior is responsive to changes in contingencies, the analysis of the effects of positive reinforcement (independent of skill instruction) has become a routine procedure in the technology of brief experimental analysis of academic performance problems (Daly, Hofstadter, Martinez, & Andersen, 2010).

The other type of consequence that has been investigated is error correction. Incorrect responses should be corrected immediately by modeling the correct answer and having the learner practice the correct responses, preferably repeatedly (Worsdell et al., 2005), and, if the error is made during text reading, by having the learner reread the entire phrase, not just the error word (O'Shea, Munson, & O'Shea, 1984). The latter may work by increasing the cost of errors, a cost that may be avoided in the future by reading more carefully.

For the nonreader, the text as instructional antecedent does not yet exert stimulus control over the learner's behavior, meaning simply that the nonreader cannot read the text regardless of how strong the positive consequences for responding may be. To be able to reinforce responding, the teacher must prompt correct responses to the presentation of the text. The instructional hierarchy (Haring & Eaton, 1978) has proven to be a useful heuristic for prompting discriminated responding (Ardoin & Daly, 2007; Martens & Eckert, 2007; Wolery, Bailey, & Sugai, 1988), especially reading (Daly, Lentz, & Boyer, 1996). According to the instructional hierarchy, with effective instruction, skill proficiency progresses as responding first becomes accurate, then fluent, and then generalizes to other settings. The effective teacher maximizes practice time by first targeting accuracy of responding and then building fluency while continuously programming for generalization (Daly, Lentz, & Boyer, 1996). To promote accuracy of responding, the teacher uses modeling (e.g., reading the text to the student before having the student read it aloud) and prompting (e.g., providing a partial prompt, such as the first sound of a word, and having the student then read the entire word) while ensuring that every response is consequated (to ensure continuous reinforcement for correct responding and to correct every error response). When responding is accurate, fluency building is achieved through repeated practice opportunities and reinforcement for increases in rate of responding. As such, the feedback ratio changes from 1:1 to an intermittent schedule because responding is largely accurate when response fluency becomes the goal of instruction. Reinforcing rate of responding can be accomplished through contingent access to preferred stimuli or activities, timed trials, performance feedback, and performance charting (Daly et al., 2007).

The teacher increases the likelihood of generalized reading improvements by building generative skills and bringing responding to fluent levels while strategically using instructional materials that provide multiple and varied response opportunities across stimulus exemplars (i.e., word and text presentation; Daly et al., 2007). Another strategy for promoting generalization is to first have students practice responding in isolation (e.g., reading words with short vowels on flashcards) and then immediately have the student practice responding in the natural stimulus context (e.g., read words with short vowels in books; Grossen & Carnine, 1991). Therefore, judicious sequencing of prompting strategies for carefully sequenced skills, with appropriate instructional materials and reinforcing consequences for behavior, strengthens responding as it goes from nonexistent to fluent across progressively more complex stimulus conditions until the reader can respond to text without any additional assistance. Fortunately, teachers are not left to their own devices to try to coordinate and accomplish all of these tasks. Some strong behavior-analytic reading instruction programs are available that put all the pieces together for the reading teacher.

Behavior-Analytic Reading Instruction Programs: Packaging the Principles, Process, and Materials

On the basis of the behavioral analysis of reading acquisition presented in this chapter, teaching reading involves sequencing the learner's exposure to print (textual stimuli) in a manner that brings the learner's responding under stimulus control of letters (letter names, phonemes), letter combinations (phonetic regularities of textual stimuli), and words. The effective teacher builds stimulus control through differential reinforcement (complemented by the use of response-prompting strategies) and programs reading experiences to produce generalization to novel words and reading in novel settings. The two mechanisms for delivering effective instruction are the design of the curriculum (which guides task content and presentation) and the delivery of instruction as the child responds to curricular texts (during which antecedents and consequences are applied to increase the probability of correct responses to the text).

Howell and Nolet (2000) defined *curriculum* as "a structured set of learning outcomes, or tasks, that educators usually call goals or objectives" (p. 35). They pointed out that whereas instruction defines how to teach, curriculum defines what to teach. Curriculum content should therefore outline the objectives (behavioral repertoires) to be achieved (mastered) by learners. Because the terminal behavior is composed of multiple prerequisite skills, a well-designed curriculum is organized into progressively ordered functional task sequences that prepare the learner for the real world. School districts most often select a commercially available reading program for their core reading curriculum. Commercially available programs specify learner objectives and provide guidance to the teacher (more or less explicitly and more or less well) about what types of instructional tasks to present and how to present them through lesson plans. Two of the most prominent commercially available reading programs based on operant principles of behavior (stimulus control in particular) are Direct Instruction (DI) and Headsprout Early Reading program. We discuss each in turn.

Direct Instruction. DI curriculum materials are designed to provide clear antecedent stimuli and consistent consequences (i.e., differential reinforcement) for student responding in every teaching interaction (Carnine, Silbert, Kame'enui, & Tarver, 2010). The instructional design of the curriculum is guided by six instructional principles: (a) Rules and strategies are explicitly taught, (b) a variety of examples are presented to aid the acquisition of discriminated responding, (c) examples are sequenced to be minimally different from each other, (d) response prompts are systematically faded, (e) students are taught to apply learned rules to novel skills (teaching general case strategies), and (f) correction procedures are used after incorrect responses (Gersten, Carnine, & White, 1984). Teaching includes rapid pacing, use of signals for how and when to respond, and small-group instruction to encourage group participation and increase student engagement. Another important component of DI programs is the emphasis on continuously measuring student performance and progress to determine whether students have mastered skills or whether more practice is needed before moving on (Gersten et al., 1984).

In studies comparing curricular reading programs, DI reading (i.e., the published curricula developed by Engelmann and associates) is consistently superior to other published core reading programs (Adams & Carnine, 2003). The effectiveness of DI was first demonstrated in a large, longitudinal study conducted in the 1970s by the U.S. Department of Education and referred to as *Project Follow Through*. The government commissioned various groups to examine the impact of different instructional programs (e.g., DI, open classroom models, Piagetian-derived approaches, discovery learning, and other non-DI behavioral models) on student outcomes, particularly those of low-income and minority students (Gersten et al., 1984). DI produced superior outcomes on standardized tests of reading and math by the end of third grade, and the independent evaluator reported that students participating in the DI program had, on average, caught up to their middle-class peers (Gersten et al., 1984). Despite the federal government's spending millions of dollars on Project Follow Through and the seemingly clear implications of its findings, DI was not widely adopted by the public schools (Grossen, 1995).

The evidence base for DI reading programs (e.g., Reading Mastery, Corrective Reading) has continued to grow and consistently demonstrated positive effects for students. Adams and Carnine (2003) conducted a meta-analysis of 17 studies that investigated the effects of DI for students with learning disabilities. They found an average effect size of .81 for reading (i.e., decoding and comprehension), meaning that the average student receiving DI scored .81 standard deviation above the control group mean after instruction—a large and educationally significant effect (Cohen, 1988). The results of two randomized controlled trials published after the Adams and Carnine meta-analysis provided further support for DI, particularly for students with limited English proficiency. In these studies, students receiving instruction in a supplemental DI program scored significantly higher on several measures, including word attack (i.e., sounding out phonetically regular words), passage comprehension, and oral reading fluency, than students receiving no supplemental program (Gunn, Smolkowski, Biglan, & Black, 2002) or a typical supplemental literacy program (Kamps et al., 2007).

Reading Mastery has fared well in comparison with other commonly implemented core programs when used for regular classroom instruction. Coyne-Crowe, McDonald-Connor, and Petscher (2009) examined the effect of six core reading programs (i.e., Reading Mastery, Open Court, Harcourt, Houghton Mifflin, Scott Foresman, and Success for All, all of which emphasize the code-emphasis approach) on oral reading fluency of almost 30,000 first-, second-, and third-grade students. In first and third grade, students receiving instruction in Reading Mastery demonstrated significantly greater growth in reading fluency than students in any of the other programs. In second grade, Success for All results matched the Reading Mastery results, and both exceeded the results of the other four programs. More students in Reading Mastery also met or exceeded achievement benchmarks throughout the year than students in the other programs. The defining features of Reading Mastery and other DI programs are the careful sequencing of skills, explicitness of instruction, and focus on mastery of content as a basis for student progression through the curriculum, which may be the reason for Reading Mastery's success relative to other curricular programs. In addition, DI is based on synthetic phonics (i.e., teaching letter–sound correspondence and then blending), which is superior to other types of phonics instruction such as embedded phonics, which places greater emphasis on comprehension and less explicit emphasis on teaching decoding (NICHD, 2000). These features are particularly important because many students lack the prerequisite phonemic awareness, language, and vocabulary skills on school entry (Foorman et al., 2006; Snow et al., 1998; Torgesen et al., 2001).

Headsprout. Behaviorally based reading instruction is available (for a fee) over the Internet through the Headsprout Early Reading program (available at http://www.headsprout.com), an individualized reading program delivered in an engaging format for children ages 4 to 7. (A comprehension program also exists for children age 7 and older.) Lessons are typically completed in approximately 20 minutes and are appropriate for children who can pass an initial tutorial that introduces the types of activities children will encounter and the skills necessary to navigate the program (i.e., use of a computer mouse, basic understanding of concepts such as "first," "next," and "not"; Florida Center for Reading Research, 2006; Twyman et al., 2004). Made up of two 40-lesson reading programs, Headsprout Early Reading teaches decoding (starting with phonological awareness, which encompasses simple sound manipulations in words such as rhyming and alliteration all the way up to more complex phonemic awareness skills of blending and segmenting sounds in words) and beginning comprehension through the Reading Basics program (Lessons 1–40). Reading fluency and comprehension are taught through the Reading Independence program (Lessons 41–80). Headsprout has deep roots in the precision teaching tradition and is based on principles of curriculum design that have been implemented and refined at Morningside Academy (Johnson & Layng, 1992).

Headsprout was developed through an intentional instructional design process (Twyman et al., 2004). First, the developers performed a content analysis (based on the five areas of early literacy shown in Table 16.1), which provided a clear statement of the objectives of each training module. The next steps involved determining the criterion tests, developing curricular materials that established prerequisite skills, building the instructional sequence, using performance data for adjustments to the curricular materials and sequence, and developing effective consequences that would maintain learner performances. Development was nonlinear and is ongoing because refinements continue to be made on the basis of data collected from online learner responses. Because results are measured continuously and uploaded to Headsprout's server for analysis, program development and refinements are based on data from thousands of children. Twyman et al. (2004) stated, "Headsprout used data from more than 30 million responses, across more than 10,000 learners, in a scientific approach to the design of its early reading program" (p. 56). In other words, the recording of every response of every child who goes through the program creates a vast database for program revision and improvement. Learner performance is measured in terms of accuracy, fluency, and error patterns, which allow the program creators to conduct systemic analyses of instructional sequences and other program components.

Four basic principles guide selection and delivery of instructional sequences (Layng, Twyman, & Stikeleather, 2004). First, tasks are selected so as to keep errors to a minimum from the very beginning of the program. Second, mastery criteria are used to ensure that the learner has achieved skill mastery (i.e., appropriate behavioral frequencies) before new instructional tasks are introduced. Third, guided practice using modeling, feedback, and error correction drives the instructional lesson. Finally, cumulative review of previous content and application of skills to new instructional tasks are used to promote generalized responding. Layng et al. (2004) presented data from large samples demonstrating that (a) response opportunities are very high (based on the number of instructional items presented), (b) correct responses are also high (based on the number of learner responses), and (c) error rates (also based on the number of learner responses) are low throughout the lessons.

Layng et al. (2004) reported the results of several preliminary studies of the Headsprout curriculum. In field trials of the curriculum, a preschool sample of 20 children improved by one grade-equivalent unit after forty 20-minute lessons, and the percentage of students meeting or exceeding grade-level performance on a criterion-referenced developmental test in an elementary school more than doubled after completion of Headsprout lessons. Similarly, Clarfield and Stoner (2005) found improved oral reading fluency after implementation of Headsprout for three students with attention deficit/hyperactivity disorder. The students demonstrated higher mean levels of oral reading fluency (15 more words correct per minute than at baseline; range = 12–19) and accelerated weekly growth (1.86 more words per week than at baseline; range = 0.77–3.29) during Headsprout instruction than during typical classroom instruction. In addition, student off-task behavior decreased from a mean of 33% during typical classroom instruction to a mean of 4% during Headsprout instruction. The What Works Clearinghouse (http://ies.ed.gov/ncee/wwc) described the available database on Headsprout as small. One study (Huffstetter, 2005) met the What Works Clearinghouse criteria for evidence standards. The What Works Clearinghouse reported that Huffstetter (2005) demonstrated that Headsprout has potentially positive effects for oral language and print knowledge. The clearinghouse report cited several other studies of Headsprout but gave several reasons why they did not meet the What Works Clearinghouse standards for review or standards for experimental design. These findings are encouraging; however, additional research, preferably using randomized assignment to treatment and control conditions, is needed to further examine the program's effectiveness and efficacy.

CONCLUSION

Behavior analysts interested in teaching reading share the world's goal of teaching students to love to read. However, reading itself is probably not what the reader falls in love with. Rather, reading is more likely to be a high-probability activity if it allows the reader to contact extratextual sources of reinforcement. If the reading teacher has done his or her job, the reader is blissfully ignorant of the significant effort that has been made to carefully program reinforcement contingencies and reading opportunities and can enjoy the benefits of reading. Educational research has described effective reading instruction as a process of explicit, flexible, responsive, and differentiated instruction in the five critical areas of literacy (Table 16.1). In this chapter, we demonstrated how principles of operant behavior can be used to design effective teaching of reading in line with an abundance of reading research (both within and outside of the tradition of applied behavior analysis) to produce strong learner outcomes. Stimulus control and differential reinforcement are at the heart of this process. The teacher adds response prompts and careful selection of reading tasks to differential reinforcement to bring about generalized reading improvements across increasingly complex textual repertoires that prepare learners to understand and act on text on their own, making it an independent and highly useful skill for readers.

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CHAPTER 17

SLEEP: A BEHAVIORAL ACCOUNT

Neville M. Blampied and Richard R. Bootzin

Sleep, the innocent sleep,
Sleep that knits up the ravell'd sleeve of care,
The death of each day's life, sore labour's bath
Balm of hurt minds, great Nature's second course,
Chief nourisher in Life's feast.
—William Shakespeare, *The Tragedy of Macbeth*, Act II, Scene 2

Sleep is at once ubiquitous, necessary, familiar, and mysterious. Almost all animal species sleep, and all humans certainly do. Sleep appears to be necessary for optimum functioning and well-being, but its fundamental biological and psychological role is unclear (Siegel, 2005). Reflecting this, sleep is studied by many sciences, including molecular biology, genetics, physiology, biochemistry, pharmacology, neuroscience, ecology, evolutionary biology, anthropology, and the health sciences (e.g., Franken, Kopp, Landolt, & Lüthi, 2009; McKenna, Ball, & Gettler, 2007; Vassalli & Dijk, 2009) as well as psychology. In this chapter, we provide a perspective from the science of behavior analysis. We discuss the development and regulation of sleep and common problems of sleep over the life span from a behavioral perspective. Chronic night waking is the most common sleep problem in infancy, and insomnia, the inability to regularly obtain sleep of sufficient frequency, duration, and quality, is the most common sleep problem among adult humans (Mahowald & Schenck, 2005); these are the focus of this chapter. We draw on Bijou (1993) for a general behavior-analytic perspective on human development, emphasizing development as "progressive changes in interactions between the behavior of an individual and the people, objects, and events in the environment" (p. 12).

SLEEP—A BEHAVIOR OR A STATE?

A key question to ask at the outset is, "Is sleep a behavior?" B. F. Skinner (1953, p. 155) argued that it is, saying, "We may conveniently regard sleep as a special form of behavior." Although what exactly Skinner meant by *special* is unclear, it seems unlikely that he regarded sleep as falling outside the operant or Pavlovian behavior categories. If sleep does belong to one or both of these categories, however, then it must have properties consistent with class membership, including, in the Pavlovian case, being elicited by some specific unconditioned stimulus and, in the case of operant behavior, being strengthened by reinforcing consequences. Despite much investigation, however, neither general nor species-typical environmental unconditioned stimuli for eliciting sleep, nor reinforcers for maintaining and strengthening sleep, have been discovered (Blampied & France, 1993).

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Indeed, if such knowledge were available, then the problem of insomnia would likely have long since been solved.

The Sleep State

Rather than viewing sleep as a behavior, viewing it as a biobehavioral state is more constructive (Blumberg & Lucas, 1996; Thoman, 1990). This state provides a context in which a wide range of biological, behavioral, and psychological processes and variables are organized and modulated. As is the case with other biobehavioral states (e.g., being alert, being pregnant), behavior is involved in the transition into the state, the maintenance of the state, and the termination of the state, but the state itself is not a behavior. What is particularly distinctive about sleep, relative to most other states of the organism, is that it is associated with a major reduction in the range and intensity of overt behavior associated with the state because of strong inhibition of motor activity by the brain. The covert activities during sleep, including cognitive processes and dreaming, along with other evidence of intense neural activity and metabolism, testify to sleep's being an active state of the central nervous system, seemingly important for the growth, nurture, and maintenance of the brain, and these functions continue to stimulate much interest (Blumberg & Lucas, 1996; Hobson, 2005; Nielsen & Stenstrom, 2005; Stickgold, 2005) while continuing to defy full elucidation.

Humans, in common with all other mammals (except cetaceans; Siegel, 2005) and most other animals, cycle regularly between states of wakefulness and sleep (Fort, Bassetti, & Luppi, 2009). This cycle is a circadian rhythm (Dibner, Schibler, & Albrecht, 2010), entrained by the light–dark, day–night cycle of the environment (Turek, 1998) and modulated by other influences (Saper, Scammell, & Lu, 2005), including drugs (Boutrel & Koob, 2004). These rhythms depend on the expression of "clock genes" in many tissues, coordinated by activity in the suprachiasmatic nucleus of the hypothalamus (Franken & Dijk, 2009; Shaw & Franken, 2003). The entrainment of the circadian rhythm depends both on neural input from the retina and on the hormone melatonin, which is secreted by the pineal gland (Cassone & Natesan, 1997; Zee & Manthena, 2007). Individual variation in aspects of sleep, such as preferred duration and chronotype—whether an individual wakes early ("morningness" or "larks") or goes to sleep late ("eveningness" or "owls"; Taillard, Philip, & Bioulac, 1999)—may be related, in part, to specific clock-gene genotypes (Franken & Dijk, 2009).

Resonating with this circadian sleep–wake cycle is a second, homeostatic motivational process called *sleep pressure* (Borbély, 1998; Borbély & Achermann, 1992). Sleep pressure increases during periods of wakefulness and decreases with the duration and quality of the subsequent sleep episode, and it can be measured using the Multiple Sleep Latency Test (Carskadon & Dement, 1987; Wise, 2006). Sleep pressure may accumulate over time, given intervening episodes of brief or poor-quality sleep, and may also be related to the intensity of activity in the waking period. As sleep pressure increases, the propensity to enter sleep increases, but it can be inhibited or facilitated depending on the phase of the circadian cycle and other features of the environment. Prolonged sleep deprivation induces high levels of sleep pressure that leads to deterioration in performance and intrusions (called *microsleeps*) of sleep episodes of increasing frequency and duration into the waking phase. These have potentially severe consequences for the individual and others if they interrupt complex performances, such as driving a vehicle (Åkerstedt, 1998; Gander, Marshall, Harris, & Reid, 2005; Philip & Åkerstedt, 2006).

Episodes of sleep are further divided into cyclic phases, distinguished by gross patterns in the brain's electrical activity. One of these phases, *non–rapid eye movement* (NREM) sleep, is itself divided into subphases, of which slow-wave sleep, characterized by high-amplitude, low-frequency oscillations in brain waves and relaxed muscle tone, is the deepest (Borbély, 1982; see Vassalli & Dijk, 2009, Table 2). The NREM sleep state is usually the stage entered first in a sleep episode. Rapid eye movement (REM) sleep episodes then interrupt NREM sleep, and during REM sleep, brain activity is characterized by low-amplitude, fast activity not unlike that observed during waking, associated with profound muscle relaxation and rapid eye movements beneath closed eyelids (Blumberg & Lucas, 1996; Vassalli & Dijk, 2009). The NREM and REM sleep states have separate regulatory circuits in the brain (Vassalli & Dijk, 2009), and both are subject to separate homeostasis. For NREM sleep, the latency to enter the sleep state, the duration of the first episode, and the amount and intensity of slow-wave sleep are strongly influenced by sleep pressure. In contrast, REM sleep seems to be homeostatically regulated by the amount of prior REM, so that deprivation of REM sleep will be followed by REM rebound, with increased frequency and duration of REM sleep in subsequent sleep periods (Borbély, 1982).

Behavior Analysis and Sleep

Given this view of sleep as a state, not a behavior, how may it be viewed from a behavior-analytic perspective? A behavioral perspective must respect the knowledge of the neurobiology of sleep but extend the analysis to use the concepts of behavior analysis, with a particular focus on the contexts, behavior, and interactions occurring in the lead up to, and at the transition into, the state. Sleep may be defined behaviorally, independent of knowledge of its neurophysiology, using these criteria: Sleep frequently requires the individual moving to and remaining in a species-typical, and often an individual-typical, location. Before and during sleep, the individual normally adopts a species-typical posture and is inactive. The sleep state is one of behavioral quietude, during which arousal thresholds are elevated. Motivation to enter the sleep state is a function of the duration and quality of prior sleep and generally increases with time since awakening. Sleep duration and arousal thresholds diminish with sleep, and both rebound after sleep deprivation (see Vassalli & Dijk, 2009).

In what follows, we first outline the general framework of a behavior analysis of sleep and then consider how it has been applied to sleep in infants and in adults. The key starting point for this analysis was provided by Bootzin (1977), who wrote,

> Falling asleep is conceptualized as an instrumental act [i.e., it is not a reflex response] emitted to produce reinforcement (i.e., sleep). Thus, stimuli associated with sleep become discriminative stimuli for the occurrence of reinforcement. Difficulty in falling asleep, then, may be due to inadequate stimulus control. (p. 29)

This concept was elaborated by Blampied and France (1993; see also France & Blampied, 1999; France, Blampied, & Henderson, 2003) to consider behavioral quietude, especially when associated with typical sleep postures (Boynton & Goodenough, 1930), as a consummatory response at the end of a behavioral chain. Consummatory responding is behavior (e.g., eating a piece of food, playing a game) through which a reinforcer is consumed or enjoyed, an idea that is consistent with Premack's (1959) principle that reinforcers are fundamentally activities, not objects. This sleep consummatory response permits a transition into sleep, with this transition into the sleep state being a primary reinforcer of the behavior that preceded it.

Sleep pressure may be viewed as representing the organism's motivational state with respect to sleep, and variables affecting sleep pressure, especially sleep deprivation, are motivating operations—in particular, establishing operations (Michael, 1982, 2000) that increase both the effectiveness of an event as a reinforcer and the current frequency of all behavior with a history of reinforcement by that event. Sleep itself, if of sufficient depth and duration, is an abolishing operation (i.e., resembling satiation), reducing the value of sleep as a reinforcing event.

If the behavior leading to quietude and sleep initiation—the sleep preparation and initiation sequence—is thought of as a behavioral chain, then the sequence of behavior will be under the control of discriminative stimuli (S^Ds), with each S^D in the sequence serving to set the occasion for the next behavior while acting as a conditioned reinforcer for the prior response (Cooper, Heron, & Heward, 2007, p. 435; Fantino & Romanowich, 2007). A clinically useful metaphor to describe this is to liken it to the glide path, with its various navigational signals, that a plane must follow to safely reach the runway. As Bootzin (1977) noted, sleep difficulties may arise because appropriate S^Ds have never been established with sufficient strength or reliability to ensure that the sleep preparation and initiation sequence is regularly or reliably completed.

More important, these S^Ds may be exteroceptive (in the external environment), proprioceptive (arising from the position of the body), and interoceptive (arising from internal organs; Thompson, 2007). In addition to other possible discriminative functions, interoceptive stimuli are potentially available to be recognized as sleepiness or tiredness and may become the basis of tacts (i.e., verbal responses under the control of nonverbal stimuli; Skinner, 1957, pp. 81–82) such as "I am tired." As are other verbally expressed discriminations, these tacts are learned socially through interactions within each individual's verbal community (Skinner, 1963). Because the relevant antecedent stimuli include private events (i.e., interoceptive S^Ds), establishing consistent and accurate discrimination of them is more difficult (Skinner, 1957, 1963), which may lead to variability in discriminative performance across time for any one person and between different individuals, all factors potentially contributing to the failure to develop appropriate S^Ds for sleep (Bootzin, 1977). Nevertheless, learning to accurately discriminate these S^Ds may be very important to achieving good sleep, for instance, by guiding timely choice of sleep-facilitating environments, while also permitting people to communicate with others about their need for sleep (Bijou, 1993).

Moreover, a particular property of the sleep preparation and initiation behavior chain is that it requires the reduction of behavior until the state of behavioral quietude is attained and maintained for a sufficient duration, typically several minutes. The chain is, therefore, vulnerable to disruption by any S^Ds and associated behavior that interfere with this progression into quietude. To extend the aeronautical metaphor, it is easy to get off course by following other stimuli. Thus, in addition to the direct failure to establish appropriate S^Ds, a second source of sleep difficulties may also arise because of the existence of repertoires of, and S^Ds and reinforcers for, activities that disrupt the chain and interfere with sleep initiation (Blampied & France, 1993; Bootzin, 1977; Bootzin & Nicassio, 1978). Furthermore, although the sleep initiation chain has only one reinforcer (sleep), many reinforcers, both positive and negative, may be available to maintain competing repertoires, sometimes with highly salient S^Ds (e.g., a bedroom may contain a bed, a computer with Internet access, a widescreen television; see Adam, Snell, & Pendry, 2007; Van den Bulck, 2007).

Because all behavior occurs in a context of choice (Herrnstein, 1970), the relative value of the concurrently available reinforcers will determine choice among them, with reinforcer value being a function of the quality, quantity, frequency, delay, and other properties of the reinforcing event (Davison & McCarthy, 1988). Conceptually, therefore, sleep initiation is the terminal link of one of two or more concurrent chains of behavior, in which the likelihood of falling asleep is a joint function of both the probability that the sleep initiation chain is chosen and the reliability with which the sleep initiation chain, once chosen, is completed and reinforced by sleep. Basic choice research (see Volume 1, Chapter 14, this handbook), especially that relating to concurrent chains, has suggested that the variables controlling the choice of any chain may be different from the variables controlling the completion of the chosen chain, with choice being a function of the relative value of the terminal reinforcers (of which sleep is one), whereas completion of the chain is influenced by the availability of both conditioned and primary reinforcers (Fantino & Romanowich, 2007). The immediacy of the reinforcers accessed within the chain may exert a strong influence on choice, making the choice of the chain leading to sleep particularly vulnerable to disruption by more immediately accessible reinforcers available for other choices.

Although not hitherto expressly incorporated in these behavioral models, acknowledging that a transition into sleep may also be negatively reinforcing is important, in that it permits escape from or avoidance of aversive events. Babies will fall asleep to escape from intense stimulation, and children and adults will sleep to escape discomfort, distress, and pain (Maurer & Maurer, 1998). Sleep may also be a way of avoiding social demands imposed by others (e.g., demands for work, recreation, conversation, sex).

The role of Pavlovian conditioning in these models is also underdeveloped because the conceptual models have to date focused on the chains of operant behavior and associated S^Ds that facilitate or impair sleep. Yet Pavlovian behavior does play a part. The neural and endocrine events that coordinate sleep onset and maintenance are potentially conditionable responses (Exton, Bull, King, & Husband, 1995; Pawlyk, Jha, Brennan, Morrison, & Ross, 2005) via Pavlovian conditioning, and their elicitation by exteroceptive, proprioceptive, and interoceptive conditioned stimuli (CSs) may well facilitate sleep initiation and maintenance (Evans & Bond, 1969; Poser, Fenton, & Scotton, 1965) and contribute to the quality and the duration of sleep episodes, as suggested by Ferber (1985). Models of insomnia have emphasized the role that chronic, implicitly conditioned arousal plays in interfering with sleep onset and maintenance (e.g., Riemann, Kloepfer, & Berger, 2009), making Pavlovian processes of great importance.

MEASUREMENT OF SLEEP, FUNCTIONAL ANALYSIS, AND THE DIAGNOSIS OF SLEEP PROBLEMS

Techniques for the measurement of sleep include direct physiological measurements, direct nonphysiological observation and measurement, measurements by way of logs or diary records, and questionnaires. In this section, we briefly review these types of measures and also briefly consider functional analysis and existing diagnostic schemes relating to sleep problems. Note that Bootzin and Engle-Friedman (1981); Buysse, Ancoli-Israel, Edinger, Lichstein, and Morin (2006); Currie (2006); and Morin and Edinger (2003) comprehensively discussed sleep assessment and diagnosis; discussions specifically regarding children and adolescents, adult insomnia, and older adults can be found in Wickwire, Roland, Elkin, and Schumacher (2008); Taylor, McCrae, Gehrman, Dautovich, and Lichstein (2008); and Ancoli-Israel, Pat-Horencyzk, and Martin (1998), respectively.

Polysomnography

The event that had the greatest impact on sleep science was the development of the electroencephalograph, a system of scalp electrodes, amplifiers, and chart recorders that permitted the continuous recording of brain electrical activity, and its pioneering use since the 1930s by Kleitman and others to study sleep (Stepanski, 2003). The electroencephalograph continues to be a major direct physiological measure of sleep state. In polysomnography (PSG), electroencephalograph measures are supplemented by an array of other physiological measures, typically including eye movements (to detect REM-associated eye movement); other muscle activity, often that of the jaw and the legs (to monitor depth of relaxation and periodic limb movements); heart rate; blood oxygenation via peripheral pulse oximetry; and respiration (via nasal and oral airflow and chest movements). Measures of blood oxygen and respiration are used particularly in diagnosing obstructive sleep apnea, a common condition in which recurrent airway collapse during sleep causes cessation of inspiration and build up of carbon dioxide in the blood, necessitating arousal from sleep for breathing to be reinitiated. Chronic sleep apnea leads to severe fragmentation of sleep and chronic fatigue, along with numerous other detrimental impacts on health and well-being (Moyer, Sonnad, Garetz, Helman, & Chervin, 2001).

Because of its technical requirements, PSG is often carried out in specialized clinics and generally requires the client to sleep overnight for at least one night under the supervision of a sleep technician. The PSG records are then analyzed to report information about the sleep episode, including sleep onset and wake times, sleep efficiency (total minutes asleep divided by total minutes in bed × 100), time spent in each sleep stage, number and time of any arousals, and information about respiration, oxygen saturation, cardiac activity, leg movements, and body position during sleep (Griebel & Moyer, 2006; Kryger, Roth, & Dement, 2005). PSG may be difficult to use with individuals, especially children (e.g., those with autism or hyperactivity), who have difficulty tolerating the electrodes, and the sleep experienced in the unfamiliar laboratory situation may not closely resemble typical sleep for at least some individuals. Technical developments permitting PSG to be carried out at home in a familiar environment have considerably mitigated these problems (Buysse et al., 2006).

PSG is regarded as the gold standard for the description and diagnosis of sleep problems, but its technical complexity and cost have also led to the development of several other objective measures of sleep. PSG has been used to validate these alternatives, at least during their development (Acebo, 2006).

Actigraphy

Actigraphy refers generally to the continuous recording of activity (Tryon, 1991) and specifically to the measurement of bodily activity during sleep (Sadeh & Acebo, 2002), with the activity being detected and recorded by small, wristwatch-sized devices, usually worn on the wrist or ankle, that detect movements of the wearer and store them for later downloading and computer analysis. A variety of actigraphs are commercially available, and each requires a specific computer algorithm to decode and analyze its output. Unfortunately, agreement between different models of actigraph may be low (Acebo, 2006). Modern actigraphs may also record levels of illumination to distinguish night and day recordings, and the user may also input information about bedtimes and wake times and so forth. Many nights' data can be stored before a download is required.

Depending on the particular software used, the actigraph may report graphs of activity level, often minute by minute across each night, and the raw information (along with information obtained separately on bed and wake times) can be used to measure sleep onset and duration, percentage of active sleep (regarded as a measure of REM sleep), percentage of quiet sleep (NREM sleep), number of state transitions, longest sleep interval, and percentage of time awake, and other aggregate measures may also be extracted. In direct laboratory comparisons of actigraphy and PSG, with normal sleepers rather than with people with insomnia, correlations between methods for measures such as sleep efficiency were typically more than .8, whereas within-participant test–retest reliability over 5 nights has been described as adequate (Sadeh & Acebo, 2002).

The actigraph is relatively light, unobtrusive, and nonrestricting and can be used over many nights without requiring recharging or data downloads and across a wide age range (Cole, Kripke, Gruen, Mullaney, & Gillin, 1992; Sadeh, Acebo, Seifer, Aytur, & Carskadon, 1995). Nevertheless, despite its convenience, the technique has limitations, especially in normal, clinical use in home settings, the most significant of which is that it necessitates the inferring of sleep state from activity, and activity can be low or zero without the individual necessarily being asleep. The quiet wakefulness of insomnia is easily mistaken for sleep, leading to overestimation of sleep duration. Equally, a child asleep while being driven in a car may be reported as awake because of vehicle movement. Users are recommended to also keep daily diary logs for comparison against actigraph records (Sadeh & Acebo, 2002; So, Adamson, & Horne, 2007). Actigraphy is especially useful in identifying difficulties in sleeping and waking in synchrony with normal circadian rhythm, but it is somewhat less accurate in assessing problems in falling asleep (sleep onset latency, or SOL; Buysse et al., 2006; Sadeh & Acebo, 2002). For these reasons, questions continue to be asked about the use of actigraphy in sleep research generally, and particularly in the assessment of insomnia, but its use in clinical intervention studies is generally endorsed, although caution is required if clients also have neurological or movement disorders (Sadeh & Acebo, 2002). Most commercially available actigraphs also do not record sleep-relevant events other than activity, which is also a limitation.

Videosomnography

The use of videorecording (now called *videosomnography*) to study sleep was pioneered by Anders and Sostek (1976) in investigations of infant sleep. It has been used mostly with infants and children, perhaps because privacy concerns limit its acceptability at older ages. The technique has benefited greatly from technical advances, especially in the development of very small video cameras that are able to produce high-resolution video even in low-light conditions and in digital recording. The equipment is now relatively unobtrusive and portable and can be left in place in homes and bedrooms for many nights. Digital videosomnography files can now be retrieved via the Internet if desired.

Typically, the recording is viewed time compressed (i.e., viewed at a faster speed than recorded), so that time spent coding the record is reduced, but no automatic algorithm is yet available to obviate manual scoring by trained coders. Various scoring systems can be used to derive measures of sleep such as time spent in bed, time in active–REM and quiet–NREM sleep, time awake, and so forth (Fuller, Wenner, & Blackburn, 1978), and interobserver agreement is generally high, as is agreement with PSG (Anders & Sostek, 1976; Fuller et al., 1978). An audio channel is also available, and vocalizations, along with gestures, other activities, and parental or sibling interactions can all be detected and coded. Videosomnography has advantages over all other systems in the range of data it gathers in the natural sleep environment (Sitnick, Goodin-Jones, & Anders, 2008). Researchers have exploited these advantages not only to study sleep states but also to check the reliability of other measures, including diaries (e.g., France & Blampied, 2005; Henderson, France, Owens, & Blampied, 2010), actigraphy (e.g., Sitnick et al., 2008), the compliance of parents with treatment instructions, and any generalization of self-soothing (i.e., the capacity to return to sleep without parental assistance) across the night (e.g., Healey, France, & Blampied, 2009).

Sleep Diaries and Questionnaires

Sleep diaries or sleep logs are almost universally used, even when other types of recordings are made. Diaries may be kept by the sleeper (in the case of older children, adolescents, and adults), by others (parents or caregivers in the case of infants; bed partners in the case of adults), or both. For examples of diaries or logs, see Ancoli-Israel et al. (1998); Bootzin, Engle-Friedman, and Hazelwood (1983); or Currie (2006) for an adult diary and Wickwire et al. (2008) for a child diary. Prospective sleep diaries may be kept daily for as long as 2 weeks or more to establish baseline patterns of sleep and then continued during treatment and follow-up.

Parents' diaries of their child's sleep have been assessed for accuracy in several ways: against VSG (as noted earlier), against sound and motion detectors adjacent to the child's bed (France & Hudson, 1990; Lawton, France, & Blampied, 1991), and against telephone checks by the researcher and records kept by a spouse or friend (France & Hudson, 1990), and their reliability is generally found to be high and not inferior to parent records of other child behavior (Blampied & France, 1993; Henderson et al., 2010). For adults, self-monitoring has been compared with PSG and has consistently been found to overestimate time to fall asleep (SOL) by an average of 30 minutes and to underestimate total sleep time by an average of 40 minutes (Currie, 2006). Accuracy of self-report is positively reactive to reliability assessment, at least when clients are warned that their self-monitoring will be compared against actigraphy (Carney, Lajos, & Waters, 2004).

Diaries are used to quantify several measures of sleep. For both adults and children, investigators will determine the SOL, total time spent awake (wake after sleep onset), and total sleep time each night, from which sleep efficiency (defined as for PSG; see Polysomnography section) can be calculated. Adults may also rate their subjective satisfaction with their sleep, usually on a Likert scale (Currie, 2006). Infant sleep diaries can be used to quantify the frequency and quality of parent attentive and nurturant responses (as measures of potential reinforcers for night waking and of compliance with therapy instructions; e.g., Healey et al., 2009) and can also be quantified by using the Sleep Behavior Scale (France & Hudson, 1990; Richman, 1981), a measure that can be used to give a weekly composite score and to classify participating children as being in the clinical or nonclinical range for sleep disturbance (e.g., France, Blampied, & Wilkinson, 1999).

For the further assessment of adult sleep, many scales can be used to assess aspects of sleep, along with any of numerous psychometric instruments for the measurement of psychopathology and individual differences. Given that insomnia is often associated with other conditions (Harvey, 2008), broad assessment is recommended in both research and clinical settings. A list of some of the commonly used questionnaires is provided in Morin and Edinger (2003), and guidance regarding their use can be found in Moul, Hall, Pilkonis, and Buysse (2004).

Functional Analysis and Diagnosis

Behavior analysis has a strong preference for direct observational measurement of the phenomena of interest rather than indirect measurement (Johnston & Pennypacker, 1993) and for functional assessment rather than diagnostic categorization (Yoman, 2008). Yoman (2008) concisely explained,

> *Functional analysis* is a fundamental tool of applied behavior analysis for examining the relationship between behavior and the environment. In performing a behavioral analysis . . . the behavior of interest and its antecedents and consequences [is described] in observable measurable terms. *Observable terms* means that the thing described can be picked up with one of the five human senses . . . sometimes assisted by special instruments. . . . *Measurable terms* means that the observation can be objectively recorded in terms of a number (e.g., frequency, latency, duration, intensity, etc.). . . . Functional analysis uses the scientific method to describe three components within the analysis, form hypotheses about their interrelationships, and then test these hypotheses. . . . These three components [are] antecedents, behaviors, and consequences. (pp. 325–326)

Of all the measures we have discussed, the data from questionnaires and psychometric scales are least likely to meet these requirements, and so it is no surprise that research into sleep from a behavioral perspective has tended to place less reliance on their use.

Equally, although several schemes exist for the diagnostic categorization of sleep problems in children and adults, including the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text revision; American Psychiatric Association, 2000) and the *International Classification of Sleep Disorders, Revised* (American Academy of Sleep Medicine, 2001), behavioral sleep researchers have made relatively little use of these nosologies, generally preferring to undertake some form of functional assessment. Several forms of functional assessment are now distinguished, including indirect methods based on structured interviews, descriptive assessments using records of direct observations of behavior and the environmental context in which it occurs (sometimes called *A–B–C logs*, which a well-designed sleep diary will resemble), and functional analyses of the kind developed for the analysis of challenging behavior in which a variable suspected of maintaining the sleep problem is systematically manipulated (see Cooper et al., 2007, and Iwata & Worsdell, 2005, for comprehensive summaries of different forms of functional behavioral assessment). Currie (2006) described the use of structured interviews in sleep assessment, and Brown and Piazza (1999) advocated the use of functional analysis for children's sleep problems. Major ethical and practical barriers to using functional analyses for sleep problems, such as those commonly occurring in the privacy of people's homes throughout the hours of the night, exist, and examples of such use are very rare, possibly nonexistent (see Brown & Piazza, 1999).

UNDERSTANDING AND TREATING PEDIATRIC SLEEP DISTURBANCE

Although what constitutes good sleep for infants (as well as for older children, adolescents, and adults) is influenced by age, developmental history, culture, and family circumstance (e.g., Adam et al., 2007; Dahl & El-Sheik, 2007; McKenna et al., 2007; Milan, Snow, & Belay, 2007), the universality of sleep means that a broad prescription of good sleep is possible. This prescription envisages that during infancy and early childhood, the child develops the capacity to obtain sleep of sufficient regularity and quality that health and development are optimized and time awake is not disrupted by excessive tiredness and intrusive naps. The child's bed preparation routine will meet family and cultural expectations with regard to time, place, and procedure and will be emotionally and socially positive and free of coercion and resistance. The child may be put to bed awake and will initiate sleep without difficulty or undue delay, and sleep will thereafter be of age-appropriate duration. If the child wakes, he or she will be able to self-soothe and reinitiate sleep, unless parental care is needed (Blampied & France, 1993; France & Blampied, 2004). This prescription can easily be generalized across the life span.

Achieving good sleep at the outset requires the extended interaction of biopsychosocial processes that continuously and dynamically involve the child, his or her parents, caregivers, siblings, and other family members and is influenced by many factors, including child maturation, temperament, parental personality and adjustment, family well-being and resources, and the wider ecology of the family and its community (Goodnight, Bates, Pettit, Staples, & Dodge, 2007; Sadeh, Tikotzky, & Scher, 2010). The core of the process involves the child and the parents or caregivers learning, through mutual interaction, how to facilitate and maintain good sleep, however good sleep is defined by the particular family, its culture, and circumstances (Dahl & El-Sheik, 2007; France & Blampied, 1999).

Defining Pediatric Sleep Disturbances

When this learning does not occur by a certain age, forms of pediatric sleep disturbances (PSDs) may develop (France & Blampied, 2004). The major PSDs include

- *Problems of bedtime resistance and sleep location:* Bedtime resistance is more commonly observed in older infants and children and involves active noncompliance with bed preparation routines, delaying tactics, tantrums, avoidance of and escape from bedtime, and demands for prebed rituals. It may also be associated with the child routinely sleeping in locations other than where the parents desire the child to sleep (e.g., cosleeping[1] in the parents' bed or, less commonly, with siblings), sometimes because the child relocates there as part of the bedtime resistance behavior or because the child is moved by the parents to stop or prevent crying, distress, tantrums, and so forth.
- *Problems of sleep-onset delay, measured by SOL:* The infant or child has difficulty in falling asleep when put to bed and continues to cry or call out during this period. When sleep onset is delayed in infants and young children, it typically reflects persistent patterns of parent interaction during the settling period (see the Treating Pediatric Sleep Disturbance section later in this chapter) that interfere with the process of learning to sleep.
- *Recurrent night waking with signaling:* After first falling asleep, the child repeatedly wakes and cries out during the night and requires parental attention before resuming sleep. The child may be relocated to the parents' bed after one of these wakings to reduce further nighttime disturbance. Note that the waking is not what is problematic, because it is a vulnerability inherent in infants' typical sleep architecture; the problem is the inability to self-soothe and thus resume sleep, leading to crying, and so forth. (See the Treating Pediatric Sleep Disturbance section later in this chapter.)
- *Fears and anxieties associated with nighttime and bedtime* (King, Ollendick, & Tonge, 1997).

These PSDs often co-occur, especially sleep-onset delay and night waking (J. A. Owens & Burnham, 2009).

A second set of PSDs may be identified as biomaturational rather than psychosocial (Ferber, 1990). These PSDs include parasomnias (undesirable behavior such as sleepwalking), sleep terrors, and rhythmic movements, such as headbanging, occurring during sleep, particularly in NREM sleep and at sleep–wake transitions. Also included in this category are circadian rhythm disorders (Herman, 2006), which involve an individual's sleep–wake phases getting out of synchrony with the day–night cycle of the family or community, so that the individual is awake or asleep at inappropriate times. A range of medical conditions, for example, narcolepsy (in which the individual recurrently, frequently, and abruptly falls asleep), also affect sleep–wake cycles, but a full discussion of these biomaturational disorders lies outside the scope of this chapter (see Mindell, 1993, for a review).

Understanding Pediatric Sleep Disturbance

Dramatic changes occur in the sleep of infants during their first weeks, months, and years of life (Henderson et al., 2010; Scher, 2006; Thomas,

[1]Cosleeping (or bed sharing) is a contentious issue. France and colleagues (e.g., France, 1994; France & Blampied, 2004) have consistently adopted the pragmatic position that cosleeping is a problem only if the parents, or the wider family, community, or culture, regard it as undesirable. However, we should note, first, that family and culturally sanctioned cosleeping does not preclude the development of PSDs (e.g., Lee, 1992; Madansky & Edelbrock, 1990) and, second, that cosleeping in infancy is a risk factor for sudden infant death syndrome (see Scragg et al., 1993; Wilson, 2007).

1995). Although these changes in sleep may be substantively endogenously driven, they are influenced by psychological and social processes (as noted earlier), and understanding this biopsychosocial interaction holds the key to understanding the development of, intervening successfully with, and perhaps preventing PSDs.

The newborn infant sleeps much of the time (typically 16 out of every 24 hours), waking at any time of the day or night for feeding and nurturant care (Hiscock, 2008; Thomas, 1995). Over the first weeks and months of life, a circadian rhythm begins to impose on these episodes of sleeping and waking so that both become more consolidated, with longer sleeping at night and longer waking periods in the day. T. Moore and Ucko (1957) found that the proportion of infants sleeping uninterrupted between the hours of midnight and 5:00 a.m. over 4 consecutive weeks increased from 19% at 1 month to 90% at 10 months. Recently, Henderson et al. (2010) gathered data from 75 typically developing children over their first 12 months and used survival analysis to detect the median survival time for night waking when the criterion was sleeping 5 of 6 nights without waking between 10:00 p.m. and 6:00 a.m., an ecologically valid measure of sleeping through the night that requires the child to sleep during times congruent with typical family sleep time. At age 5 months, half the sample were meeting this criterion. Some evidence also exists that parental manipulation of feeding times may promote this sleep consolidation process (Pinilla & Birch, 1993; Thomas, 1995).

In addition to this circadian entrainment, other developmental changes occur to sleep architecture, continuing progressively throughout childhood and adolescence, and the adult pattern of sleep is not attained until late adolescence or early adulthood (Ellingson, 1985; Ferber, 1990; Wickwire et al., 2008). For the first few months of life, infant sleep is differentiated into active sleep and quiet sleep, the precursors of REM and NREM, respectively (Scher, 2006). Infant sleep is much more dominated by active–REM sleep than is that of adults, with 50% or more of infants' sleep being active–REM sleep (vs. approximately 25% for adults), although this percentage diminishes to about 30% by 12 months of age (Ferber, 1990; Hiscock, 2008). Furthermore, active–REM periods cycle more rapidly in the infant, with active–REM and quiet–NREM phases alternating on an approximately 60-minute cycle. The end of each active–REM cycle is often accompanied by an arousal, often sufficient to cause the infant to fully wake (Anders, 1979; Coons, 1987), so that infants are vulnerable to regular arousals and wakings during sleep periods. Sometimes, but not inevitably, these active–REM–associated wakes are accompanied by distress and crying, to which parents may respond. Ferber and Boyle (1983) distinguished between partial arousals, in which the child resumes sleep without distress and crying, and full waking arousals, which may be signaled by crying or calling out. This cycle of arousal is normal, and if problems occur, they are problems of sleep reinitiation, not of sleep maintenance (Ferber, 1985). Sleep reinitiation after a full arousal without the experience or expression of distress is evidence that an infant has developed the capacity for self-soothing, which is regarded as a key capacity of infants (and, for that matter, of adults), underpinning adaptive sleep regulation (Anders, Halpern, & Hua, 1992; Goodlin-Jones, Burnham, Gaylor, & Anders, 2001).

The developmental challenge for the child is, first, to learn to go to sleep when initially put to bed and then, second, to learn to self-soothe and resume sleep after arousals; the challenge for the parents is to facilitate rather than interfere with this learning. Epidemiological research in many countries has suggested that PSDs are commonly experienced by families with an infant or young child, with the exact frequency reported depending on the severity of the criteria used. Most research has focused on recurrent night waking, finding that 10% to 25% of infants and young children are chronic night wakers (meaning that they wake at least once most nights per week), and 15% to 20% take excessive time (>30 minutes) to settle to sleep (e.g., Armstrong, Quinn, & Dadds, 1994; Fergusson, Shannon, & Horwood, 1981; Hiscock, Canterford, Ukoumunne, & Wake, 2007; Scott & Richards, 1990). Children do not necessarily "grow out" of night waking and other PSDs (Gaylor, Burnham, Goodlin-Jones, & Anders, 2005; Lam, Hiscock, & Wake, 2003; Zuckerman, Stevenson, & Bailey, 1987), and children who have learned to sleep through the night quite often develop sleep problems later in childhood, often in association with illness or a change in family circumstances (e.g., the birth of a sibling). Such later disruptions in sleep may affect 19% to 50% of families (Fergusson et al., 1981; T. Moore & Ucko, 1957). Children's sleep difficulties are a major source of parental stress (Fergusson et al., 1981), are associated with later behavioral problems (Goodnight et al., 2007), and are potentially harmful to child and family well-being (Dahl, 1996; J. A. Owens, Fernando, & McGuinn, 2005; Schwebel & Brezausek, 2008; Smart & Hiscock, 2007; Stoléru, Nottelman, Belmont, & Ronsaville, 1997). Parents resort to a range of prescription and nonprescription sedatives[2] and alcohol in attempts to deal with PSDs (Armstrong et al., 1994; Johnson, 1991; Scott & Richards, 1990), generally without great success (France et al., 1999; Johnson, 1991).

Treating Pediatric Sleep Disturbance

If one combines the idea that sleep initiation is a behavior chain under stimulus control with the understanding that infants need to counteract their vulnerability to regular arousals by learning to self-soothe and resume sleep, this combination focuses attention on aspects of stimulus control associated with bed preparation, sleep initiation, and sleep resumption. The analysis must recognize that these S^Ds have various sources, including those proprioceptively and interoceptively present in the child or produced by the child's own behavior (e.g., fatigue, sleep posture, and self-soothing behavior; Anders et al., 1992), those present in the bed environment (e.g., comfort objects), and those provided by parents' activities (e.g., feeding, rocking, singing; Anders et al., 1992; Holliday, Sibbald, & Tooley, 1987). Then, in the next stage of the analysis, understanding that at any time these sleep-facilitating S^Ds and associated behavior may be disrupted by competing S^Ds and behavior draws attention to the competing contingencies of reinforcement for both parent and child behavior that may enhance or interfere with sleep. Best-practice interventions for PSDs must incorporate both a stimulus-control focus and a contingency-management focus (Sanders, Bor, & Dadds, 1984), although particular interventions may emphasize one element more than the other.

Parents and caregivers necessarily provide the procedures and routines that accompany bed preparation for infants and young children (Anders et al., 1992; Beltramini & Hertzig, 1983; Ferber, 1990; Sadeh et al., 2010). The distinctiveness of the cues provided and the regularity with which they are experienced are critical to the establishment of the bed-preparation chain, and many interventions for PSDs have an initial component that teaches parents the necessity of establishing a standard prebed routine, one that involves positive parent–child interaction but is not highly arousing (France & Hudson, 1990; Pritchard & Appleton, 1988; Sanders et al., 1984; Seymour, 1987). Such recommendations for establishing good sleep in children can be traced back to J. B. Watson (1928, as cited in Stepanski, 2003). This combination of quiet, pleasant, prebed activities, accompanied by praise for compliance with parent instructions, termed *positive routines,* has been shown to be effective in managing bedtime resistance (Adams & Rickert, 1989).

For families and cultures in which the infant is expected to learn to sleep alone, if the final stages of the bedtime chain, notably behavioral quietude, are to come under appropriate stimulus control, infants must be given the opportunity to settle to sleep while they are awake; otherwise, neither external bed-related cues nor appropriate proprioceptive and interoceptive cues can come to control sleep initiation (Blampied & France, 1993). In the first weeks of life, infants typically go to sleep while feeding and being held, but the proportion of infants placed into the crib awake increases to about 50% at 8 months of age (Anders et al., 1992). Parents may avoid placing their child into the crib or bed while she or he is awake and take steps to ensure that the child is asleep first, through feeding, cuddling, rocking, and so forth, having learned that these rituals avoid distress (Adair, Bauchner, Philipp, Levenson, & Zuckerman, 1991; Keener, Zeanah, & Anders, 1988). This negatively reinforced parental behavior may

[2]The most common treatment for both child and adult sleep problems is nonprescription and prescription pharmaceuticals. Discussion of these is outside the scope of this chapter. Kuhn and Weidinger (2000) discussed the pharmacotherapy of infant sleep disturbance, and Taylor et al. (2008) reviewed pharmacological treatment of adult insomnia.

avoid distress for both the child and the parents during the sleep-onset period, but it interferes with the development of natural stimulus control from bed location and sleep posture cues and predicts continued sleep problems in infants (DeLeon & Karraker, 2007). Furthermore, exposure to, and habituation of, distress-evoking cues also needs to be accomplished. If some aspects of the bed setting (e.g., darkness, being alone) are distress evoking (involving emotions and Pavlovian responses), then exposure to these cues, preferably in a graduated way (Gordon, King, Gullone, Muris, & Ollendick, 2007), is needed if desensitization is to occur, again pointing to the need for the child to be placed in bed awake while being given other forms of support to mitigate distress (Sadeh, 1994).

If bed-associated cues and self-soothing have not become established as S^Ds for sleep initiation during the initial sleep-onset period, then these cues are not able to function as sleep S^Ds (and nor will sources of emotional distress be habituated to) when the child later wakes during REM arousals (Ferber, 1985, 1990). In contrast, the child who has initially learned to go to sleep under the control of these stimuli will again encounter them if and when he or she wakes later in the night. The stimuli will then set the occasion for the resumption of sleep; these waking arousals will not result in crying, calling out, and other evidence of distress; and the child's sleep will be normal and of good quality because the child has mastered the skill of self-soothing (Anders et al., 1992) and parents have refrained from unduly interfering in the process.

The other aspect of the behavior analysis of interventions for PSDs focuses on the contingencies operating to shape and maintain both child and parent behavior. A key suggestion in this regard was made by Williams (1959), who identified parental attention as the reinforcer for bed-associated tantrums in a toddler and treated the problem by teaching the parents to withhold their attention, an example of operant extinction.

Extending Williams's (1959) intervention to younger children with PSD, France and Hudson (1990) treated children aged 8 to 20 months by instructing the parents to withhold attention for night waking and crying (unless they suspected the child was ill or in danger, in which case they were to check the child in silence and in minimal light, and either suspend the program if the child was ill or remedy any immediate problem with minimal interaction). This procedure, now often called *systematic ignoring* (sometimes *planned ignoring*), was shown to be effective using a multiple-baseline-across-subjects design, reducing both the frequency of wakings and their duration (France & Hudson, 1990). Many replications of the systematic ignoring procedure and recent reviews of interventions for children's sleep problems have all concluded that extinction-based treatments for PSD meet the Chambless and Hollon (1998) criteria as having well-established efficacy (Kuhn & Elliot, 2003; Kuhn & Weidinger, 2000; Mindell, 1999; J. A. Owens & Burnham, 2009; J. A. Owens, Palermo, & Rosen, 2002).

All these reviews noted, though, that systematic ignoring has problems, in particular the occurrence of postextinction response bursts (Lerman & Iwata, 1995) and parental reluctance to let children cry. The postextinction response burst that may occur in the first few nights of the intervention (e.g., France, Blampied, & Wilkinson, 1991; France & Hudson, 1990) is distressing to both the child and the child's parents, and if the parents give in and attend to the child, that reinforces the child's behavior at higher rates and intensities. These perceived difficulties with systematic ignoring have led to the search for alternatives, some of which have modified the extinction procedure in ways designed to make it less stressful or objectionable to parents, and some of which have added additional components designed to reduce child distress.

The most common modification of the basic extinction procedure has been through various adaptations of a procedure developed by Ferber (1985), in which parents are instructed to systematically delay their response to the child over successive crying episodes or nights (e.g., Adams & Rickert, 1989; Durand & Mindell, 1990). Alternatively, to remove the contingency that might have rewarded the child for persisting with crying until the parents attended, Lawton et al. (1991) had parents attend to crying immediately, but also to fade the duration of their attending systematically until they did not attend at all (equivalent to instigating extinction by systematically reducing the magnitude of the reinforcer to zero). Kuhn and Elliot (2003) have classified these various forms of graduated extinction as having well-established efficacy. Kuhn and Elliot (2003) also noted a further adaptation of graduated extinction, termed *minimal-check extinction,* in which parents briefly respond to crying, at times that vary depending on the particular study, but typically about 10 minutes after the onset of the cry, with a very brief check to ensure that the child is safe and to rearrange disturbed bedding, all done in low light and with minimal interaction (France & Blampied, 2005; Pritchard & Appleton, 1988). However, France and colleagues (France & Blampied, 2005; Healey et al., 2009) have reported that forms of graduated extinction are often associated with poorer parental compliance, unauthorized modification of the procedures, and slower reduction in the frequency of night waking and total time spent crying relative to unmodified systematic ignoring and that they do not regard graduated or minimal check extinction procedures as contemporary best practice.

Interventions to reduce child distress have combined systematic ignoring either with sedative medication or with a procedure called *parental presence* (also *extinction with parental presence*; Sadeh, 1994, 2005). In this procedure, the parent remains in the room with the child at initial bedtime and after later wakings until the child has at least gone to sleep, positioning themselves on a bed or in a chair such that the child is aware of the parent's presence, but the parent does not further interact with the child. France and Blampied (2005), in a multiple-baseline, randomized controlled comparison of systematic ignoring, minimal check, and parental presence procedures, concluded that parental presence was the most effective procedure, producing the most rapid reduction in night wakings and the largest reduction in duration of crying and distress. Sadeh (1994, 2005) conceptualized the parental presence procedure within an attachment theory and separation anxiety perspective. Extending this, France and Blampied (2005) suggested that the stimuli associated with the parent might additionally be safety signals (see Lohr, Olatunji, & Sawchuk, 2007, for a review of safety signals in clinical contexts) and function as inhibitors of arousal and distress, whereas the lack of parental response functions as extinction for operant crying. These speculations about the mechanisms underlying the parental presence procedure have not, however, been tested. Safety signals are CSs established by Pavlovian conditioning such that they serve as reliable predictors of the omission of an aversive unconditioned stimulus and become CSs that inhibit fear, in contrast to alternative CSs that elicit distress. Once established as safety signals, these stimuli also become positive reinforcers (Mackintosh, 1974; Weisman & Litner, 1969), strengthening behavior that produces them, and so if parents respond by providing both their presence and nurturing responses after their child's waking, the parents' very presence is a reinforcer, as are the activities they engage in with the child. Sedative medication (e.g., trimeprazine tartrate[3]) is on its own not notably effective in treating PSDs (France et al., 1999; Ramchandani, Wiggs, Webb, & Stores, 2000); however, when combined with systematic ignoring and with the drug faded over the first 10 days of intervention, trimeprazine eliminated postextinction response bursts and was associated with significant reduction in night waking and total crying, although a slight rebound occurred when the drug was withdrawn (France et al., 1991). Selim, France, Blampied, and Liberty (2006) have also shown that faded doses of trimeprazine in combination with parental presence is an effective treatment for PSD in cases in which other treatments have failed, leading to treatment resistance.

In this analysis, the contingencies shaping and maintaining the child's PSD are primarily positive (reinforcement from attention and other parental activities; safety signals), although negative reinforcement via escape from fear and discomfort may also play a part. The contingencies affecting the parents' behavior, however, are largely based on negative reinforcement—they escape and avoid their child's resistance, tantrums, crying, and distress. This combination of contingencies is characteristic of a coercive behavior trap (Blampied & France,

[3]Trimeprazine tartrate is no longer licensed by the U.S. Food and Drug Administration for administration to children younger than 2 years.

1993; France & Blampied, 1999; Patterson & Reid, 1973). Various aspects of parent personality, temperament, mental health, and family circumstances increase a family's vulnerability to entering this trap (France & Blampied, 1999; J. A. Owens & Burnham, 2009). Once entered, the behavior trap contingencies tend to extend the behavior in time as both parents and child learn to anticipate each other's behavior, increase the range of behaviors incorporated in the coercive repertoire, and intensify the behavior. This process may account for the development of prolonged bedtime and elaborate sleep initiation rituals and their increase over time (Beltramini & Hertzig, 1983; Durand & Mindell, 1990; Sanger, Weir, & Churchill, 1981).

Behavioral parent training is the standard way of assisting parents to escape coercive behavior traps of many kinds, and rigorous evaluations have shown it to be highly effective (e.g., Bank, Patterson, & Reid, 1987; see also Dunlap et al., 2006, and Kazdin, 1997, for reviews). Several self-help manuals specifically address parents coping with children's sleep problems (e.g., Ferber, 2006; Mindell, 2005; J. A. Owens & Mindell, 2005; Sadeh, 2001), and assistance with sleep problems is often included in general parenting guides (e.g., the Triple-P Positive Parenting Programme; Sanders, 1992). Users should ensure that the book they choose contains up-to-date advice about the relative merits of systematic ignoring, graduated or minimal check extinction, and parental presence (France & Blampied, 2005).

Clinical experience has suggested that parents will do best when given advice and support both during the initial few days of intervention and later when they institute maintenance procedures (France, 1994; France, Henderson, & Hudson, 1996; Healey et al., 2009). Despite the often-expressed concerns by lay and professional writers about the stressfulness of behavioral interventions for PSDs (France, 1994; France et al., 1996), research has suggested that with good professional and family support, the procedures are not unduly stressful, the difficulties are worse in anticipation than in reality, and systematic ignoring and parental presence procedures are highly acceptable to parents (France et al., 1991, 1999; Lawton, Blampied, & France, 1995; Lawton et al., 1991; Reid, Walter, & O'Leary, 1999; Selim et al., 2006). Knowing that research has shown that these behavioral interventions have no adverse effects on infant security and well-being is also reassuring (France, 1992, 1994; Reid et al., 1999), although this research is astonishingly little cited, and unwarranted claims about the dangers of behavioral interventions have continued to be made (e.g., Australian Association for Infant Mental Health, 2004; Feeney, 2007). Evidence also exists that maternal well-being is also improved, along with the infant's sleep (Hiscock & Wake, 2002).

For children older than 2 years, less research into sleep problems and their treatment is available, perhaps reflecting a common viewpoint that children postinfancy and preadolescence generally enjoy good sleep (Wickwire et al., 2008). This view is unduly optimistic, and sleep problems have an estimated prevalence of between 25% and 40% among children and adolescents (Mindell & Meltzer, 2008). The evidence (see the section Understanding and Treating Pediatric Sleep Disturbance earlier in this chapter) of continuities between infant sleep problems and sleep and other behavioral problems later in childhood, plus the emerging evidence that sleep problems in middle childhood are associated with adolescent drug and alcohol use (Wong, Brower, Fitzgerald, & Zucker, 2004) and with adult anxiety and depression (Gregory et al., 2005) emphasizes the need for continued research into, and therapy for, sleep problems throughout childhood.

Sleep problems are especially common in children with various diagnoses, such as attention deficit/hyperactivity disorder and autism spectrum disorders (Mindell & Meltzer, 2008; Piazza, Fisher, & Sherer, 1997), and they contribute substantially to the individual, family, and community burden of these conditions; however, detailed consideration of these special populations is outside the ambit of this chapter. Reviews are provided by Ivanenko, Crabtree, and Gozal (2005); J. A. Owens (2005); J. A. Owens and Davis (2006); L. J. Owens, France, and Wiggs (1999); Richdale (1999); Schreck (2001); and Wiggs and France (2000). This area both is clinically neglected (Mindell & Meltzer, 2008) and also needs much further research (Wiggs & France, 2000).

The increasing cognitive and verbal skills of older children open up the possibility of using general behavioral parenting strategies to deal with sleep difficulties (J. A. Owens et al., 2002). Research has shown that interventions, often involving a package of several behavioral techniques, are successful in improving both bed resistance and sleep difficulties among children of this age. Common components include psychoeducation for the parents in appropriate management of child behavior, including giving clear instructions about parent expectations and family rules, behavior rehearsal, descriptive praise, and other forms of reinforcement (e.g., Ronen, 1991; Sanders et al., 1984). One innovative procedure (Freeman, 2006; B. A. Moore, Friman, Fruzzetti, & MacAleese, 2007) combined systematic ignoring of bedtime disruptions during the settling phase with a bedtime pass—a card that gives the child one opportunity to leave the bed after bedtime, with parents ignoring all subsequent disturbances. Another innovation (Burke, Kuhn, & Peterson, 2004) involved the combination of social stories (*The Sleep Fairy* story) that provide a model of a good sleeper, with tangible rewards (in the form of small trinkets left under the child's pillow for discovery in the morning) for bedtime compliance and undisturbed sleep all night. This intervention can be seen as a combination of modeling (Bandura, 1977) and reinforcement. Both Burke et al. (2004) and B. A. Moore et al. (2007) evaluated the acceptability of these procedures for the parents and reported high acceptability.

Parasomnias, such as sleep walking and night terrors, are relatively common among children (Wickwire et al., 2008) and have been successfully treated using scheduled awakenings (Rickert & Johnson, 1988). In this procedure, sleep diaries are used to establish the time at which the parasomnia is likely to occur, and then the child is woken 15 to 30 minutes before that time, briefly kept awake, and then allowed to go back to sleep. Once several nights without the parasomnia are achieved, scheduled awakenings are typically faded out by omitting them on an increasing number of nights. Durand and Mindell (1999) and Durand (2002) found that scheduled awakenings were successful in treating parasomnias in typically developing children and children with autism and that the procedure was acceptable to parents.

The common adolescent problem of delayed sleep phase syndrome (a circadian rhythm disorder; Herman, 2006) appears to be caused, in part, by an interaction between a normal developmental shift in circadian rhythm that delays sleep onset by approximately 2 hours, combined with changes in lifestyle, social interaction patterns, academic demands, and employment that favor later bedtimes, factors now exacerbated by the availability in the bedroom of television, computer and Internet games, cell phones, and instant messaging (Van den Bulck, 2007). The result is a pattern of delayed sleep onset into the early morning hours and difficulty in waking up at socially acceptable times in the morning (Mindell & Meltzer, 2008). The treatment, sometimes called *chronotherapy,* involves imposing a strict and consistent sleep–wake schedule, via graduated implementation (Czeisler et al., 1981; Ferber, 2006), sometimes supplemented by exposure to bright light (to promote endocrine regulation) on wakening (Mindell & Meltzer, 2008). Adherence to the treatment requires a motivated client and family and careful planning for maintenance because the natural tendency is for the circadian shift to reoccur (Mindell & Meltzer, 2008). Behavioral family therapy, especially through encouragement of reinforcement for treatment compliance, has obvious applications as an adjunct to chronotherapy.

ADULT INSOMNIA

The core complaint of individuals diagnosed with insomnia is that they have difficulty in getting to sleep, that they wake often, that the sleep they get is not refreshing, or all of these (Leshner, 2005; Milner & Belicki, 2010; Taylor et al., 2008). Insomnia can be usefully subdivided into categories on the basis of duration: Insomnia of a few days duration is transient, that lasting a few weeks is short term, and that lasting longer is chronic (Milner & Belicki, 2010). Transient and short-term insomnia occurs in response to life events such as stress, illness, shift work, and jet lag and is likely to be treated, if it is treated at all, by self-medication or in primary health care settings. Chronic insomnia is that most likely to present for specialist psychological therapies (Milner & Belicki, 2010).

For a formal diagnosis of chronic insomnia, the problem must have been experienced at least 3 nights per week for at least 1 month, with SOL of more than 30 minutes and sleep efficiency of less than 85%, and the individual must be experiencing clinically significant distress or impairment. For a diagnosis of primary insomnia, other contributing medical or psychological conditions must be ruled out, otherwise the insomnia is termed *comorbid insomnia* (Milner & Belicki, 2010; Morin & Edinger, 2003). When insomnia occurs comorbid with some other problem, such as depression, anxiety, or pain and illness (and such comorbidities are common), contemporary evidence has suggested that the insomnia requires specific treatment rather than assuming that treatment of the comorbid condition will resolve the insomnia (Morin, 2010).

Chronic insomnia is a very common problem, with epidemiological studies indicating a prevalence of 12% to 15% among adults in the community and as high as 50% among clients in primary health care. At diagnosis, the average duration of chronic insomnia is about 10 years (see Krueger & Friedman, 2009; Leshner, 2005; Milner & Belicki, 2010; Ohayon, 2002; and Taylor et al., 2008, for summaries of the epidemiological data). The personal, family, community, and social burden of insomnia is enormous because of its association with psychological distress, physical and mental illness, interpersonal conflict, accidents, and productivity losses (Access Economics, 2005; Åkerstedt, 1998; Philip & Åkerstedt, 2006), and the estimated economic costs of insomnia exceed $30 billion in the United States (Leshner, 2005; Taylor et al., 2008) and AU$30 million in Australia (Access Economics, 2005).

Understanding Adult Insomnia

A behavioral account of adult insomnia shares much in common with the earlier discussion of infant sleep problems, which is not surprising, given that Bootzin's (1977) analysis was developed for adult insomnia and only later extended to children (Blampied & France, 1993). On the foundation laid by Bootzin, other investigators have added additional behavioral and cognitive elements, so that several behavioral and cognitive–behavioral models and associated treatments for adult insomnia are now available (see Taylor et al., 2008, for a concise summary of these treatments).

What these models have in common with the infant development models (discussed in the section Behavior Analysis and Sleep earlier in this chapter) is a focus on the role of stimulus control and appropriate and inappropriate S^Ds. However, contemporary theories of adult insomnia stress the role of cognitions as precipitating and perpetuating factors maintaining insomnia (Taylor et al., 2008). It is worth remembering, in the context of this chapter, that within behavior analysis, cognitions are forms of behavior: "Cognitive process are behavioral processes; they are things people do" (Skinner, 1989, p. 17). Although models of infant sleep have not ignored the role of parental cognitions (Sadeh, 2005; Sadeh, Flint-Ofir, Tirosh, & Tikotzky, 2007), the focus has been on the contingencies of positive and negative reinforcement that influence both child and parent behavior. Nevertheless, just as contingencies of reinforcement constitute a behavior trap for the parents of sleep-disturbed infants, cognitions—in the form of maladaptive beliefs, worries, and ruminations, along with overt behavior that brings short-term relief at the cost of long-term distress—can be seen as equally constituting a trap affecting those with adult insomnia (Harvey, 2002; Morin, 1993). Furthermore, although not featured in the cognitive–behavioral theories of adult insomnia, insomnia or, more precisely, complaints about insomnia are behavior that can make contact with socially mediated reinforcers, just as complaints about illness and chronic pain may be maintained by solicitous social attention and escape from social demands, as Fordyce (1978; see also Romano et al., 1992) pointed out. Because insomnia is often comorbid with chronic pain in children and adults (Long, Krishnamurthy, & Palermo 2008; Smith & Haythornthwaite, 2004), the treatment of both might benefit from a closer alignment of theories about, and treatments for, them. Note also that socially mediated reinforcers, if they do play a role in adult insomnia, parallel the reinforcement from caregiver attention that maintains children's wakings (Williams, 1959).

Treating Adult Insomnia

As Bootzin, Smith, Franzen, and Shapiro (2010) noted, all behavior therapies for insomnia are fundamentally self-help treatments. The role of the clinician is to assess the client's problem and then to provide the client with a clear rationale for the treatment. The treatment itself is prescribed as homework. In clinical practice, treatment is often a package of several elements, with stimulus control therapy (SCT; Bootzin et al., 2010) the core element. The rationale for SCT is to establish stimuli in the bedroom environment as controlling S^Ds for the initiation of sleep and to ensure that any CSs present are sleep facilitative rather than sleep disruptive (e.g., by being CSs for physiological arousal). The standard set of SCT instructions is shown in Table 17.1, and a detailed rationale for each instruction is given in Bootzin et al. (2010). The key instructions are Numbers 2 and 3 (Table 17.1) because they reliably establish the contingency between the bedroom and bed S^Ds, the behavior that prepares for transition to sleep, and the reinforcer of sleep. The requirement to leave the bedroom if sleep is not quickly achieved breaks the association between the bed S^Ds and wakefulness.

SCT is often combined with a psychoeducational approach to insomnia termed *sleep hygiene* by Hauri (1977; see also Stepanski, 2003). Sleep hygiene instructions (Table 17.1) overlap somewhat with those for SCT but extend the focus to include practices of daily life thought to be sleep facilitative. Sleep hygiene, or more generally, sleep education, is now regarded as a necessary, but not sufficient, component of effective treatment for insomnia (Stepanski, 2003; Stepanski & Wyatt, 2003). These interventions are now often combined with sleep restriction (Spielman, Saskin, & Thorpy, 1987), an intervention that increases motivation to sleep. Baseline sleep diary data are used to prescribe an initial nightly time in bed (normally the baseline average total sleep time, and never less than 5.5 hours). This time is then incremented weekly as long as

TABLE 17.1

Comparison of Sleep Hygiene and Stimulus Control Instructions

Sleep hygiene	Stimulus control
1. Curtail time in bed.	1. Lie down to go to sleep only when you are sleepy.
2. Never try to sleep.	2. Do not use your bed for anything except sleep: That is, do not read, watch television, eat, or worry in bed. Sexual activity is the only exception to this rule. On such occasions, the instructions are to be followed afterward when you intend to go to sleep.
3. Eliminate the bedroom clock.	3. If you find yourself unable to fall asleep, get up and go into another room. Stay up as long as you wish, and then return to the bedroom to sleep. Although we do not want you to watch the clock, we want you to get out of bed if you do not fall asleep immediately. Remember the goal is to associate your bed with falling asleep *quickly!* If you are in bed more than 10 minutes without falling asleep and have not gotten up, you are not following this instruction.
4. Exercise in the late afternoon or early evening.	4. If you still cannot fall asleep, repeat Step 3. Do this as often as is necessary throughout the night.
5. Avoid coffee, alcohol, and nicotine.	5. Set your alarm and get up at the same time every morning irrespective of how much sleep you got during the night. This will help your body acquire a consistent sleep rhythm.
6. Regularize the bedtime.	6. Do not nap during the day.
7. Eat a light bedtime snack.	
8. Explore napping.	
9. Monitor use of hypnotics.	

Note. Updated sleep hygiene Instructions are from Stepanski and Wyatt (2003), and stimulus control instructions are from Bootzin, Smith, Franzen, and Shapiro (2010).

sleep efficiency remains high (typically >90%). If sleep efficiency falls below 85%, time in bed is decreased for the next week (Spielman et al., 1987).

Another component that is often included along with SCT is relaxation training or meditation, for use either before going to bed or during night waking to facilitate resumption of sleep. Stress leading to hyperarousal, both physiological and cognitive, has long been recognized as contributing to insomnia (Bonnet & Arand, 2010; Rosch, 1996), and the contribution of relaxation to promoting sleep can be traced back to the work of Jacobson on progressive muscle relaxation in the 1930s (Stepanski, 2003) and its extension by Borkovec (1982). In contemporary practice, cognitive hyperarousal, especially in the form of general worries or specific worries and anticipatory ruminations about sleep difficulties, is more likely to be addressed by direct cognitive–behavioral therapy.

The first cognitive models of insomnia (Morin, 1993) were derived from the work of Beck and earlier scholars (see Stepanski, 2003) and are predicated on the assumption that insomnia is maintained by maladaptive and dysfunctional beliefs, expectations, and attributions about the nature of sleep, the necessity of sleep of particular quality and duration, and inevitable negative consequences if expectations about sleep are not met (Brand, Gerber, Pühse, & Holsboer-Trachsler, 2010; Morin, Stone, Trinkle, Mercer, & Remsberg, 1993). These maladaptive cognitions result in vicious cycles of anticipatory worry about sleep, hypervigilant attention to sleep-relevant cues, and narrowing of attention to an undue focus on sleep, an escalation of emotional distress if sleep difficulties are experienced, ineffectual safety behavior in attempting to manage sleep difficulties, and catastrophic anticipation of the negative effects of sleep disruption (Harvey, 2002). This leads to chronic rumination about sleep and to emotional distress, which exacerbates insomnia. Cognitive therapy for insomnia involves helping the client accurately identify his or her particular suite of maladaptive, dysfunctional cognitions about sleep and then teaching the client to challenge these cognitions whenever they occur and replace them with more adaptive cognitions (Harvey & Tang, 2003; Milner & Belicki, 2010; Taylor et al., 2008).

All of these behavioral and cognitive–behavioral therapies have been shown to be effective. Meta-analyses of outcome research have indicated effect sizes (Cohen's *d*) averaging 0.88 for SOL and 0.65 for wake after sleep onset (Morin, Culbert, & Schwartz, 1994) or more (Smith et al., 2002). When individual components were examined, SCT often emerged as the most effective single component in the behavioral treatment of insomnia (Bootzin et al., 2010; Morin et al., 1994; Murtagh & Greenwood, 1995). Behavior therapy is as effective, or more effective, depending on the particular measure, than pharmacotherapy (Smith et al., 2002), especially for SOL.

The literature on the treatment of sleep problems in older adults is growing (Ancoli-Israel et al., 1998). The quantity and quality of sleep tend to deteriorate with age (Floyd, Medler, Ager, & Janisse, 2000), although these changes are neither inexorable nor inevitable (Vitiello, 2009), and sleep problems, especially when comorbid with other health problems, are recognized as contributing strongly to reduced quality of life and health in older people (Bloom et al., 2009). The behavioral and cognitive–behavioral treatments we have discussed have been found to be effective in treating insomnia in older adults, although changes to accommodate particular circumstances (e.g., living in residential care) are often required (Ancoli-Israel et al., 1998; Bloom et al., 2009). A meta-analysis of randomized controlled trials of behavioral interventions for insomnia in middle-aged and older people found robust, positive effect sizes for all sleep measures other than total sleep time (Irwin, Cole, & Nicassio, 2006).

Despite this evidence for effectiveness, Harvey and Tang (2003) have expressed disquiet that the effect sizes reported for cognitive–behavioral therapy of insomnia are typically lower than those found for the treatment of anxiety disorders and that a significant minority of clients do not experience clinically significant improvement in symptoms. Morin (2003) has also drawn attention to weaknesses in current research, in particular the absence of a consensus as to what an optimum outcome of insomnia treatment is and the failure to document positive outcomes in domains of quality of life and long-term health benefits. This attention has emphasized the need for more innovative treatment development research into cognitive and behavioral treatments for insomnia (Bootzin et al., 2010; Bootzin & Stevens, 2005). The contribution of single-case research designs to research innovations in the treatment and prevention of sleep problems should not be overlooked (see Volume 1, Chapters 5 and 8, this handbook).

PREVENTION, EARLY INTERVENTION, AND FUTURE RESEARCH NEEDS

The need for early intervention and prevention of sleep problems is acknowledged (Morin, 2010), but overall, the issue has received limited attention. What early intervention and prevention might mean is determined by the context and the age of the individuals concerned. Perhaps because it is conceptually and operationally simpler to define in the context of infancy and childhood, more attention has been paid to prevention of infant and child sleep disturbances than to prevention of sleep disturbances affecting adults. Primary prevention, in this context, means delivering an intervention directed at parents either prenatally or quite soon after the infant is born, with a successful outcome being a clinically significant reduction in the incidence of sleep problems in the treated families, assessed over the 1st year or so of life. Early intervention (sometimes called *secondary prevention*) involves providing an effective intervention soon after the sleep problem is detected so as to prevent it from becoming entrenched or worsening (Kuhn & Elliot, 2003). A related public health perspective requires the widespread and timely provision of information via books, magazines, and TV (Sadeh, 2005), and perhaps elementary treatment (often provided by paraprofessionals in setting such as well child clinics), to achieve a reduction in the incidence of the problem within the target population.

Examples of these approaches exist. Wolfson, Lacks, and Futterman (1992) provided training in infant sleep management to couples attending childbirth classes and reported that at ages 6 to 9 weeks postbirth, their infants were sleeping better than those in the control group (although the group difference disappeared by 20 weeks). Several researchers have provided parents with brief sleep management training when their infants were 2 to 3 weeks old (Symon, 1999, as cited in Kuhn & Elliot, 2003), 3 months old (Kerr, Jowett, & Smith, 1996), and 4 months old (Adair, Zuckerman, Bauchner, Philipp, & Levenson, 1992) and have reported that the intervention reduced sleep problems. Advising mothers about feeding schedules along with the provision of general advice about infant sleep has also been shown to improve infant sleep in the first months of life (Pinilla & Birch, 1993; St. James-Roberts, Sleep, Morris, Owen, & Gilham, 2001), although compliance with the information was typically low (St. James-Roberts et al., 2001). Mindell (1999) concluded that parent education delivered in the 1st year of life meets the Chambless and Hollon (1998) criteria for an empirically well-established treatment.

The context is both more complex and less well investigated in the case of adult sleep problems, in which the opportunity for sleep problems and concomitant difficulties to both develop and be prevented extends over a much larger part of the life span. The exact nature of the problems prevented may well change from adolescence to old age. Sleep hygiene and sleep education has been widely disseminated in popular books, magazine articles, websites, and so forth and is presumably regarded as potentially contributing to primary prevention of insomnia, but it has had little detectable impact (Morin, 2010; Taylor et al., 2008). Research into dissemination of behavioral insomnia treatments via mass media, books, and other self-help methods, the Internet, and the telephone is growing. Reviewing these dissemination innovations, Bootzin et al. (2010) noted that there appears to be a trade-off between widespread dissemination and the magnitude of treatment effects achieved, perhaps related to the lack of careful prior assessment of the problem and the identification of comorbid conditions that remain untreated. Reports of the successful use of behavioral interventions for insomnia in primary health care settings have been increasing (e.g., Goodie, Isler, Hunter, & Peterson, 2009), as have those of the use of abbreviated multicomponent treatments in a range of settings (Bootzin et al., 2010). This research has suggested that a public health approach to prevention of and early intervention with adult insomnia has potential but also that much research is yet needed to achieve consistent effectiveness in prevention or early intervention. Such an approach is certainly warranted given the evidence that few individuals who would benefit from cognitive–behavioral therapy for insomnia are actually offered the treatment (Lamberg, 2008; Morin, 2010).

Other issues that continue to need research attention are the maintenance and generality of insomnia treatments (Morin, 2010). Although outcome data have indicated that the effects of cognitive–behavioral insomnia treatments are reasonably enduring—50% of treated patients are sleeping well at 24-month follow-up (Morin, 2010)—interventions to promote maintenance, such as booster sessions, remain uninvestigated (Montgomery & Dennis, 2004). The generality of the improvement across all the domains of life known to be affected by insomnia remains largely unexplored. Indeed, several commentators have noted that assessment of the outcome of insomnia treatment is hampered by a lack of consensus about what success actually means and by the focus of outcome data on immediate measures of sleep to the neglect of measures of quality of life and remediation of psychological distress (Bloom et al., 2009; Leshner, 2005; Morin, 2010).

CONCLUSION

Children spend on average about 10 hours asleep per night, and adults spend about 7.5 to 8 hours, and so people spend about one third of each day and, therefore, inevitably, one third of their lives, asleep. Given how much people value their lives, that they should spend a third of it inactive and unconscious may seem strange; that people must, because it is in their nature to do so, is something that everyone subjectively understands. Why this is so is not all that well understood, although science has made considerable strides in understanding the biology, physiology, and psychology of sleep.

If sleep people must, and they must, then it is desirable, both individually and collectively, that it should be as good, enjoyable, restorative, health promoting, and life enhancing as one can make it. From the moment of their birth, people's individual sleep affects the sleep of those they sleep near and with, and throughout life others' sleep reciprocally affects one's own sleep (Dahl & El Sheik, 2007). This fact gives people both an individual and a collective interest in the ease, duration, and quality of their sleep. Infants must learn with parental help to regulate their sleep, which lays the foundation for good sleep for the rest of their lives. Acute or chronic disruptions of sleep may be experienced at any age, and they require coping responses and remediation.

Among the many sciences that have contributed to the understanding of sleep, the contribution of the science of behavior analysis is far from negligible. The major sleep problems of infancy, childhood, adolescence, and adulthood have been fruitfully examined from a behavior-analytic perspective, and behavioral and cognitive–behavioral interventions are now recognized as effective treatments for these problems. Indeed, they are the major alternatives to pharmacological interventions (Smith et al., 2002). This achievement is one of which the field of behavior analysis can justly be proud (Bootzin et al., 2010). If sleep is the "chief nourisher in life's feast," as Shakespeare eloquently suggested, then behavior analysis has a role to play in making its benison available to everyone throughout their lives. It would be especially so if behavior analysts began more systematically to focus their knowledge on how to prevent sleep problems from developing across the life span, from infancy to old age.

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Chapter 18

ACCEPTANCE AND COMMITMENT THERAPY: APPLYING AN ITERATIVE TRANSLATIONAL RESEARCH STRATEGY IN BEHAVIOR ANALYSIS

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Acceptance and commitment therapy (ACT; Hayes, Strosahl, & Wilson, 1999) is a behavior-analytic model of intervention and behavior change. ACT is grounded in a post-Skinnerian account of language and cognition, relational frame theory (RFT; Hayes, Barnes-Holmes, & Roche, 2001), that codeveloped with ACT. ACT and RFT are linked to an elaboration and extension of the traditional behavior-analytic model of how best to build and extend psychological knowledge, which we have termed a *contextual behavioral science* (CBS) approach (Hayes, Levin, Plumb, Boulanger, & Pistorello, in press; Vilardaga, Hayes, Levin, & Muto, 2009). In this chapter, we describe the ACT model and enough of the underlying theoretical underpinnings and scientific strategy to place data on its impact and change process in the proper context. We link CBS to the challenges faced by an inductive behavior analytic approach to translational research and system building.

UBIQUITY OF HUMAN SUFFERING, CONFLICT, AND SELF-HARM

In many ways, human beings are a spectacularly successful species in their ability to compete with other species for resources, to protect human populations from predation, and to regulate the environment to their own ends. Despite these successes, human beings in the modern world face a startling amount of emotional suffering and behavioral and social problems that threaten individual and societal health and well-being. An example of the staggering amount of individual suffering can be seen in the National Comorbidity Survey conducted from 2001 to 2003, which estimated that approximately 26.2% of Americans experience a diagnosable psychological disorder within a given year (Kessler, Chiu, Demler, & Walters, 2005) and that 46.4% experience at least one of these disorders in their lifetime (Kessler, Berglund, et al., 2005). The prevalence of psychological problems is probably much higher when one considers the number of individuals struggling with subclinical problems and adjustment issues, such as divorce, violence, stress, loss of a loved one, abuse, and substance use problems, among many others. Physical health problems linked to unhealthy behavioral patterns are also highly prevalent. For example, rates of obesity have been steadily increasing in the United States, with current estimates showing that approximately 32.2% of U.S. adults are obese (Ogden et al., 2006). When one considers these behavioral problems as well as others such as environmental issues and global climate change, violence, prejudice, inequities in the distribution of wealth, poverty, disease, inadequate health care, and poor education, the need for a more adequate behavioral science is obvious.

BROAD VISION AND NARROWING SCOPE OF BEHAVIOR ANALYSIS

Behavior analysis represents an attempt to develop a comprehensive science of behavior that addresses these challenges. A behavior-analytic approach is humble in that it seeks to identify principles of behavior in research laboratories and apply them to

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the prediction and influence of behavior. Observations of environment–behavior interactions in tightly controlled basic research studies are abstracted into broadly applicable yet precise principles. The ultimate goal of behavior analysis is bold: to develop a psychology adequate to the challenge of the human condition. Thus, basic research is part of an overall inductive strategy that seeks to rise to the challenge of even the most profound human difficulties.

The original scope and aim of behavior analysis can be seen in B. F. Skinner's writings. His utopian novel *Walden Two* (Skinner, 1948) highlighted the importance to a science of behavior of such complex issues as politics, morality, social equality, and education. The value of such a book is not the design of a specific form of society (see Skinner's introduction to the book) but rather the provision of an example of how scientists might rise to the challenge of these issues. It was a bold statement of a goal for his science: "Our culture has produced the science and technology it needs to save itself" (Skinner, 1971, p. 181). Unfortunately, in the 40 years since, behavior analysis, both basic and applied, has had its impact primarily in a narrow band of problem areas. In the applied domain, behavior analysis is truly mainstream only in the areas of special education and developmental disabilities (e.g., Charlop-Christy, Carpenter, Le, LeBlanc, & Kellet, 2002; LeBlanc et al., 2003).

In the traditional behavior-analytic narrative, behavior analysis has the behavioral principles and applied behavioral technology needed to move toward its lofty goals (Skinner, 1971). In this way of thinking, the lack of impact of behavior analysis on mainstream issues is not the result of technological or conceptual limitations and barriers, but political. Indeed, late in his life Skinner, in conversation with Paul Chance, held out only one hope for changing this picture: "winning over a substantial number of influential people—educators, writers, journalists, scientists, and scholars—who might then pressure policy makers to take effective action" (Chance, 2007, p. 158).

ORIGIN OF ACCEPTANCE AND COMMITMENT THERAPY

ACT developed within behavior analysis in the late 1970s and early 1980s (e.g., Hayes, 1984; Zettle & Hayes, 1982, 1986). ACT/RFT developers attempted to understand and apply Skinner's concept of rule-governed behavior (Hayes, 1989) and made some progress in viewing clinical phenomena that way (e.g., Zettle & Hayes, 1982). Yet, they kept coming back to the fact that no adequate definition of *rule-governed behavior* existed. Skinner defined *rules* as contingency-specifying stimuli, but there was no definition of what *specifying* means and how it develops (Parrot, 1983). ACT/RFT developers concluded that they needed a new and more robust contextual behavioral account of human language and cognition that could lead to empirical advances, both basic and applied.

At the same time, behavior therapy was becoming cognitive–behavioral therapy on the basis of the perceived inability of behavior therapy to deal effectively with the problems of cognition displayed by clients. The theories of cognition, however, were based on an information-processing model and systematic observations made in clinical work (Beck, 2005) rather than on basic behavioral science. Given the utility of the behavior-analytic approach, ACT/RFT researchers thought this abandonment of behavioral principles was too high a price to pay. They tested these early cognitive theories to see whether they explained the impact of early cognitive–behavioral therapy methods or whether there were alternative explanations consistent with principles of behavior discovered in basic science laboratories. For example, the possible effect of self-statements on therapeutic change were shown to not be the result of cognitive reappraisals but of the effects of socially mediated contingencies of reinforcement (Hayes & Wolf, 1984; Rosenfarb & Hayes, 1984; Zettle & Hayes, 1983). Bandura's (1973) notion of modeling was challenged by showing the important role of sensory reinforcement in children with aggressive behaviors (Hayes, Rincover, & Volosin, 1980), and researchers explored a behavioral account of how self-monitoring produces improvements in mood symptoms in contrast with existing cognitive accounts of this phenomena (Harmon, Nelson, & Hayes, 1980). Researchers also looked at the importance of experiential feedback versus instructions in treating social skills deficits in adults (Rosenfarb, Hayes, & Linehan, 1989). The findings from these studies led them to abandon cognitive theory and seek another way forward.

The first alternative analyses (e.g., Hayes, 1984) and basic and applied studies (e.g., Devany, Hayes, & Nelson, 1986; Zettle & Hayes, 1986) that led to ACT and RFT appeared in the early to mid-1980s (see Zettle, 2005, for a history of ACT). For example, Zettle and Hayes (1986) found that comprehensive distancing, an intervention based on an analysis of verbal social contingencies and the predecessor to ACT, produced significantly greater improvements in depression than traditional cognitive therapy. Devany et al. (1986) found that children with language disabilities did not form stimulus equivalence classes under conditions in which mental age–matched children without language disabilities were able to, which provided initial support for the idea that derived stimulus relations support the development of language abilities (subsequent research has largely confirmed that relationship; e.g., see Vause, Martin, Yu, Marion, & Sakko, 2005, but not the idea that language abilities lead to equivalence or other derived relations, which RFT from the beginning explicitly rejected). Because the results from early studies such as these proved empirically positive, outcome studies on ACT were put on hold for nearly 15 years while the basic account and strategic approach was developed. In 1999, the first ACT volume appeared (Hayes, Strosahl, & Wilson, 1999), followed 2 years later by the first RFT volume (Hayes, Barnes-Holmes, & Roche, 2001).

To understand ACT, one must understand its philosophical assumptions, basic principles, and approach to system development—that is, to consider what transpired in that 15-year gap. To that topic, we now turn.

CONTEXTUAL BEHAVIORAL SCIENCE: THE UNDERLYING SCIENTIFIC STRATEGY IN ACCEPTANCE AND COMMITMENT THERAPY AND RELATIONAL FRAME THEORY

The ACT–RFT approach to system building represents a somewhat distinct scientific development strategy that we call a *CBS approach* (Hayes et al., in press; Vilardaga et al., 2009). This strategy is based on, but also extends, traditional behavior analysis.

Functional Contextualism: The Philosophical Foundation of Acceptance and Commitment Therapy and Relational Frame Theory

Philosophical assumptions, such as how truth is defined and the unit of analysis, provide the bases for any scientific approach. These assumptions are frequently left unexamined in mainstream psychological research, but that just means that the assumptions underlying such research are unexamined, not that the research is being conducted without assumptions. Because the assumptions underlying behavior analysis are not mainstream, specifying these assumptions is part and parcel of the behavior-analytic approach (e.g., Skinner, 1974).

RFT and ACT are rooted in a particular philosophy of science known as functional contextualism (Hayes, Hayes, & Reese, 1988). Although functional contextualism differs in some of its details from radical behaviorism (especially in its explicit rejection of ontological claims, its emphasis on the a priori nature of analytic goals, and the details of its specific goals), we have argued that these assumptions make best sense of behavior analysis itself (Hayes et al., 1988). Well-known behavior analysts have disagreed, however (e.g., Marr, 1993; M. R. Ruiz & Roche, 2007), so it is more conservative to say that the assumptions of functional contextualism provide the foundation for CBS and ACT–RFT more specifically and for those in behavior analysis who agree with these modifications.

Functional contextualism defines *truth* to mean that an analysis is useful in meeting one's goals. Functional contextualists adopt as their scientific goal the prediction and influence, with precision, scope (breadth of application), and depth (coherence across levels of analysis), of the behavior of whole organisms interacting in and with a context considered historically and situationally. Prediction and influence is a unified goal—both are necessary. Thus, any analysis is true insofar as it is useful for predicting and influencing behavior and doing so in a way that applies precisely to the phenomena at hand, applies to phenomena within a specified range, and coheres across levels of analysis (e.g., biology, psychology, anthropology).

Functional contextualism is consistently disinterested in ontological truth claims, preferring to stay connected to pragmatic truth and what is useful in achieving a given purpose. One benefit of this shift is an increased flexibility in the terms and methods used. A term or methodological approach can be "correct" insofar as it serves the purpose of the analysis in one context, whereas another term or approach may be useful in another.

A science of prediction and influence requires a particular focus on manipulable controlling variables (Hayes & Brownstein, 1986). Behavior itself is never directly manipulated. What is manipulated is, and can only be, the context of behavior. Causality is viewed as a way of speaking about how to accomplish goals, not as an ontological event, and relative to the goals of functional contextualism, behavior can never cause another behavior within the same individual because influence can only be conclusively demonstrated through manipulation. Thus, despite the fact that behavior and context are part of a dynamic interaction and one cannot be defined without the other, only context can be considered causal in a functional contextual approach.

These philosophical features are fundamental to the ACT clinical model itself. For example, values define what *workability* means, and whatever is true for one's clients is pragmatic, not literal. That will become clearer as we describe ACT.

Overview of Relational Frame Theory

The earliest work on ACT was based on Skinner's (1969) concept of rule-governed behavior, but researchers soon realized that to understand what a rule was, it was necessary to understand what a verbal stimulus was. Viewing verbal stimuli to merely refer to the product of verbal behavior did not seem functionally adequate. RFT eventually provided a conceptually and empirically adequate answer.

The core idea behind RFT is that people learn to relate events in different ways, mutually and in combination, not simply on the basis of their formal properties but on the basis of arbitrary contextual cues. Young children will initially learn, for example, that a nickel is larger than a dime on the basis of their formal properties. At the point at which "larger than" becomes arbitrarily applicable, that same comparative response can be controlled socially regardless of the form of related events—for example, a dime can be larger than a nickel. These mutual comparisons can be arranged into a set of relational responses—what is said in noun form to be a *relational network*—as when a child learning that a dime is smaller than a quarter can derive that a quarter is larger than a nickel. If a nickel is valuable because the child can use it to buy candy, a dime will likely now be more so, and a quarter even more so by derivation.

From an RFT perspective, all of this occurs because the child has acquired relational operants: classes of arbitrarily applicable relational responding established originally through multiple-exemplar training and brought under arbitrary contextual control. These classes are termed *relational frames*. This approach provided an answer to the question of the nature of verbal stimuli—they are stimuli that have their effects because they participate in relational frames—but it did so much more clinically and in application.

Relational framing skills have an enormous impact on human functioning. Humans can derive a wide variety of types of relations among events (e.g., Berens & Hayes, 2007; Dougher, Hamilton, Fink, & Harrington, 2007; Dymond & Barnes, 1995; Dymond, Roche, Forsyth, Whelan, & Rhoden, 2007; Hayes, Kohlenberg, & Hayes, 1991) that allow for novel responses to occur without a direct learning history. This ability to derive relations expands the potential impact of learning histories: Two learned relations (i.e., $A > B$, $B > C$) can provide an additional four derived relations (i.e., $B < A$, $C < B$, $A > C$, $C < A$), three trained relations can lead to nine derived relations, and so on.

Relational framing is also known to interact with direct learning processes such as operant and classical conditioning. For example, a study by Dougher et al. (2007) trained some adults and not others that stimulus A was less than stimulus B and stimulus B was less than stimulus C. Next, a shock was paired with stimulus B. For both groups, stimulus A produced a smaller skin conductance response than did B, but only for the relationally trained group;

C tended to produce larger responses than B despite the absence of any history of shocks in the presence of C. In other words, the stimulus functions of C were transformed on the basis of its participation in a comparative frame with stimulus B. Studies have shown such transformations with other stimulus functions. Events can acquire discriminative-like functions by their relations to discriminative stimuli, but without the history that meets the technical definition of a discriminative stimulus (Dymond & Barnes, 1995); the same is true of reinforcers (Hayes et al., 1991). Other functions, such as learned avoidance, are altered and transformed via relational frames (Dymond et al., 2007). The fact that relational responses are contextually controlled by arbitrary and nonarbitrary cues is important. If relational responding was not contextually controlled, then the number of derived relations and functions would quickly become overwhelming. A stimulus such as the printed word *bat* would evoke a countless number of derived relations to other stimuli (e.g., baseball, vampires, flying mammals), which would evoke even further relations (e.g., sports, monsters, other mammals). Similarly, the transformation of functions produced through relational frames is also contextually controlled. Experiencing sourness or salivation in response to the contextual cue "How does a lemon taste?" can be substantially different from what the same person might experience in response to the contextual cue "How does a lemon feel in your hands?" The words *taste* and *feel* serve as a context that cues a specific transformation of stimulus functions—without this contextual control, all of the functions would transfer or be transformed, and people would eat the written words *ice cream* or run from the written word *tiger*.

Research has provided support for the idea that derived relational responding is an operant. Initially, this evidence was somewhat indirect, such as in studies demonstrating that relational operants develop over time (Lipkens, Hayes, & Hayes, 1993), are contextually controlled (Dymond & Barnes, 1995), and can come under antecedent and consequential control (Healy, Barnes-Holmes, & Smeets, 2000; Roche, Barnes-Holmes, Smeets, Barnes-Holmes, & McGeady, 2000). In more recent years, several studies have provided more convincing evidence by training relational operants through reinforced multiple exemplars, as would be expected of any operant (e.g., Barnes-Holmes, Barnes-Holmes, Smeets, Strand, & Friman, 2004; Berens & Hayes, 2007).

RFT has been applied to account for a range of complex verbal behaviors including analogical reasoning (Lipkens & Hayes, 2008; Stewart, Barnes-Holmes, Roche, & Smeets, 2002), prejudice (Weinstein, Wilson, Drake, & Kellum, 2008), spirituality (Hayes, 1984), education (Barnes-Holmes & Barnes-Holmes, 2001), self and perspective taking (McHugh, Barnes-Holmes, & Barnes-Holmes, 2004), and psychopathology and intervention (Barnes-Holmes, Barnes-Holmes, McHugh, & Hayes, 2004). Over time, this contextual behavioral account of language and cognition significantly changed how ACT treatment developers thought about applied problems and their amelioration.

How Verbal Processes Contribute to Human Suffering

The RFT account of language and cognition may provide insight into why so much human suffering occurs. In the sections that follow we explore ways in which verbal processes may contribute to human suffering, such as by increasing contact with aversive stimulus functions; narrowing behavioral repertoires; and producing rigid, ineffective patterns of behaviors based on rules and a verbally constructed sense of self.

Increased contact with aversive stimulus functions. The ability to derive relations among stimuli on the basis of arbitrary contextual cues leads to an increased probability of contacting distressing stimuli. For example, in a relational frame of comparison, a child may be praised for an achievement but be upset because the praise is not as effusive as was hoped for. Simple equivalence relations can allow clients to "reexperience" the events of a trauma when describing it (i.e., the trauma elicits negative feelings and later verbal descriptions of the trauma, being in a frame of equivalence with the trauma, elicit some of the same negative feelings). Even positive stimuli may be related to aversive stimuli indirectly through a complex network of such relational responses. For example, one may be reminded of the loss of a loved one by seeing a spectacular sunset that cannot be shared.

Narrowing of behavioral repertoires and experiential avoidance. Aversive control of behavior tends to narrow a behavioral repertoire because only a limited set of actions is likely to lead to reduction in aversive stimulation (i.e., escape or avoidance). The expansion of aversive stimulus functions through relational frames thus leads easily to narrowing of behavioral repertoires. This narrowing is particularly likely because the capacity to verbally identify a problem, predict the likely effects of several potential solutions, and select an option that is likely to achieve the desired outcome is probably a key evolutionary reason for the development of relational framing skills. However, once aversive private events are identified as bad experiences to be avoided, problem-solving skills can become focused on efforts to reduce the form, frequency, or intensity of emotions, thoughts, memories, or other private events. Because of the arbitrary applicability of relational framing, a vast number of stimuli must be avoided to evade distressing experiences. In addition, problem solving allows one to predict the occurrence of "bad" private events in situations that have never been directly encountered, leading to avoidant behavior occurring without any direct learning history and in cases in which aversive stimulation may not occur. This application of problem solving to private events can thus lead to a substantial narrowing of one's life in which one rigidly engages in ineffective patterns of avoidance and escape behaviors.

The tendency to engage in narrow, rigid patterns of behavior attempting to control the form, frequency, or intensity of distressing private events is described in ACT as *experiential avoidance.* These behaviors often produce a range of negative consequences and even a paradoxical increase in the private events that one attempts to control. For example, research has consistently found that thought suppression, although sometimes effective for short periods of time, produces a paradoxical increase in the avoided thought (Abramowitz, Tolin, & Street, 2001). Similarly, the use of suppression strategies has been found to increase reactivity to difficult tasks (Cioffi & Halloway, 1993; Levitt, Brown, Orsillo, & Barlow, 2004), reduce recovery from distress (Cioffi & Holloway, 1993; Masedo & Esteve, 2007), and increase the behavioral impact of distress (Masedo & Esteve, 2007). Experiential avoidance has been found to predict negative consequences in areas such as depression, anxiety, and chronic pain (Hayes, Luoma, Bond, Masuda, & Lillis, 2006).

RFT provides a potential account for why attempts to control private events are unlikely to be successful. First, rule-governed behavior can paradoxically increase the occurrence of the event because avoidance rules specify the stimulus to be avoided. For example, the rule "Don't think about a jelly doughnut" involves stating the rule and checking on the efficacy of the rule ("Did I think about the jelly doughnut?" or even "I'm doing good at not thinking about a jelly doughnut"). Just as the reader may be imagining the sight of a jelly doughnut (and perhaps salivating a bit more), the individual using this rule is likely to experience the same; and if this rule is used as a dieting tool, it is likely to fail. Likewise, when rules such as "You must not feel anxious" produce increased anxiety, the failure may evoke an increase in the emotion, such as having anxiety about being anxious or feeling depressed about being depressed.

Experiential avoidance can serve to further elaborate the network of relations to the aversive stimulus. Behaviors engaged in to control the private event can themselves become associated with it. For example, the rule "Watch TV so you don't think about how worthless you are" establishes a relation between TV watching and the thought "I'm worthless." Future TV watching may evoke thoughts of worthlessness as a result. In addition, engaging in avoidance behavior strengthens the future behavior regulatory effects of the private event and reinforces the maladaptive verbal processes that specify the event as a harmful experience that must be avoided.

Fusion and rule governance. Rule-governed behavior is frequently characterized by a relative insensitivity to programmed contingencies (Hayes, 1989). It is not that rule-governed behavior is inherently insensitive to consequences—it is that rules easily introduce social or other contingencies and can narrow the range of behavior available to contact changed consequences of responding (Hayes, Brownstein, Haas, & Greenway, 1986; Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986). This is not as true of directly shaped behavior (Shimoff, Catania, & Matthews, 1981).

The problem is that formulations of verbal rules can occur without strong environmental support—even self-rules can reduce sensitivity to direct consequences of responding (e.g., Rosenfarb et al., 1989). Relational framing can dominate over other sources of behavioral regulation, a process ACT theorists have termed *cognitive fusion*. Cognitive fusion can focus attention more on the past and future and less on the present, because problem-solving rules generally require an analysis of the past and predictions of the future, but this focus can further limit sources of effective contingency-shaped behaviors. These effects may help explain why measures of cognitive fusion (e.g., Avoidance and Fusion Questionnaire for Youth [Greco, Lambert, & Baer, 2008], Automatic Thoughts Questionnaire—Believability [Zettle & Hayes, 1986], Stigmatizing Attitudes—Believability [Hayes et al., 2004]) have consistently been found to predict poor psychological outcomes.

Dominance and rigidity of a verbally constructed sense of self. Literal language processes can also have negative consequences when they are overapplied to the self. A *conceptualized self* can be defined as the discrimination of an individual's own behavior in terms of his or her verbally constructed self-descriptions and evaluations. In RFT terms, this means that a relational network is established specifying the various qualities, abilities, and other features of self. A likely reinforcer for this process is the coherence of the story. This story becomes something that subsequently needs to be defended to maintain the coherence of one's verbally constructed past and future, even if it comes at the loss of more effective responses that would counter the story. Thus, a conceptualized self can lead to rigid, ineffective rule-governed behavior. RFT further adds to these areas by providing an analysis of how these effects might be changed, a topic to which we now turn.

Verbal Processes That Support Effective Behavioral Repertoires

RFT points to how human suffering is a natural result of normal language processes, but that alone is not much of a contribution. What makes RFT important is that it (a) cautions against commonsense interventions to reduce the negative impact of verbal processes and (b) suggests interventions that might be more helpful. For example, a commonsense approach to the negative impact of verbal rules would be to correct the rules. RFT, however, suggests that could be dangerous. There is no process in learning called *unlearning*—extinction inhibits past learning; it does not erase it—and changing a rule, even if successful, may leave the original learning intact and further increase cognitive fusion and rule governance in other domains. Moreover, it would elaborate the relational network. Consider a person with the thought "I'm bad" who is told to replace that thought with "No, I'm not because I [list positive things]." This will not eliminate "I'm bad" from the repertoire; it will merely embed it into a large set of relational responses. If the goal is new actions (e.g., creating meaningful relationships), that may be unhelpful.

RFT suggests an alternative exists. In RFT, some contextual factors control the derivation of relations (the relational context), and a different set of contextual factors regulate the transformation of stimulus functions (the functional context). A behavioral analysis of language and cognition requires not only the identification of the contextual cues that lead to the emission of specific forms of relational responding but also to contextual cues that lead to specific behavioral functions. A working knowledge of these contextual factors can inform methods of intervention. The dominant and ineffective impact of verbal processes on behavior is thought to be controlled by contexts of literality and reason giving. These contexts can themselves be changed. Thus, RFT suggests that in many cases, the key would be to diminish the impact of verbal stimuli by altering the social and verbal context. A host of possible methods can do this—methods that are used in ACT. For example, a person struggling with the thought "I'm bad" might sing it as an opera, say it over and over quickly, or say it in the voice of a cartoon character.

These methods alter the contexts in which "I'm bad" has aversive or repertoire-narrowing functions.

In much the same way, experiential avoidance is argued to be supported by particular contexts such as using emotions as a reason for behavior. In everyday verbal interactions, private events are often cast as problems that need to be solved by attempting to change their form, frequency, or intensity. Alternative contexts can be established in which private events are less tightly linked to overt behavior. Acceptance and mindfulness of private events is such a context, and we discuss it further in the following sections.

Verbal behavior can also be used to enhance or alter reinforcers. *Motivational augmentals* refer to cases in which the reinforcing value of a stimulus is temporarily increased through participation in relational frames. Verbal behavior can make remote consequences seem more proximal or probabilistic consequences seem more important. Values statements are examples of such verbal establishing operations (Cohen, Garcia, Purdie-Vaughns, Apfel, & Brzustoski, 2009; Elliot & Harackiewicz, 1996; Sheldon & Elliot, 1999).

A unique property of relational framing is the ability to take perspective on oneself and to take the perspective of others. RFT has termed this form of relational framing as *deictic framing,* which refers to the fact that to make accurate and consistent distinctions between I–you, here–there, and now–then, one always needs to take the perspective of a speaker. These frames are abstracted through multiple exemplars (e.g., "What are you feeling now?" or "What was she feeling then?"), and they have implications for social functioning and psychopathology. For example, deficits in deictic framing ability are related to the autistic spectrum (Rehfeldt, Dillen, Ziomek, & Kowalchuk, 2007) and to social anhedonia (Vilardaga, Estévez, Levin, & Hayes, in press; Villatte, Monestes, McHugh, Freixa i Baqué, & Loas, 2008), which is one of the known predictors of psychosis (Chapman, Chapman, Kwapil, Eckblad, & Zinser, 1994). Deictic verbal cues can be deliberately used in ACT with the aim of improving social relationships and at the same time foster a more integrated and flexible sense of self and others.

DEVELOPING A THEORETICAL MODEL OF PATHOLOGY, INTERVENTION, AND HEALTH TIGHTLY LINKED TO BASIC PRINCIPLES

Before we proceed to describe ACT, a key aspect of a CBS approach is worth mentioning. In the original vision of traditional behavior analysis, technical terms developed in basic research are used for the prediction and influence of behavior. Parenthetically, *influence* is a clearer term here than the usual term *control* because *control* means both change in behavior and elimination of variability, whereas *influence* has only the former connotation. A CBS approach envisions a more reticulated process in which basic and applied principles coevolve. For that to happen, however, user-friendly analyses are needed that practitioners can access without fully grasping the details of the basic account, while a smaller number of scientists work out technical accounts in these domains on the basis of their mutual interest.

The clinical model that underlies ACT is made up of what we call *mid-level terms.* They are not themselves technical terms but are linked to a technical account, and they orient practitioners to a domain of behavioral functions. A model composed of mid-level terms provides the scaffolding for the development of treatment interventions while linking a practitioner-friendly account to basic behavioral science.

Psychological Flexibility Model

The psychological flexibility model serves as the unifying conceptual system for ACT at an applied level. It is based on six key processes—defusion, acceptance, present moment, self-as-context values, and committed action—that are behavioral activation processes (see Figure 18.1). In what follows, we provide a review of these processes and highlight how the implications of RFT form a coherent model of psychopathology and intervention. We provide a case example to summarize how these processes are applied in therapy. We reserve empirical evaluation of each of these components of ACT for the section that follows.

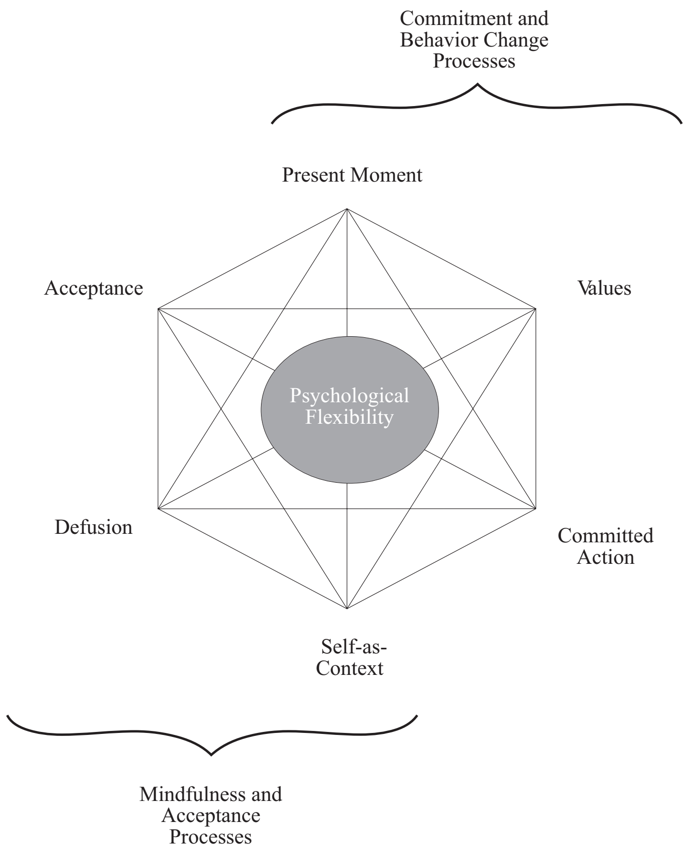

FIGURE 18.1. The acceptance and commitment therapy intervention model.

Defusion. *Defusion* interventions seek to reverse the harmful effects of cognitive fusion (see Fusion and Rule Governance section) by attempting to reduce the literal, evaluative functions of language. This reversal is accomplished by manipulating the functional contexts that control the transformation of stimulus functions produced through relational frames. In the client's daily life, the functional context is one in which evaluative statements are literally true. The ACT therapist seeks to disrupt this context so that thoughts are regarded as behavior (e.g., "I'm talking to myself about being worthless") instead of accurate descriptions of the world (e.g., "I really am worthless"). In other words, the emphasis is shifted from the products of verbal behavior (i.e., literal functions of verbal stimuli) to the process of verbal behavior, which differs from traditional cognitive therapies that seek to alter the content or frequency of verbal behavior (Beck, 1976). At the end of a successful defusion intervention, the form of verbal behavior may be unchanged (i.e., the client will still have thoughts of worthlessness), but the impact of these private stimuli will be significantly altered.

Defusion interventions do not seek to completely disrupt the literal functions of language; doing so would leave the client unable to function in human society. Instead, these interventions seek to bring relational responding under more flexible contextual control. Clients learn to engage with the verbal products of language insofar as they are helpful while being able to disengage from this process and remain sensitive to other stimuli in the environment as indicated, supporting more flexible behavioral repertoires.

One defusion intervention technique involves undermining contexts that support the literal functions of language, such as the therapist responding to clients' statements as though they are true and valid or, alternatively, need to be argued against and changed. Therapists may not respond to clients' explanations for events as actual justifications for behavior or as coherent stories. Instead, a therapist may repeatedly ask "Why?" to highlight the ultimately arbitrary nature of reasons or simply state "Thank your mind for that thought." Similarly, rather than focusing on the content of a story, therapists may comment on the process of fusion with literal functions of language, such as by saying, "It sounds as though your mind is really trying to figure this out." Other exercises involve engaging in behaviors that directly contradict one's thoughts, such as walking around the room while saying "I can't walk."

Interventions may seek to establish contexts that highlight the direct stimulus functions of language. For example, a client may be prompted to say a difficult thought in a funny voice, sing it, repeat it over and over again, or write it down. These acts serve to highlight direct stimulus functions of verbal behavior such as the sound of the words rather than their derived functions.

Acceptance. *Acceptance* interventions involve altering the repertoire-narrowing effects of experiential avoidance by establishing an alternative context in which difficult private events are actively experienced as part of a pattern of valued actions. The ACT therapist manipulates the context to disrupt the functional relation between avoidant behavior and the termination or prevention of aversive private events. In the modified context, the client is encouraged to experience the private events without attempting to control their occurrence. This acceptance process seeks to increase contact with the direct stimulus functions of private events while disrupting their verbally derived (e.g., mutually entailed) functions. Thus, acceptance interventions overlap and interact with defusion interventions. For example, clients learn to accept that they are having a thought such as "I am worthless" (i.e., *thought* is a verbal descriptor of the antecedent private event) without buying into the content of the thought (i.e., saying "I am worthless" does not entail that the client is, in fact, worthless). This aspect of acceptance serves to avoid similar ineffective, narrow patterns of behavior that may occur when the client surrenders to or wallows in private events. Instead, acceptance interventions seek to develop broad, flexible behavioral repertoires while the client remains in contact with difficult private events.

Acceptance is not the same as temporarily tolerating aversive experiences or setting a limit to what one is willing to experience. Engaging in experiential avoidance after a private event becomes too distressing may serve to maintain the avoidant functions of these private events. Rather, acceptance involves a full, active embrace of private events, no matter how distressing or how strong the urges are to avoid, dissociate, or otherwise control their occurrence. Acceptance also does not involve intentionally seeking to evoke distressing private events for their own sake. Rather, it is a process of embracing the private events that naturally occur as a result of the client's history and current context. In particular, acceptance interventions target the difficult private events that can sometimes act as barriers to engaging in valued actions. Often, the most important parts of an individual's life are also those that can evoke the most distressing thoughts, memories, emotions, and urges. It is precisely because one values a set of reinforcers that their potential loss is so painful. Acceptance is thus targeted in service of engaging in a valued life rather than just for the sake of acceptance in its own right.

Given that clients often have a long history of engaging in experiential avoidance, therapy typically includes spending a significant amount of time guiding clients to notice various behaviors that serve an experiential avoidant function and to examine the workability of this approach, both in terms of reducing the aversive private events and of living the life they want to live. One method of achieving this is creative hopelessness, which begins with the counselor compassionately guiding clients to describe the various ways they tried to solve their problem (e.g., anxiety, depression, worry, unwanted thoughts, urges or cravings to use substances). In the process, a range of experiential avoidance strategies are often identified and found to be not working in relation to the client's goals. Similarly, the client's behaviors in session, such as asking the therapist whether he or she has a suggestion for something different, can be identified and explored as other ways the client has tried to solve the problem and found it has not worked. This intervention seeks to leave clients in a place in which they feel hopeless about the approach they have taken to solving their problem (i.e., experiential avoidance), but in such a way that they feel supported, curious, and open to what is to come in therapy. This intervention serves to establish a framework in which acceptance can be explored as a viable alternative to experiential avoidance.

As a functional process, any intervention technique can be used that establishes a context in which difficult private events are intentionally experienced without engaging in control strategies. Traditional exposure technologies are sometimes useful in this regard, although less effort is directed toward reducing client distress. Instead, the ACT therapist will help the client to establish a broader, more flexible behavioral repertoire while remaining in contact with the difficult private events. This broader repertoire may include being sensitive and able to shift attention to other stimuli in the environment besides the aversive private event and engaging in behaviors independent of whether they increase or decrease the occurrence of the private event. During acceptance interventions, the client is encouraged to interact with a thought, feeling, or sensation in a variety of ways without trying to control it, such as by engaging in suppression, avoidance, or cognitive reappraisal.

Present moment. Contact with the present moment is encouraged in ACT as a means of increasing the probability that the client's behavior will be influenced by a broader range of stimuli and contingencies while reducing the dominance of verbal functions over behavior. Cognitive fusion with a verbally constructed past or future serves to reduce contact with events occurring in the present, which can contribute to ineffective and destructive patterns of behavior that are insensitive to stimuli and consequences occurring in the environment because derived stimulus functions may overwhelm the clients' capacity to contact these other important sources of behavioral control. A goal of ACT is to assist the client in achieving a continuous, nonjudgmental awareness of internal and external events that can serve to support more flexible, effective patterns of behavior.

In particular, interventions seek to establish a flexible yet focused attention to events occurring in the present moment. Flexible attention to events in the moment without focus is less effective because it is equivalent to being easily distracted. Alternatively, focused but inflexible attention can be similarly problematic and may manifest as hypermonitoring of physical sensations or other particular cues in the environment. Rather, present-moment interventions seek to support a focus on important stimuli in the environment, yet one that can shift as necessary to support flexible behavioral repertoires.

Interventions may target present-moment contact by shaping the use of language to simply describe the direct properties of stimuli, particularly private events, rather than verbally derived features such as evaluations and predictions. Therapists may also help clients to notice the workability of patterns of behavior as a means of enhancing contact with direct contingencies. Rigid patterns of attention, such as to potential evaluations from others or to particular physical sensations, may be identified and directly targeted for change. Present-moment contact is often targeted in the context of the therapeutic relationship (Wilson & Dufrene, 2009). However, more structured interventions such as contemplative mindfulness meditation practices (e.g., breathing mindfulness) may also be used.

Self-as-context. *Self-as-context* refers to a sense of self as a perspective or observer, experientially distinct from the content of experiences. The term *context* refers to the notion that the discrimination of one's own behavior as organisms, and thus one's self (Skinner, 1974), is bound to historical and current circumstances and not solely to momentary private experiences. ACT therapists aim to foster this sense of self by providing multiple exemplars of deictic relational cues, resulting in a more contextualized self. For example, the client may be asked to attend to the historical or current course of his or her thoughts and emotions (i.e., multiple exemplars of "How did you feel then and there?" "How do you feel here and now?" "How will you feel there and then?"), noticing that across their constant fluctuations there has always been an invariant, which is the perspective or point of view of a speaker or listener. This expansion of self-awareness and the discrimination of this more stable sense of self provide a more adequate contextual control over the transformation of functions of derived entailments possibly occurring at any given moment. The result is an experience of self as unchanging and independent from one's momentary self-conceptualizations and emotions. In that way, a given thought or emotion does not take control over an individual's behavior; instead, the thought or emotion is experienced within a much larger context. In other words, the individual takes a newer perspective with regard to his or her own private events.

Self-as-context can empower the other ACT processes. Often, the distinction between private events and one's larger sense of self are unclear. Approaching distressing emotions in an accepting manner can be difficult without drawing a distinction between a more contextualized sense of self and the emotion. Without this distinction, the emotion can be experienced as more threatening. Clients may describe themselves as lost in the emotion because they are unable to discriminate the emotion from other aspects of experience. Clients may also become fused with a more narrowly constructed sense of self, seeing their thoughts and feelings as who they are. Increasing contact with a sense of self-as-context can support defusion by highlighting the distinction between self and thoughts and reducing attachment to a conceptualized self.

Interventions typically seek to establish a sense of self-as-context through deictic manipulations. Experiential exercises may focus on discriminating a contextualized sense of self as distinct from momentary private events. They often highlight noticing the perspective from which other experiences are observed. For example, attention may be shifted to various thoughts, feelings, and sensations, noting how each is distinct from the perspective from which they are noticed. These exercises may include complex perspective-taking manipulations that integrate manipulations of the deictic frames I–you, here–there, and now–then. A flexible deictic framing repertoire is developed to assist in abstracting a more complex sense of I–here–now.

Values. *Values* refer to chosen, desired qualities of action that can be continuously instantiated in ongoing patterns of behavior and are never completed as a distinct goal. These verbal constructions function as both formal and motivational augmentals, establishing and enhancing the reinforcing properties of temporally extended patterns of behavior (see Volume 1, Chapter 20, this handbook), providing a positive reinforcing counterpart to the dominance of aversive control produced through language processes. The relevant qualities of ongoing behavior can be abstracted and related to chosen values, augmenting or establishing their reinforcing properties. Behavior can thus be brought partially under the control of verbally constructed consequences, increasing the capacity to engage in behavior despite aversive consequences in the moment.

Values-consistent behavior is a form of rule-governed behavior. However, because these rules specify abstract qualities rather than specific behaviors and are not reliant on a particular outcome, they tend to support more flexible behavioral repertoires than other forms of rule-governed behavior. The flexibility and reinforcement provided with values tends to produce behavior that is likely to be maintained over time.

Values establish the motivational context for the other ACT processes, providing a direction for intervention. Patterns of behavior are generally evaluated in terms of their workability in relation to one's values. Processes such as acceptance and defusion are applied insofar as they support values-consistent action. Similarly, processes that act as barriers to values, such as experiential avoidance, can be targeted in this context.

Techniques are used to assist in clarifying clients' values when relevant. Valued qualities of action may be explored in specific life domains, and clients may be instructed to track patterns of behavior that they regard as valuable to assist in abstracting chosen values. Interventions also seek to identify and disrupt verbal processes that support avoidance, pliance (rule-governed behavior mediated by social reinforcement for coordination between behavior and rule), and fusion. For example, a client may indicate that he or she values avoiding private events ("I value feeling comfortable") or complying with the wishes of others ("I should value helping others because my parents want me to"). These forms of rule-governed behavior are primarily under aversive control or arbitrary social contingencies and are likely to be rigid and ineffective. Treatment thus seeks to undermine these processes while clarifying chosen values.

Committed action. *Committed action* involves the process of building larger and larger patterns of effective action linked to chosen values while breaking ineffective patterns. This process integrates direct contingency analysis and is similar to traditional behavioral interventions. The direct contingencies that play a role in these behavioral patterns are leveraged through interventions such as exposure, contingency management, goal setting, and skills training. Barriers related to verbal processes are targeted through the other ACT processes as relevant.

Psychological flexibility. *Psychological flexibility* is the ability to engage or disengage in behavior in the service of chosen values and to contact the present moment as a fully conscious being. It represents the culmination of the six aforementioned ACT processes and is the ultimate goal of treatment. Thus, as opposed to some other treatment approaches, the goal in ACT is not symptom reduction or alleviation of distress; it is building up effective patterns of action linked to chosen values, even when distress and symptoms occur.

Case Example

To further illustrate how these processes are applied to case conceptualization and treatment in ACT, we present a brief case example. A 40-year-old man, married with two children, is presenting for therapy because of recurring panic attacks (1 to 3 times a week) that feel as though they are coming out of the blue. He describes these attacks as extremely frightening, that he feels as though he is going crazy and that he might die. In response to these panic attacks, he has been avoiding a range of activities and events that might lead to an attack. For example, he avoids crowded settings in which it might be difficult to leave if he has a panic attack and does not exercise because the increase in heart rate also makes him feel as though he might have an attack. Some of these avoidance strategies have been particularly costly. For example, he has not been to his children's performances in school plays and music productions, and he has been getting increasingly out of shape. The client says he would like to find ways to get rid of his anxiety.

This case can be conceptualized using the core ACT processes reviewed in the preceding section. The client appears to rigidly engage in behaviors to avoid, escape, or otherwise control the thoughts, sensations, and feelings related to panic attacks. He is cognitively fused with evaluations and predictions related to his panic attacks (i.e., "I'm going to die," "I can't handle this") as well as ineffective rules such as "I cannot do something if it might lead to a panic attack" and "To do things I care about, I need to not feel anxious." The client is likely to be attentive to experiences in the present moment, but this attention may be somewhat inflexible at times, such that he hypermonitors his internal experiences for signs of a potential panic attack. This hypermonitoring for and evaluating antecedents of panic attacks further contributes to patterns of experiential avoidance, which has led to significant functional impairment, particularly in relation to engaging in valued actions (i.e., his relationship with his children), as well as increasing life dissatisfaction and clinical distress.

ACT is a flexible treatment approach, and the course of therapy could be structured in many ways depending on several factors, such as how the client responds to initial intervention attempts with a given process. In this case, given the particularly central focus of experiential avoidance in the client's case conceptualization, therapy might begin with creative hopelessness in an attempt to support the client in recognizing patterns of behavior that have been focused on controlling anxiety and the costs of this approach. Once the client demonstrates an awareness of engaging in experiential avoidance, its costs, and an openness to try something different, the therapist would introduce acceptance as an alternative. Before engaging in intensive acceptance exercises, therapy would work on developing his capacity to notice and defuse from thoughts related to panic, establishing more flexible present-moment awareness, and developing self-as-context.

One way these processes could be targeted is through mindfulness exercises. For example, the client might be asked to imagine a stream with leaves floating down it and to imagine placing each thought he has on a leaf. This exercise would provide an experience of simply noticing his thoughts as thoughts rather than engaging in their specific content as well as noticing when he becomes cognitively fused with his thoughts rather than completing the exercise. Exercises may also involve his simply noticing experiences in the moment, while highlighting the distinction between what he notices and who is noticing to build on a sense of self-as-context.

Another key component for targeting acceptance, defusion, present-moment, and self-processes would be modeling, instigating, and reinforcing these processes within the context of the therapeutic relationship. Most forms of avoidance and fusion, on the one hand, or values-based actions, on the other, are linked to social processes such as being right, regulating impressions, or accomplishing social ends, which means that the relationship itself can be a vehicle for discriminating and shaping flexibility processes—a point that has rightly long been made in clinical behavior analysis by developers of functional analytic psychotherapy (Kohlenberg & Tsai, 1991; see Chapter 1, this volume). At the end of this portion of therapy, the client would demonstrate some capacity to flexibly attend to experiences, including aversive private events, in the present moment without engaging in experiential avoidance or becoming fused with literal functions of language and while distinguishing between these experiences and himself as the observer.

With this set of skills in place, therapy would then move toward supporting the client in identifying and engaging in valued actions, independent of whether aversive private events (particularly antecedents to panic attacks) are predicted to or actually occur. This would first involve supporting the client in clarifying and connecting with his values as a way to motivate and guide his actions, which would include a similar process of modeling, instigating, and reinforcing values talk within the context of the therapeutic relationship. Specific exercises such as reflecting on what he would want to have written on his tombstone may also be used. Therapy would then move to committed action, in which specific behavioral commitments could be identified that are linked to values and support acceptance of difficult private events. In this case, the client may begin by completing exposure to antecedents related to panic attacks such as increasing his heart rate by going up the stairs with the therapist there to support a flexible, accepting, and defused stance toward his experiences. The client would be encouraged to identify and connect with how his behavioral commitments are linked to his values. These commitments would be expanded over time to completing activities in his everyday life that he has been avoiding and that are valued (i.e., going to a school play). Barriers to completing commitments, particularly internal barriers, would be identified and targeted through further acceptance, defusion, present-moment, self, and values interventions as indicated. Therapy would end when the client demonstrates significantly improved psychological flexibility, as evidenced by having built up patterns of valued activity in his life while having substantially reduced patterns of activity linked to avoidance and ineffective rules, particularly in relation to panic attacks.

A wide variety of evidence exists on the seven processes just mentioned—studies that link each to RFT (e.g., Villatte et al., 2008) or show their role in psychopathology or treatment (Hayes et al., 2006). We examine this evidence throughout the rest of the chapter.

Expanded Use of Methodologies to Test the Theoretical Model and Treatment Technology

CBS seeks to test treatment technologies, as well as the underlying theoretical model and basic principles, through a variety of methodologies, including group designs. This approach differs significantly from the traditional behavior-analytic approach to research. Behavior analysis has often been characterized by the predominant use of single-case time-series research methods. Although these methods provide many benefits in studying the behavior of individual organisms (e.g., an emphasis on establishing visually observable treatment effects), they are not appropriate for answering all questions faced by psychologists.

Of particular importance is that time-series designs do not test the relevance and general applicability of an analysis to a given population (although see Volume 1, Chapter 7, this handbook, for an opposing view). Given that behavioral principles are applied at the level of the individual organism interacting in and with a context, testing their impact at the individual level is important as well. However, it does not directly inform an understanding of the degree to which a given functional analysis is generally applicable to a particular population, defined functionally or topographically. This question is of ultimate importance in scaling behavior-analytic analyses and interventions to deal with public health problems, which has been always been part of the strategy underlying behavior analysis. Failing to conduct this research has negative implications for the dissemination of behavior analysis as well as for increasing the knowledge base. CBS seeks to determine the generality of the theoretical model by testing the impact of treatment technologies at a group level as well as in time-series designs.

The tight link between treatment technologies, theoretical models, and basic principles allows for a test of the applicability of a functional analysis at a higher level of abstraction (i.e., across organisms and contexts). All forms of behavioral intervention are based on hypothesized or tested behavioral functions informing treatment. This testing must usually be done one person at a time because histories differ so widely. When dealing with functions that are dominantly established by language itself, however, a great deal of overlap can exist between people, and thus considerable commonality can be found in the functional interpretations that emerge. For example, the ACT model posits that processes such as experiential avoidance, fusion, and psychological inflexibility frequently play a critical role in the maintenance and exacerbation of chronic pain. The applicability of these functional processes to individuals with chronic pain has been tested in group studies, which have found that those who demonstrate higher acceptance and psychological flexibility in relation to pain tend to have better outcomes (McCracken & Eccleston, 2003, 2005). Furthermore, research has found that ACT interventions targeting these processes among adolescents with idiopathic chronic pain produced improvements, maintained after a 6-month period, in functional disability, pain intensity, pain interference, catastrophizing, and school attendance, compared with participants in a wait-list control group (Wicksell, Melin, Lekander, & Olsson, 2009). The effects of ACT on chronic pain outcomes are accounted for by changes in psychological flexibility and its related processes (Wicksell, Olsson, & Hayes, 2011), and brief acceptance-only interventions can produce reductions in physical impairment (e.g., flexion, extension, active sit-up) in individuals with low back chronic pain compared with wait-list control participants (Vowles et al., 2007). Overall, these various applications of group design methods test whether the abstracted functional analysis applies to a general, topographically defined population at multiple levels, which would be difficult to determine with a more rigid reliance on time-series designs alone.

Testing the components of acceptance and commitment therapy. Testing the independent and cumulative impact of treatment components is important. It can directly inform further refinement of a treatment package. Components found to be inactive can be modified or removed, and active components can be further enhanced and emphasized. In addition, treatment components in a CBS approach are tightly linked to the underlying processes of change specified in the theoretical model. Thus, examining the effects of treatment components provides important information regarding the theoretical model. If the model specifies a particular component as important for producing clinical gains but is found to have little impact, then the model needs to be corrected.

Often, treatment components are tested through large-scale dismantling studies in which the efficacy of a complete treatment package is compared with that of the treatment package with a particular set of components removed. This type of study provides a direct assessment of whether the treatment component is contributing to the efficacy of the intervention. However, these designs are also very time consuming and often only occur late in treatment development after multiple randomized controlled trials (RCTs) and dissemination have occurred. At this point, if a treatment component is found to be ineffective, it is much more problematic to modify the treatment approach accordingly.

CBS emphasizes the use of microcomponent studies as another potential method for testing treatment components. These studies are typically small-scale, laboratory-based studies that test the impact of a brief intervention in a highly controlled setting on clinically relevant outcomes, which allows for a tighter control of the treatment components being tested. The treatment outcomes in these studies are more general, often using nonclinical populations and focusing on more broadly relevant features of behavior such as task persistence and recovery from mood inductions, thus providing a test of the treatment component more generally rather than in relation to a narrowly defined disorder. In addition, these studies are relatively cheap and easy to conduct, allowing for component testing to occur early and throughout treatment development without requiring substantial grant funding or time-consuming studies.

More than 40 component research studies have consistently supported the efficacy of treatment technologies targeting the specific processes of change in ACT (F. J. Ruiz, 2010). These studies have suggested that many of these components are psychologically active, as demonstrated by their impact on clinically relevant outcomes compared with inactive control conditions. For example, acceptance component interventions have been found to produce higher levels of persistence in distressing tasks (Levitt et al., 2004; Vowles et al., 2007) and willingness to engage in exposure (Eifert & Heffner, 2003). Defusion component interventions have been found to reduce the distress associated with and believability of negative self-relevant statements (Masuda, Hayes, Sackett, & Twohig, 2004; Masuda et al., 2008). Values component interventions have been found to produce higher levels of persistence in distressing tasks (Branstetter-Rost, Cushing, & Douleh, 2009; Páez-Blarrina et al., 2008), reduce distress from stressful tasks (Creswell et al., 2005), improve grades in minority students (Cohen et al., 2009), and improve responsiveness to health messages (Harris & Napper, 2005). Overall, this evidence supports the independent impact of acceptance, values, and defusion on clinically relevant outcomes.

Research has not yet tested the independent impact of self-as-context and contact-with-the-present-moment components on clinically relevant outcomes compared with inactive conditions in microcomponent studies. However, research has been conducted that provides some support for the utility of these components. Within the sensate focus literature, studies have found that brief, present-moment awareness interventions can sometimes produce higher levels of persistence and less pain or discomfort in distressing tasks than interventions such as distraction and suppression (Cioffi & Holloway, 1993; Michael & Burns, 2004). In addition, a recent small dismantling study compared the impact of a complete ACT treatment with a treatment without the self-as-context component in a population of veterans diagnosed with posttraumatic stress disorder (Williams, 2006). Participants in the complete ACT intervention experienced significantly greater decreases in posttraumatic stress disorder symptoms at follow-up than participants in the ACT without self-as-context intervention, suggesting the importance of this component for treatment.

Studies have also compared specific combinations of ACT components with inactive control conditions. Interventions that combine aspects of the mindfulness components of ACT (acceptance, defusion, self-as-context, and present moment) have been found to reduce reactivity to distressing tasks (Hayes, Bissett, et al., 1999; Masedo & Esteve, 2007) and increase persistence in tasks (Masedo & Esteve) compared with nonintervention control conditions. Studies have also found similar outcomes when combining mindfulness components and values (Gutiérrez, Luciano, Rodríguez, & Fink, 2004; McMullen et al., 2008; Páez-Blarrina et al., 2008).

Component studies also provide the opportunity to test important features of the theoretical model. The outcomes that tend to be affected more by ACT components are consistent with theoretical predictions. Studies have consistently demonstrated that ACT components have an impact on task persistence, willingness, and believability of thoughts. However, findings are much less consistent regarding the impact on the frequency and intensity of distressing thoughts, feelings, and sensations, with some studies showing a positive impact with ACT components (Masedo & Esteve, 2007; Masuda et al., 2004) and others finding no impact (Branstetter-Rost et al., 2009; McMullen et al., 2008;

Páez-Blarrina et al., 2008). This trend in studies supports the ACT model in which interventions seek to change the function of thoughts, feelings, and sensations in relation to overt behavior, whereas changes in their frequency, form, or intensity are more secondary and not explicitly targeted. Studies have also found that ACT components produce much higher rates of persistence when one experiences high levels of pain and discomfort than do inactive and suppression or distraction intervention conditions (Gutiérrez et al., 2004; McMullen et al., 2008; Páez-Blarrina et al., 2008). This desynchrony effect in which the relationship between pain and overt behavior is disrupted is consistent with the prediction that ACT works by changing the function of private events rather than their form or intensity.

Testing processes of change. Another important feature of treatment testing is to examine the processes through which treatment produces an effect. This feature provides a strong test of the theoretical model and has implications for further treatment development. Mediational analysis in particular is a useful way to test the processes of change in an intervention (Kazdin, 2007). Mediational analysis examines several factors (see Figure 18.2) including whether treatment affects the process of change (Path a between treatment and mediating process), whether the process of change is related to the behavioral outcome after controlling for treatment (Path b between mediator and outcome), and whether Paths a and b account for the effect of treatment on outcome (i.e., leaving little or no variance to be accounted for by Path c′ between treatment and outcome). Each of these tests provides important information regarding the theoretical model and intervention.

Path a tests whether treatment affects the specified processes of change more than a comparison condition. This comparison tests whether the treatment, compared with an inactive intervention, affects the process of change, controlling for non–intervention-related confounds. If a treatment is unsuccessful in affecting the processes of change, it suggests either a failure of the technology or a failure of the model in specifying a manipulable process, assuming the process-of-change measure is reliable and valid in the given context. A more stringent test is conducted when a similar, active treatment is used because it tests the specificity of the treatment approach in targeting the processes of change. If the treatment does not produce a differential impact on the processes of change, it suggests that the theoretical model is not specific to that treatment approach and accounts for a more general feature of intervention.

Path b tests whether a process of change is related to a clinical outcome when controlling for the impact of treatment. It provides a stringent test of the applicability of the process to the clinical problem of interest. To detect a significant effect, the variations in the process have to be related to outcomes in both treatment groups, and relatively consistently. Thus, Path b can provide support for the model of psychopathology by examining whether particular processes predict behavioral outcomes.

Path c′ directly assesses whether the observed effect of treatment on clinical outcomes is accounted for by its impact on a particular process of change. This analysis is a central component of testing the

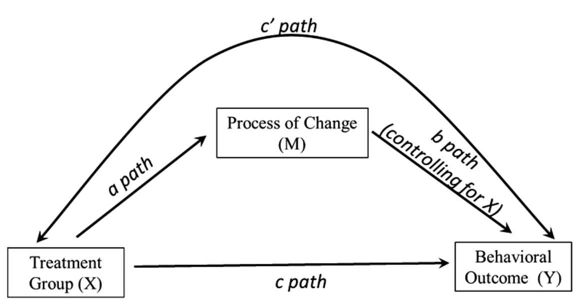

FIGURE 18.2. **Mediational analysis model.**

theoretical model because it tests whether the theory accurately specifies how the treatment affects clinical outcomes. It provides very strong support for a theoretical model, especially if the result is consistently replicated.

ACT outcome studies have generally included an explicit focus on examining processes of change. Measures have been developed to assess these theoretical processes and have been included in almost every outcome study conducted. Studies have consistently found that ACT affects the theoretically specified processes of change and that changes in these processes predict changes in outcomes (Hayes et al., 2006). In addition, formal mediational analysis has been conducted in at least 21 RCTs (Levin, Hayes, & Vilardaga, 2008). These studies have consistently found that the differential impact of ACT on clinical outcomes is mediated by changes in acceptance and psychological flexibility (Gifford et al., 2004; Gregg, Callaghan, Hayes, & Glenn-Lawson, 2007; Lundgren, Dahl, & Hayes, 2008; Lappalainen et al., 2007), defusion (Hayes et al., 2004; Zettle & Hayes, 1986; Zettle, Rains, & Hayes, in press), mindfulness (Lazzarone et al., 2007), and values (Lundgren et al., 2008). Successful mediation has been demonstrated in ACT RCTs across a broad range of clinical populations, including depression, psychosis, anxiety, chronic pain, self-harm, smoking, burnout, weight loss or maintenance, chronic illness, self-stigma and stigma toward others, and adopting evidence-based treatments (Levin et al., 2008). Furthermore, these mediational effects were demonstrated even when compared with structured interventions such as pharmacotherapy (Gifford et al., 2004), multidisciplinary care (Wicksell et al., 2009), and cognitive–behavioral therapy (Zettle & Hayes, 1986; Zettle et al., in press).

These effects provide strong support for the ACT theoretical model. This level of consistency in mediational analysis is rarely achieved, particularly when one considers the range of mediational measures, clinical populations, and comparison conditions included. Demonstrating mediation across such a broad scope of problems suggests that these processes apply across a significant range of problems and that ACT can affect these areas through the theoretically specified processes of change. In addition, studies demonstrating mediation with active comparison conditions highlight ACT's specificity in targeting these processes of change. If pharmacotherapy and cognitive–behavioral therapy were equally as efficacious in affecting processes such as defusion and acceptance, it would raise concerns regarding whether the ACT approach is unique. The ability for ACT to have more of an impact on these processes than other empirically supported therapies suggests this approach is different, and one that is quite effective given the broad applicability of these processes to a range of clinical problems.

Testing the applicability of the model across a broad range of outcomes. Another way to test the applicability of the model is to examine it across a range of diverse populations that share a similar functional diagnostic dimension. This test can be done by conducting a series of outcome studies for a broad range of problems using a treatment that targets a similar underlying set of processes. If positive effects are consistently observed, it provides strong support for the scope of the analysis in identifying important functional variables for intervention. In addition, the limits of the theoretical model and intervention are identified much more quickly in this expansive approach to treatment testing, providing information regarding important areas for further research.

ACT has been tested across a very broad range of problem areas. Outcome studies, including RCTs, open trials, and time-series designs, have found positive effects for ACT in several different areas including depression, anxiety, psychosis, chronic pain, substance use, smoking, coping with chronic illness, weight loss or maintenance, burnout, self-stigma, stigma toward others, sports performance, and learning other treatment approaches (Hayes et al., 2006; Hayes et al., in press; F. J. Ruiz, 2010). These findings lend support to the theoretical model by demonstrating the broad applicability of the ACT model and treatment technology. Processes such as experiential avoidance, fusion, and psychological inflexibility appear to be important functional variables across many topographically distinct problems and can be affected by targeting processes such as acceptance, defusion, and psychological flexibility. In addition, some of these problems are quite difficult to treat or represent new areas of application for psychotherapy such as epilepsy (Lundgren et al., 2008), obesity (Lillis, Hayes, Bunting, & Masuda, 2009), and stigma (Hayes et al., 2004).

ACT's efficacy has been supported by these outcome studies. Hayes et al. (2006) conducted a meta-analysis of 17 ACT RCTs, including unpublished studies, estimating a medium Cohen's *d* effect size of 0.66 on primary outcomes at posttest and follow-up. A meta-analysis by Öst (2008) of 13 published ACT RCTs found similar results, estimating a medium Hedge's *g* effect size of .68 on primary outcomes at posttest. Another meta-analysis by Powers, Vörding, and Emmelkamp (2009) of 18 published ACT RCTs found a slightly lower effect size, estimating a medium Hedge's *g* effect size of .42 for disorder-specific symptoms and of .59 for general distress and impairment or disability combining posttest and follow-up. These meta-analyses, two of which were conducted by non-ACT researchers, indicated the active impact of ACT on clinical outcomes across a range of problem areas.

Effectiveness, Dissemination, and Training Research

Treatment outcome research within clinical psychology has typically taken a stage-based approach in which studies testing the effectiveness and dissemination of treatments do not occur until the final stage of treatment testing. However, determining the effectiveness of interventions with everyday clinicians and treatment settings for more heterogeneous clients is crucial because it is how treatments are generally applied. Taking an active role in studying how best to disseminate and train clinicians in the effective implementation of the intervention package is an important task for researchers. The observed lack of adoption of evidence-based treatments by clinicians (Sanderson, 2002) may be attributed to researchers' inattention to dissemination and training factors.

CBS involves active attention to effectiveness, dissemination, and training research. Relative to the standard treatment development process (Rounsaville, Carroll, & Onken, 2001), these studies are conducted early on to determine how best to train clinicians in the intervention approach and whether it may produce improved clinical outcomes with typically seen clients. The first ACT outcome study after RFT was developed was an effectiveness study (Strosahl, Hayes, Bergan, & Romano, 1998) that found that line clinicians randomized to training in ACT produced significantly better outcomes among outpatient clients than those who were not assigned to the training. Since then, two additional effectiveness studies have found that novice-level clinicians trained in ACT have produced equivalent (Forman, Herbert, Moitra, Yeomans, & Geller, 2007) or better outcomes (Lappalainen et al., 2007) with heterogeneous clinical populations than did those trained in cognitive–behavioral therapy. In addition, many of the published ACT outcome studies have included more heterogeneous populations than those typically treated in RCTs. For example, Bach and Hayes (2002) included individuals with comorbid substance use, other psychological disorders, or both in a psychosis outcome study and found a similar reduction in rehospitalization rates as with treatment as usual among those with and without comorbid disorders. This and similar findings (e.g., Bond & Bunce, 2000; Forman et al., 2007; Twohig et al., 2010) provide further support for the applicability of ACT to real-world clinical populations. These studies have provided initial evidence suggesting that everyday line clinicians can be trained in ACT to produce improved outcomes with the clients they typically serve.

SUMMARY AND CONCLUSIONS

Whether behavior analysis can engage the range of challenges facing humanity today remains a question. Behavior analysis has provided insight into the variables controlling the human activities responsible for these challenges and has offered some solutions that have proven useful (consider, e.g., Chapters 1, 3, 10, and 19 of this volume). However, any reasonable observer would have concerns about behavior analysts' ability to affect change. Skinner himself apparently reached a point of pessimism later in life when faced with the lack of an impact of behavioral science on global problems (Chance, 2007).

From an ACT–RFT perspective, behavior analysts have often greatly underemphasized the role of verbal behavior in these problems and their possible solutions. In the absence of a powerful approach to language and cognition, behavior analysts were left with no alternative but to focus primarily on direct contingency analyses. When doing so, however, the excessive impact of immediate consequences over delayed consequences can seem impossible to avoid. In contrast, ACT–RFT research has suggested that language itself can help diminish that problem by altering how delayed consequences are contacted (e.g., Dixon & Holton, 2009). The impact of aversive control can be impossible to alter, but acceptance and mindfulness are now known to considerably alter the excessive impact of aversive control (McMullen et al., 2008). The susceptibility to short-term reinforcing effects of sugar, drugs, alcohol, and other chemicals can seem unavoidable, even though researchers are learning how to diminish regulation by such stimuli (e.g., Hayes et al., 2004; Lillis et al., 2009)

The ACT–RFT approach rests on the hypothesis that verbal behavior plays a critical role in the development, maintenance, and exacerbation of many of these problems as well as in their potential alleviation. Careful consideration of ways to counteract the harmful effects of verbal behavior is important as is that of how to use verbal behavior to support more effective behaviors. Although Skinner's (1948) analysis provided an initial foundation for a behavior-analytic approach to verbal behavior, it has its limitations (Hayes & Hayes, 1992). RFT builds on Skinner's account and may serve to further a functional understanding of verbal behavior, highlighting particular important features of language and cognition such as the ability to derive relations and the transformation of stimulus functions produced through relational framing. This has led to the development of ACT as an applied theoretical model of intervention, pathology, and health that seeks to reduce the harmful behavior-regulatory effects of verbal behavior, particularly the repertoire-narrowing processes of fusion and experiential avoidance, while simultaneously leveraging verbal processes to produce broader, more effective patterns of behavior linked to chosen values. These developments point to a potential path for furthering the capacity of behavior analysis to meet the significant problems humans are encountering.

Developing a comprehensive science of behavior presents significant challenges. Beyond the specific theoretical and technological developments, the ACT–RFT research program reflects an alternative scientific strategy within behavior analysis, CBS, that may serve to vitalize and empower the field in meeting its broad vision. In this chapter, we have reviewed ACT, but we have done so in the context of explicating the elements of a CBS approach as a translational and knowledge development strategy. CBS orients to a more clearly explicated set of philosophical assumptions underlying the scientific approach, which emphasizes truth based on achieving the goals of the research program: prediction and influence of behavior with precision, scope, and depth. Basic research and applied research need to be brought together by focusing on areas of shared interest in which work on each level informs work on the others. Mid-level terms are used to support the application of principles and technical terms to the prediction and influence of behavior in particular domains, providing a framework for interventions and enhancing the capacity to test theoretical models in a reticulated fashion. Finally, a diverse set of research methods are used to test the technology and underlying theoretical model, including examining the effects of specific treatment components, efficacy across a broad set of populations, mediation and moderation analyses, effectiveness of treatment in real-world clinical settings, and evaluations of training and dissemination techniques.

Taken together, our hope is that these developments help move behavior analysis back toward central concerns in psychology. A rise in the popularity and impact of ACT and RFT, which is easy to demonstrate objectively (e.g., see http://www.contextualpsychology.org), is evidence that this is occurring. Just as important, they also move behavior analysis back toward its original expansive vision. The needs of human beings demand nothing less.

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CHAPTER 19

VOUCHER-BASED CONTINGENCY MANAGEMENT IN THE TREATMENT OF SUBSTANCE USE DISORDERS

Stephen T. Higgins, Sarah H. Heil, and Stacey C. Sigmon

Substance use disorders (SUDs) represent a highly prevalent and costly public health problem in the United States and most other developed and developing countries. Indeed, almost one-fifth (18%) of the U.S. population will experience an SUD at some point in their lifetime and the associated economic burden in terms of lost productivity and increased morbidity and mortality is estimated at $5 billion or more annually (Galanter & Kleber, 2008). The need for greater scientific understanding of SUDs as well as effective interventions for preventing and treating these disorders is tremendous. The field of behavior analysis has made numerous contributions to a scientific analysis of SUDs. Among those contributions is the use of contingency management (CM) to treat SUDs (Higgins, Silverman, & Heil, 2008), which is the focus of this chapter.

CM involves the systematic application of reinforcing or punishing consequences to promote and sustain behavior change. When used in the treatment of SUDs, CM interventions usually focus not only on increasing abstinence from drug use, but also on increasing clinic attendance, adherence with medication regimens, and other therapeutic targets such as vocational goals (see Higgins et al., 2008). CM is typically used as part of a more comprehensive treatment intervention for SUDs, but it has also been used as an effective stand-alone treatment, depending on the particular type of SUD and population. CM treatments for SUDs have taken different forms over the approximately 40 years in which they have appeared in the scientific literature, including, for example, earning clinic privileges contingent on objectively verified drug abstinence among methadone maintenance patients (e.g., Stitzer, Iguchi, & Felch, 1992), forfeiting a professional license contingent on drug use among drug-dependent health care workers (e.g., Crowley, 1985–1986), earning temporary housing among homeless drug-dependent individuals contingent on abstinence from drug use (e.g., Milby, Schumacher, Wallace, Freedmen, & Vuchinich, 2005), and earning vouchers exchangeable for retail items contingent on abstinence from drug use among individuals dependent on cocaine and other drugs (e.g., Higgins et al.,1991). As we discuss in greater detail later, the practice of offering abstinence-contingent vouchers exchangeable for retail items or other monetary-based consequences for promoting behavior change is the most thoroughly researched of these different types of CM and thus is the primary focus of this chapter.

SCIENTIFIC RATIONALE

The overarching rationale for using CM in the treatment of SUDs is based on the extensive empirical evidence demonstrating the important contribution of operant conditioning in the genesis and maintenance of drug use. An extensive literature has demonstrated that most of the drugs that humans abuse will also function as unconditioned positive reinforcers in laboratory animals (Griffiths, Bigelow, &

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Henningfield, 1980). That is, when intravenous drug injections are delivered contingent on lever pressing or other arbitrary operant responses, laboratory animals will readily acquire voluntary drug-taking behavior. Indeed, normal laboratory animals are capable of engaging in the dangerous extremes in drug consumption that were once thought to be uniquely characteristic of human SUDs. Animals given unconstrained opportunities to self-administer intravenous injections of cocaine, for example, will do so to the exclusion of taking basic sustenance and, barring experimenter intervention, will continue in that behavior to the point of death (Aigner & Balster, 1978; Johanson, Balster, & Bonese, 1976). Another important aspect of this animal self-administration literature in terms of understanding the rationale for CM is that although drug-produced reinforcement can be quite powerful, it is also malleable depending on environmental context (Higgins, Heil, & Lussier, 2004). This malleability has typically been demonstrated by showing that increasing the cost of responding, or more generically the unit price, decreases consumption and also by showing that introducing alternative reinforcers to compete with drug reinforcement decreases drug consumption as well (Bickel, DeGrandpre, Higgins, & Hughes, 1990; Higgins, 1997). Similar relationships have also been demonstrated in laboratory-based operant conditioning studies with humans. Drug use by individuals dependent on alcohol, cocaine, marijuana, nicotine, or opioids has been shown to be sensitive to environmental context, especially the introduction of alternative nondrug reinforcers made available contingent on abstaining from drug use (Higgins, Heil, & Lussier, 2004).

Additional scientific rationales for using CM to treat SUDs are based in more recent scientific developments. For example, an emerging area of behavioral economic research on delay discounting has shown that individuals with SUDs exhibit a greater discounting of the value of temporally delayed reinforcement than do matched control participants without SUDs (Bickel, Miller, Kowal, Lindquist, & Pitcock, 2007). Considering that most of the naturalistic reinforcers associated with discontinuing drug use (improved physical health, family life, employment) are delayed in time whereas those derived from drug use are relatively immediate, it makes sense that systematically providing a more immediately available substitute reinforcer contingent on therapeutic progress, as is done in CM, might help to bridge the temporal gap between stopping drug use and reaping naturalistic rewards for doing so. At the level of brain function, chronic drug use can directly diminish frontal lobe cortical functions that are thought to be important to sustaining responding under contingencies involving temporal delays (Garavan & Hester, 2007). Such diminished frontal lobe functioning has been theorized to leave individuals with SUDs at increased risk for relapse to the relatively immediate reinforcement that drug use represents. Note that CM appeals to this same bias toward more immediate over delayed reinforcement, but it capitalizes on it to promote recovery from SUDs. That is, CM takes advantage of the same behavioral process of reinforcement and bias toward more immediate sources of reinforcement over delayed sources of reinforcement that is thought to be central to the genesis and maintenance of SUDs to promote recovery from them (Higgins, Heil, & Lussier, 2004).

Early Contingency Management Studies

Among the most impressive of the early studies on CM in the treatment of SUDs was one conducted with men with alcoholism in the mid-1970s (Miller, 1975). In this study, 20 homeless men with severe alcohol dependence were randomly assigned to a control condition or CM intervention. The men in the control condition received the usual social services in the form of food, clothing, and housing, whereas the men in the CM condition received those same services only so long as they sustained abstinence, verified through breath-alcohol testing and staff observation of signs of sobriety. Evidence of drinking resulted in a 5-day suspension from such services. The intervention resulted in a significant reduction in arrests for public drunkenness and an increase in days of employment among those in the CM condition compared with those in the control condition. Note that the reinforcer (i.e., social services) was delivered contingent on objective evidence of the nonoccurrence of drinking, which represents a differential-reinforcement-of-other-behavior schedule of reinforcement, which is the basic reinforcement schedule used in the CM studies focused on promoting drug abstinence discussed in this chapter.

Despite the promising results of this initial controlled study with men with alcoholism, it had no programmatic follow-up. Indeed, no body of programmatic research on CM and SUDs emerged until the work of Stitzer and colleagues (e.g., Stitzer, Bigelow, Liebson, & Hawthorne, 1982), which focused mostly on patients enrolled in methadone therapy for opioid dependence but also included some seminal studies on CM with cigarette smokers (see Stitzer & Higgins, 1995). Methadone is a medication that is highly effective in preventing physical withdrawal and suppressing illicit opioid use among patients with opioid dependence, but it does not address the other types of drug use disorders and related problems that these patients often exhibit. These early studies by Stitzer and colleagues can be thought of as proof-of-concept investigations in the development of the CM treatment literature (see Stitzer & Higgins, 1995). That is, they were initial investigations focused on demonstrating that contingent positive reinforcement in the form of access to clinic privileges, cash payments, or adjustments in methadone dose could change drug use and other therapeutic targets in a clinical population and setting.

Stitzer et al.'s (1982) study with outpatients with opioid dependence provides an example from this important area of initial CM research. Ten patients who were receiving methadone maintenance treatment for heroin dependence but who continued abusing benzodiazepines (e.g., diazepam) were invited to participate in a study that used a within-subject reversal design. During a 12-week intervention period, these individuals could earn 2 days of clinic privileges, a cash payment ($15.00), or a 20-milligram methadone dose adjustment contingent on objective evidence of abstinence from recent benzodiazepine use (i.e., benzodiazepine-negative urine toxicology results). Reinforcers were not available during two baseline periods that preceded and followed the intervention. During the intervention period, 43% of specimens were benzodiazepine negative compared with only 3.6% of specimens in the initial period and 7.9% of specimens in the final baseline period, providing robust evidence of sensitivity to the intervention. Studies such as this one provided clear evidence that CM could be quite helpful in treating opioid-dependent outpatients.

Voucher-Based Contingency Management

The U.S. cocaine epidemic of the 1980s and 1990s created the context in which CM made substantial progress toward gaining recognition as an evidence-based treatment for SUDs. Scientists and policymakers alike were grossly unprepared for the cocaine epidemic, which generated a much more insidious problem than almost anyone anticipated, including a rapid increase in demand for treatments for cocaine dependence (Grabowski, 1984). Many different interventions were investigated, with most producing dismally negative outcomes in terms of failing to increase retention in treatment or abstinence from cocaine use (Higgins & Wong, 1998), although several uncontrolled studies conducted with health care workers dependent on cocaine suggested that CM might have promise (e.g., Crowley, 1985–1986). In this context of tremendous demand and few promising leads, results achieved with a treatment featuring a CM component using vouchers exchangeable for retail items gained considerable attention. These results were reported in the form of an initial pilot study and a subsequent randomized controlled clinical trial (Higgins et al., 1991, 1993).

We introduce this voucher-based form of CM by briefly describing the results achieved in the initial randomized clinical trial (Higgins et al., 1993). In that trial, vouchers were combined with intensive counseling based on the community reinforcement approach (CRA). The study involved a comparison of CRA plus vouchers with standard care in the form of drug abuse counseling. The voucher program was implemented around a fixed schedule of urine toxicology monitoring. Cocaine-negative specimens earned points that were recorded on vouchers and provided to patients. Points began at a low value ($2.50) and increased with each consecutive negative test result. A cocaine-positive test result, or failure to provide a scheduled specimen for testing, reset the voucher value back to the initial low value from which it could again escalate. This reset feature is the only element of aversive control (i.e., negative punishment) in voucher-based CM, which is otherwise a completely reinforcement-based intervention. No money was given to patients. Instead, points were used to purchase retail items, with clinic staff making all purchases. Maximum earnings possible across 12 weeks were $997.50 in purchasing power, with average earnings being approximately 60% of maximum. Thirty-eight cocaine-dependent outpatients were randomized to one of the two treatments. As is shown in Figure 19.1, cocaine abstinence levels in the two treatments were comparable at the start of treatment. Thereafter, those receiving standard care soon either dropped out of treatment or continued using cocaine consistent with the negative outcomes being reported in the literature at that time, whereas most of those assigned to CRA plus vouchers abstained from cocaine use at greater levels than had previously been reported except for the pilot study of the same treatment (Higgins et al. 1991). Although the research designs used in those two initial studies did not permit one to isolate the contribution of the voucher program on outcomes apart from the counseling component, subsequent randomized trials demonstrated that voucher-based CM was a major contributor to the positive outcomes achieved with the CRA-plus-vouchers treatment (Higgins et al., 1994; Higgins, Wong, Badger, Ogden, & Dantona, 2000).

Also of great importance to establishing the efficacy of this treatment approach was a series of randomized clinical trials by Silverman and colleagues (Silverman, Chutuape, Bigelow & Stitzer, 1999; Silverman et al., 1996, 1998) conducted with individuals with cocaine dependence enrolled in methadone maintenance therapy. These trials were important in several ways, including that (a) they were conducted in methadone clinics, whereas the initial studies took place in a research clinic focused exclusively on treatment of cocaine dependence; (b) patients were mostly African American, whereas patients in the initial studies were almost exclusively Caucasian; (c) the clinic was located in a large urban setting, whereas the initial studies were conducted in a small town; and (d) they demonstrated that investigators other than those who developed the intervention could obtain positive outcomes with this treatment approach.

The seminal study extending voucher-based CM to the large, inner-city setting was conducted with 37 patients enrolled in methadone maintenance treatment for opiate dependence who were also

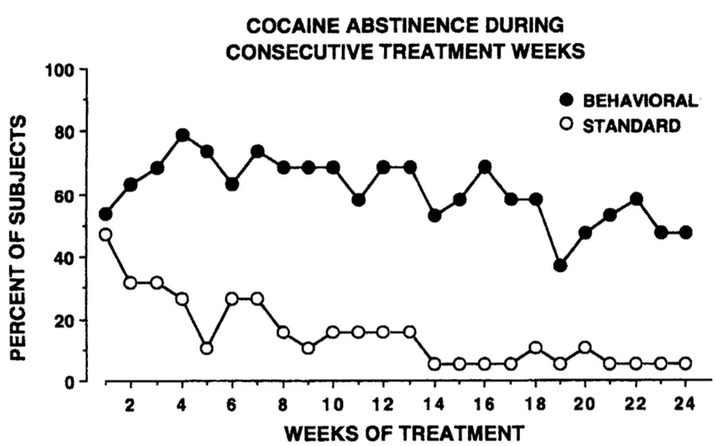

FIGURE 19.1. Abstinence from cocaine among cocaine-dependent outpatients given behavioral treatment or standard drug abuse counseling. Filled symbols represent the behavioral treatment group, and open symbols represent the standard drug abuse counseling group. From "Achieving Cocaine Abstinence With a Behavioral Approach," by S. T. Higgins, A. J. Budney, W. K. Bickel, J. R. Hughes, F. Foerg, and G. Badger, 1993, *American Journal of Psychiatry, 150,* p. 766. Copyright 1993 by the American Psychiatric Association. Reprinted with permission from the *American Journal of Psychiatry*.

intravenous cocaine abusers (Silverman et al., 1996). The schedule arrangement was largely the same as in the original studies. Patients were randomly assigned to 12 weeks of a condition in which vouchers were earned contingent on cocaine abstinence or to a noncontingent control condition in which vouchers were earned in the same amount and pattern as in the experimental condition but independent of cocaine use. Those patients assigned to the abstinence-contingent voucher condition achieved significantly greater cocaine abstinence than those patients assigned to the control condition. For example, 47% of patients assigned to abstinence-contingent vouchers achieved between 7 and 12 weeks of continuous abstinence compared with 0% of patients in the noncontingent voucher control condition (Figure 19.2). Only one patient (6%) assigned to the noncontingent control condition

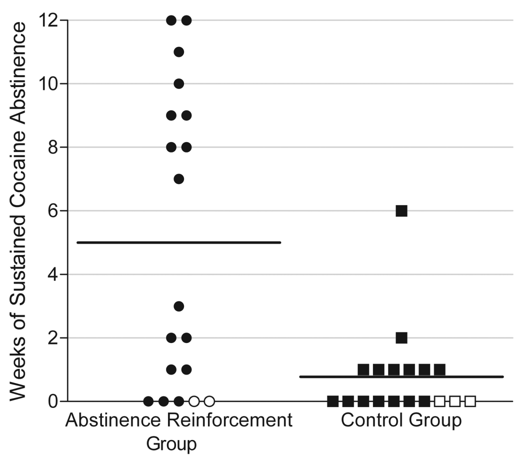

FIGURE 19.2. **Longest duration of sustained cocaine abstinence achieved during the 12-week voucher condition. Each point represents data for an individual patient; the lines represent group means. The data for the 19 abstinence reinforcement patients are displayed in the left column (circles), and the data for the 18 control patients are displayed in the right column (squares). Open symbols represent patients who dropped out of the study early. From "Sustained Cocaine Abstinence in Methadone Maintenance Patients Through Voucher-Based Reinforcement Therapy," by K. Silverman, S. T. Higgins, R. K. Brooner, I. D. Montoya, E. J. Cone, C. R. Schuster, and K. L. Preston, 1996, *Archives of General Psychiatry*, *53*, p. 413. Copyright © 1996 American Medical Association. All rights reserved. Reprinted with permission.**

achieved more than 2 weeks of continuous cocaine abstinence. These results provided compelling evidence supporting the generality of earlier findings with voucher-based CM to inner-city populations and methadone patients. Other trials in that same clinic extended the efficacy of abstinence-contingent vouchers to promoting abstinence from illicit opioid abuse (Silverman et al., 1996), demonstrated that the use of opioids sometimes decreased along with cocaine use when CM explicitly targeted only cocaine abstinence (Silverman et al., 1998), and supported the efficacy of increasing the magnitude of the vouchers to promote a treatment response in those who initially failed to respond at lesser voucher values (e.g., Silverman et al., 1999).

Growth of the CM literature. Voucher-based CM has now been shown to have efficacy with a broad range of different types of SUDs and special patient populations and in a wide range of clinical settings. Two edited textbooks have been published outlining these various applications (Higgins & Silverman, 1999; Higgins, Silverman, & Heil, 2008) and at least one meta-analysis focused exclusively on voucher-based CM has been published that offered robust support for its efficacy (Lussier, Heil, Mongeon, Badger, & Higgins, 2006). In the only meta-analysis we are aware of comparing different psychosocial treatments for SUDs involving illicit drugs, CM produced a larger effect size than either cognitive–behavioral therapy or relapse prevention interventions (Dutra et al., 2008). The largest effect sizes in that meta-analysis were observed with CM combined with CRA.

Growth in scientific and clinical interest in CM is also evident in results displayed from a literature search on the term *contingency management* using PubMed, the search engine of the National Library of Medicine. Figure 19.3 shows a cumulative plot of the number of yearly CM citations related to the topic of SUDs. The level of growth is striking and, as we characterize it later, is associated with a high degree of efficacy across different types of SUDs, special populations, and therapeutic targets.

The Lussier et al. (2006) meta-analysis we mentioned earlier reviewed the published literature from January 1991 through March 2004. We do not

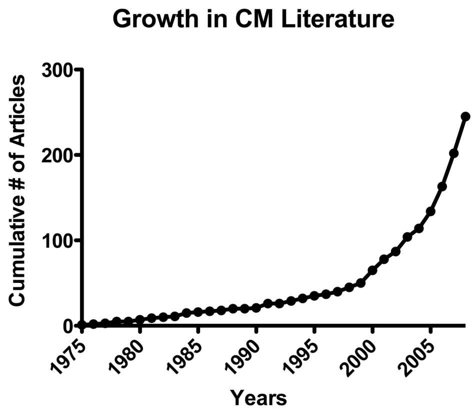

FIGURE 19.3. **Cumulative plot of the number of citations identified in a PubMed search of the term *contingency management* (CM) involving substance use disorders. The search included all citations through October 2009.**

comment further in this chapter on studies from that period. Instead, our focus in the remainder of this chapter is on the voucher-based CM literature published after the period covered in the meta-analysis (April 2004 through November 2009). As with the earlier review, we examined only studies that involved contingent vouchers or a related monetary-based CM intervention, were published in a peer-reviewed journal, included an experimental comparison condition, used a research design in which treatment effects attributable to CM could be dissociated from other aspects of treatment, and was an original experimental study.

We used the PubMed search engine in the literature search for this review; the search terms were *vouchers* and *contingency management,* alone and paired with the terms *drug dependence, substance abuse,* and *cigarette smoking.* We also browsed reference sections of published articles. Across the approximately 5-year period, we identified 72 controlled studies published in peer-reviewed journals in which voucher-based CM was used to treat SUDS, for a yearly average of 14.4 reports. Five of these reports were excluded from further consideration because they did not meet one or more of the aforementioned inclusion criteria, leaving 67 reports that satisfied inclusion criteria.

Consistent with the prior review, most studies (50 reports, or 75%) focused on increasing abstinence from drug use. The remaining studies fell into two categories, (a) those examining the efficacy of contingencies on other therapeutic goals, including adherence to medication regimens, retention in community SUD treatment, and attendance at work therapy (seven reports, or 10%), or (b) those examining the efficacy of placing contingencies on both abstinence from drug use and meeting other therapeutic goals or comparing contingencies on abstinence with those placed on other therapeutic goals (10 reports, or 15%). Also consistent with the prior review was the overwhelming degree of support for efficacy. Statistically significant treatment effects of CM were reported in 59 (88%) of the reports reviewed, with that breaking down further to 90% (45 of 50) among studies focused on abstinence only, 70% (7 of 10) among studies targeting abstinence and other behaviors or comparing those two approaches, and 100% (7 of 7) among studies targeting medication compliance, treatment retention, and attendance at work therapy. The somewhat lower level of success in studies targeting behavior change in multiple targets simultaneously compared with those with more focused targets is also consistent with prior CM reviews (Lussier et al., 2006).

We have organized our discussion of this more recent voucher-based CM literature in terms of seven research trends that we discerned: (a) treatment of special populations, (b) extending use into community settings, (c) improving longer term outcomes, (d) investigating various parametric questions, (e) using the intervention as a research tool rather than treatment intervention per se, (f) combining the intervention with pharmacotherapies, and (g) extending the intervention to additional substance use disorders. For illustrative purposes, we describe in detail at least one study associated with each of the trends.

Treatment of special populations. Treating SUDs in special populations is an important current trend in the development of voucher-based CM. For example, we identified at least nine studies over the past 5 years testing the efficacy of voucher-based CM for cigarette smoking cessation in special populations, including adolescents (Krishnan-Sarin et al., 2006), college students (Correia & Benson, 2006; Irons & Correia, 2008; Tevyaw et al., 2009), pregnant women (Heil et al., 2008; Higgins, Heil, Solomon, et al., 2004), individuals enrolled in treatment for other SUDs (Dunn, Sigmon, Thomas, Heil, & Higgins, 2008; Robles et al., 2005), and individuals residing in rural areas isolated from usual smoking-cessation services (Stoops et al., 2009).

The use of voucher-based CM to promote cessation from smoking during pregnancy is the most fully developed among these important efforts, and we use a study by Heil et al. (2008) on that topic to illustrate the research in this area. Study participants were 82 women who were still smoking on entering prenatal care. They were randomly assigned to a condition in which vouchers were earned contingent on biochemically verified abstinence from recent smoking or to a noncontingent control condition in which vouchers were delivered independent of smoking status. The vouchers were in place from study entry, usually toward the end of the first trimester, through 12 weeks postpartum. If a woman abstained completely throughout antepartum and postpartum, she could earn approximately $1,150 in purchasing power; the mean voucher earnings in this condition was $461 (*SD* = $456). Women in the noncontingent-voucher control condition received vouchers independent of smoking status and at values of $15 per visit antepartum and $20 per visit postpartum, with mean earnings of $413 (*SD* = 163), which did not differ significantly from earnings in the contingent condition.

Biochemically verified abstinence was significantly greater among women in the contingent-voucher condition than in the noncontingent-voucher condition at the end-of-pregnancy assessment (41% vs. 10%) and 12-week postpartum assessments (24% vs. 3%; Figure 19.4). Mean weeks of continuous abstinence during the antepartum period was also significantly greater in the contingent-voucher than the noncontingent-voucher conditions, with those in the former achieving 9.7 weeks (*SD* = 1.9) and those in the latter achieving 2.0 weeks (*SD* = 0.8). Additionally, a significantly greater percentage of women assigned to the contingent-voucher than the noncontingent-voucher conditions sustained abstinence through the third trimester (27% vs. 3%), which is the trimester in which fetal growth appears to be especially affected by maternal smoking.

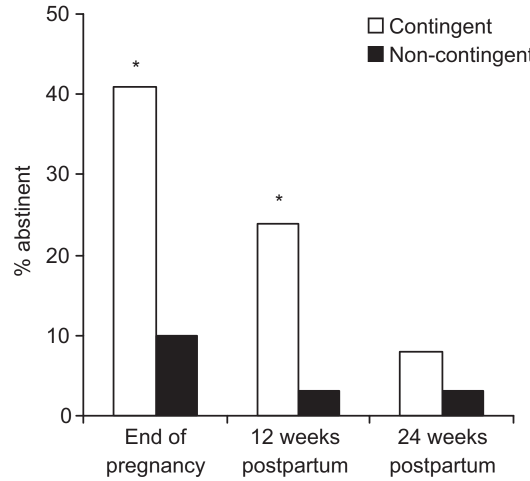

FIGURE 19.4. Point-prevalence abstinence at the end of pregnancy and at 12 and 24 weeks postpartum. Women in the contingent condition (n = 37) received voucher-based contingency management contingent on biochemically verified smoking abstinence, and women in the noncontingent condition (n = 40) received vouchers independent of smoking status. An asterisk indicates a significant difference between conditions ($p < .05$). From "Effects of Voucher-Based Incentives on Abstinence From Cigarette Smoking and Fetal Growth Among Pregnant Women," by S. H. Heil, S. T. Higgins, I. M. Bernstein, L. J. Solomon, R. E. Rogers, C. S. Thomas, . . . M. E. Lynch, 2008, *Addiction*, *103*, p. 1013. Copyright 2008 by the authors. Reprinted with permission.

Treatment effects were no longer significant at the 24-week assessment (8% vs. 3%) in this trial, although they had been in an earlier trial (27% vs. 0%) conducted using the same treatment conditions and by the same team of investigators (Higgins, Heil, Solomon, et al., 2004). Serial ultrasound assessments of fetal growth conducted at 30 and 34 weeks gestation revealed significantly greater increases in estimated fetal weight in the contingent condition treatment condition than in the noncontingent treatment condition (Figure 19.5, top panel). In addition, estimated growth rates on two of the three individual parameters used to compute fetal weight (fetal femur length, fetal abdominal circumference) were significantly greater in the contingent condition than in the noncontingent condition (Figure 19.5, bottom panels).

Worth mentioning is that a recent meta-analysis of all treatments investigated for promoting smoking

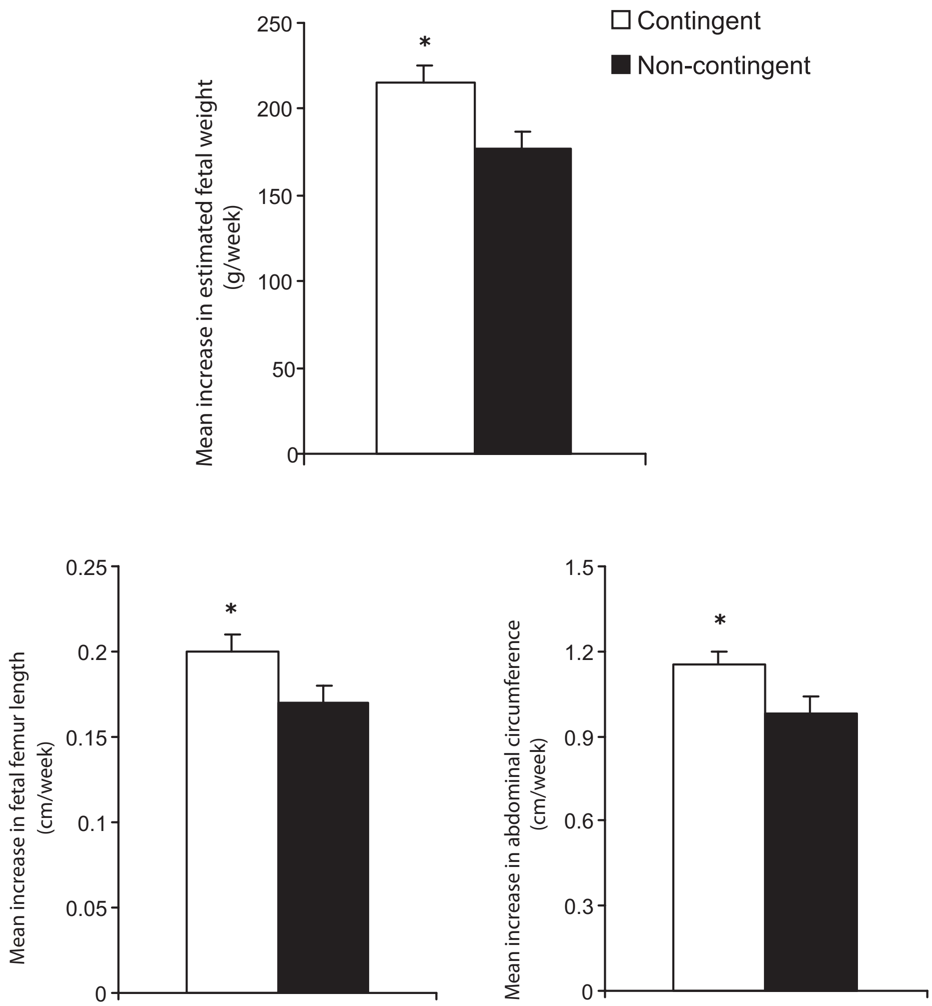

FIGURE 19.5. Mean (± standard error of the mean) rates of growth in estimated fetal weight (top panel), fetal femur length (bottom left panel), and fetal abdominal circumference (bottom right panel) between ultrasound assessments conducted during the third trimester. Women in the contingent condition ($n = 37$) received voucher-based contingency management contingent on biochemically verified smoking abstinence, and women in the noncontingent condition ($n = 40$) received vouchers independent of smoking status. An asterisk indicates a significant difference between conditions ($p < .05$). From "Effects of Voucher-Based Incentives on Abstinence From Cigarette Smoking and Fetal Growth Among Pregnant Women," by S. H. Heil, S. T. Higgins, I. M. Bernstein, L. J. Solomon, R. E. Rogers, C. S. Thomas, . . . M. E. Lynch, 2008, *Addiction*, *103*, p. 1015. Copyright 2008 by the authors. Reprinted with permission.

cessation among pregnant women identified voucher-based CM as producing the best outcomes (Lumley et al., 2009). Voucher-based CM appears to have tremendous potential for making a substantive contribution to improving outcomes in this serious public health problem.

Another special population with whom voucher-based CM has promise is people who are dually diagnosed (SUDs and other serious mental illness). We identified four studies on that topic in our review, all of which reported significant treatment effects (Drebing et al., 2005, 2007; Sigmon & Higgins, 2006; Tracy et al., 2007). Two of the studies supported the feasibility of using contingent vouchers to promote abstinence from cocaine, alcohol, and marijuana in the population with dual diagnoses (Sigmon & Higgins, 2006; Tracy et al., 2007), and the two other studies represented a more thorough investigation of the efficacy of contingent vouchers for promoting abstinence and job seeking among veterans enrolled in compensated work therapy (Drebing et al., 2005, 2007). Considering that compensated work therapy programs operate in veterans hospitals located throughout the United States, that they service large numbers of veterans with SUDs and other psychiatric disorders, and that improvements in the program are needed, this area appears to be a promising one in which voucher-based CM could make a substantive contribution.

The review identified two studies among special populations that further support the application of contingent vouchers for increasing participation in vocational training among people who are chronically unemployed and abuse intravenous drugs (Wong, Dillon, Sylvest, & Silverman, 2004a, 2004b) and two randomized clinical trials that support the efficacy of contingent vouchers for increasing adherence with antiretroviral medications among HIV-positive individuals dependent on illicit drugs (Rosen et al., 2007; Sorensen et al., 2007). The vocational training studies are part of Silverman et al.'s (2005) programmatic research effort, discussed earlier, examining the use of abstinence-contingent work therapy as a form of maintenance therapy. The studies on adherence with antiretroviral medications have suggested that some form of contingent-vouchers maintenance therapy may also be an important future direction to investigate with certain subgroups in that population.

Last, we identified one study supporting the efficacy of voucher-based CM for improving retention of pregnant women who abused illicit drugs in outpatient treatment (Svikis, Silverman, Haug, Stitzer, & Keyser-Marcus, 2007). Systematically using CM to improve outcomes with pregnant women who abuse illicit drugs is an important area of investigation ripe for programmatic development.

Extending the intervention into community clinics. Another important research effort has focused on moving voucher-based CM from university-based research clinics into community settings. Our literature review provided evidence that this effort is succeeding on multiple fronts. One particular direction with great potential is the implementation of CM through employer-based health programs. In an important study along those lines, Volpp et al. (2009) invited 878 employees of a large corporation who had reported smoking five or more cigarettes per day in an earlier survey to enroll in smoking-cessation treatment. For half of those employees, the invitation was coupled with an opportunity to earn financial incentives in the form of $100 for completion of a community smoking-cessation program, $250 for achieving biochemically confirmed abstinence from smoking within 6 months of agreeing to participate in the study, and $400 for remaining abstinent 6 months after first establishing abstinence from smoking. Adding contingent reinforcement to the effort to promote smoking cessation significantly improved outcomes; 15.4% versus 5.4% of those in the incentives versus no-incentives conditions enrolled in smoking cessation programs, 10.8% versus 2.5% completed those programs, 20.9% versus 11.8% were biochemically confirmed abstinent from smoking within 6 months of study entry, and 14.7 versus 5.0% and 9.4% versus 3.6% remained abstinent from smoking at the 9- to 12-month and 15- to 18-month follow-ups, respectively—all statistically significant treatment effects.

These results provide clear evidence that employer-based CM programs can promote healthy behavior change among employees in the area of SUDs. If employers discern economic benefit from having a healthier workforce, then this creates a potential mechanism for funding CM programs. The economic benefit need not come from improved productivity per se, although that is a distinct possibility that merits evaluation, but also from reductions in health care costs resulting from the increased morbidity associated with smoking or other unhealthy behavior. This area is new and much more remains to be learned, but it appears to be a promising future direction for CM and health-related behavior change.

Another direction in efforts to move voucher-based CM into community settings is one led by Petry, Peirce, et al. (2005) that aims to encourage community substance abuse clinics to use this treatment approach. The overarching goal of that effort is to demonstrate that one can use voucher values lower in cost than were used in most of the seminal studies described earlier while retaining improved outcomes compared with those obtained without CM. To that end, Petry and colleagues devised an intervention whereby study participants earn intermittent rather than continuous reinforcement for achieving therapeutic targets, which is accomplished by allowing patients to earn draws from an urn contingent on biochemically verified abstinence. The urn contains vouchers with differing payment amounts, with most offering low or no monetary earnings and a few offering higher earnings. In at least six controlled studies that were identified in our review (Alessi, Hanson, Wieners, & Petry, 2007; Ledgerwood, Alessi, Hanson, Godley, & Petry, 2008; Peirce et al., 2006; Petry, Alessi, Marx, Austin, & Tardif, 2005; Petry, Martin, & Simcic, 2005; Petry, Peirce, et al., 2005), the intervention was shown to increase abstinence or clinic attendance and treatment retention among people who abused illicit drugs enrolled in community clinics, including two multisite trials (Peirce et al., 2006; Petry, Peirce, et al., 2005).

This research effort is important because community clinics, which virtually always operate on limited budgets, are likely to be more open to adopting an evidence-based treatment that involves lower costs. Important to keep in mind and often misunderstood, though, is that overwhelming evidence has shown that the size of the treatment effects obtained with voucher-based CM decrease as the magnitude of the reinforcement used decreases (Lussier et al., 2006). No evidence has shown that Petry, Peirce, et al. (2005) have surmounted or altered that relationship. Instead, they have demonstrated that one can use incentives of a lower average value than are typically used in conventional voucher arrangements and still improve outcomes relative to no-incentive conditions, which is important. What they have not shown empirically is that their adaptation of the original schedule arrangement can produce larger treatment effects at lower costs compared with prototypical voucher programs. Indeed, in two trials conducted by Petry, Alessi, et al. (2005) and Petry, Alessi, Hanson, and Sierra (2007) in which their schedule arrangement was compared with a prototypical voucher arrangement using comparable overall reinforcement magnitude, no significant differences were found between the two arrangements in treatment outcomes. It merits mention that the area of optimal scheduling of alternative reinforcers to reduce rates of drug-maintained responding is that in which nonhuman research has the potential to make substantive contributions to CM (e.g., LeSage, 2009).

Other researchers are also investigating lower-value CM programs in community clinics (Brooner et al., 2007; Rowan-Szal, Bartholomew, Chatham, & Simpson, 2005). Again, no evidence has suggested that these investigators have devised a method for producing treatment effect sizes comparable to those achieved at higher voucher values but at a more affordable cost. Instead, as in the studies by Petry, Alessi, et al. (2005) and Petry et al. (2007), they have shown that costs can be lowered to more affordable levels while still retaining significant clinical benefit for patients in terms of improving treatment outcomes.

Four additional international examples relevant to the goal of integrating CM into community practices merit mention. One project conducted in Spain demonstrated that vouchers exchangeable for goods donated by community businesses were efficacious in treating cocaine dependence (Garcia-Rodriguez et al., 2009). The use of donated goods as the reinforcers for which the vouchers are exchanged illustrates community support and removes questions about funding the extra costs associated with the incentive program. A second project currently underway in the United Kingdom is examining the feasibility of nationwide adoption of voucher-based CM for treatment of SUDs after a recommendation to that effect from the National Institute on Clinical Excellence, an independent body in the United Kingdom responsible for providing national guidance on health promotion (Pilling, Strang, & Gerada, 2007). The third involves the use of voucher-based CM for smoking cessation among pregnant women in routine clinical practice in certain locations within the United Kingdom. For example, a program titled "Give It Up for Baby" located in Tayside, Scotland, uses vouchers exchangeable for grocery items to promote smoking cessation among economically disadvantaged mothers, the group most at risk for smoking during pregnancy (Ballard & Radley, 2009). The fourth example is the growing use of conditional cash transfer programs throughout low- and middle-income countries worldwide, some of which explicitly include elements of voucher-based CM (Lagarde, Haines, & Palmer, 2007). Conditional cash transfer programs are aimed at eliminating chronic poverty. In these programs, mothers earn cash supplements contingent on adherence with infant inoculations, supplemental feeding, and school enrollment and attendance, among other health-related goals. Tens of millions of families participate in these programs, which, without question, represent the largest CM effort ever undertaken (Higgins, 2010). It is still too early to thoroughly evaluate their effectiveness, but initial results look promising (Lagarde et al., 2007). Although these programs do not target SUD per se, they are nevertheless particularly relevant to discussions of dissemination of CM into community settings for addressing public health problems.

Also worth mentioning is that voucher-based CM is being successfully extended to other public health problems. For example, reports of successful controlled trials have recently appeared in the medical literature, extending the approach to increasing adherence to anticoagulant medications in patients at increased risk for stroke and bleeding complications (Volpp, Loewenstein, et al., 2008), increasing weight loss in obese adults (Volpp, John, et al., 2008), and increasing activity levels among sedentary elders (Finkelstein, Brown, Brown, & Buchner, 2008). This extension of voucher-based CM to other public health problems that have behavioral proximal causes is an important direction in which we anticipate considerable future growth.

Investigating longer term outcomes. From early in the development of the voucher-based CM approach to treatment of cocaine dependence, interest in its longer term outcomes has been present (Higgins et al., 1995). Research on how to directly improve longer term outcomes has taken two complementary directions that were discernible in the results of our review. The first seeks to build on correlational data suggesting that one key to fostering longer term abstinence is increasing during-treatment continuous abstinence (Higgins et al., 2000). In an experimental test of this notion conducted with outpatients dependent on cocaine, Higgins et al. (2007) demonstrated that increasing during-treatment continuous abstinence by increasing reinforcer magnitude (i.e., voucher monetary value) also improves longer term abstinence levels during a 2-year period of posttreatment follow-up. In this study, 100 cocaine-dependent outpatients were randomly assigned to one of two treatment conditions: CRA combined with abstinence-contingent vouchers set at twice or one half of the usual voucher value. Consistent with the main hypothesis, outpatients assigned to the higher-value condition achieved significantly greater cocaine abstinence during the 24-week treatment period and during an 18-month posttreatment follow-up period (Figure 19.6).

The second direction of research on this topic of improving longer-term outcomes is focused on voucher-based maintenance therapy. This important effort is being led by Silverman et al. (2005), who are systematically investigating whether integrating voucher-based CM for abstinence from drug use with vocational training initially and then paid employment thereafter may be a means for developing a self-sustaining intervention that can remain in place long term. Two recent trials have resulted in positive outcomes that are quite promising in terms of supporting the feasibility of establishing an efficacious maintenance intervention of voucher-based CM for treatment of outpatients who are chronically unemployed, urban, and dependent on intravenous cocaine and opioids (DeFulio, Donlin, Wong, & Silverman, 2009; Silverman et al., 2007).

Conducting parametric studies. As is appropriate and necessary in treatment development, many studies in the CM literature have also addressed various parametric questions about this treatment approach. We identified 13 reports of that nature in our literature review. The focus of these studies ranges widely but includes a wealth of potentially important and creative investigations about how to optimize and further expand this efficacious treatment approach. Examples include experiments on prototypical voucher-based CM combined with computer-delivered therapy (Bickel, Marsch, Buchhalter, & Badger, 2008), Internet-based CM delivered without regular in-person interaction (Dallery, Glenn, & Raiff, 2007), different scheduling

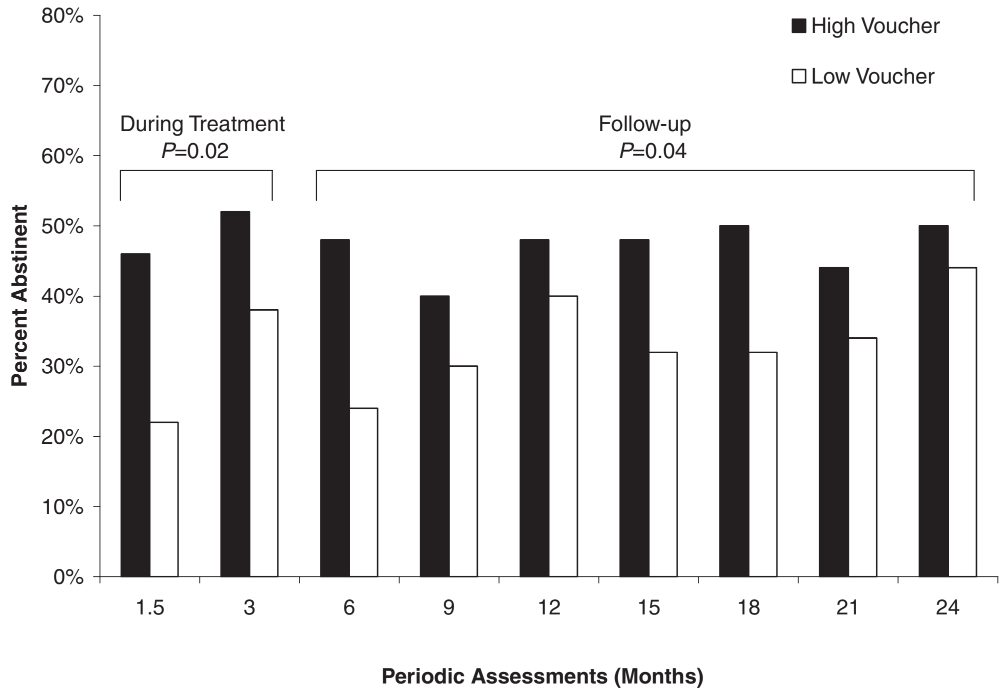

FIGURE 19.6. Percentages of patients abstinent from cocaine at periodic assessments conducted during treatment and posttreatment follow-up. Data points represent point-prevalence abstinence at the respective assessments. *Abstinence* was defined as self-report of no cocaine use in the past 30 days and cocaine-negative urine toxicology results. Data points for the high-value and low-value voucher conditions are represented by closed and open symbols, respectively. Brackets show how the periodic assessments were divided in a categorical modeling analysis and associated significance levels. From "Effects of Varying the Monetary Value of Voucher-Based Incentives on Abstinence Achieved During and Following Treatment Among Cocaine-Dependent Outpatients," by S. T. Higgins, S. H. Heil, R. Dantona, R. Donham, M. Matthews, and G. J. Badger, 2007, *Addiction, 102*, p. 276. Copyright 2007 by the authors. Reprinted with permission.

arrangements to optimize outcomes (Katz et al., 2004; Roll & Shoptaw, 2006), repeated exposure to the intervention (Sigmon, Correia, & Stitzer, 2004), and the possibility of using group rather than individual reinforcement contingencies (Kirby, Kerwin, Carpenedo, Rosenwasser, & Gardner, 2008). Some of these studies offer important but clearly incremental advances, and others represent novel advances. All are important and underscore the health of this area of investigation.

To illustrate work in this area, we describe results from a controlled study using an innovative, Internet-based adaptation of this treatment approach developed by Dallery et al. (2007). Twenty heavy smokers participated in this study, which used a within-subject reversal design. Twice daily, study participants made time-and-date-marked video recordings of themselves taking a breath carbon monoxide (CO) test, which they sent to the clinic electronically for smoking-status verification by study staff. During baseline conditions, voucher-based incentives were earned independent of smoking status, but during a 2-week intervention period, payment was contingent on reductions in smoking for the initial 4 days and complete abstinence from smoking for the remaining 10 days. Smoking, as evidenced by breath CO levels, decreased significantly during the intervention compared with the initial baseline period. What is notable about this Internet-based intervention is its potential to increase the convenience and reduce the expense associated with the typically intensive monitoring of smoking or other drug use status that is necessary to effectively implement voucher-based CM. This innovation also offers a potential method for offering CM treatment to individuals living in remote rural areas, which has been done successfully in at least one study (see Stoops et al., 2009).

Using the intervention as a research tool. An application of substantial scientific value but rarely discussed is the use of voucher-based CM as a research tool. The CM technology gives researchers the potential to experimentally alter drug use practices in individuals dependent on drugs for sustained periods of time while they reside in their usual drug-use environments. For example, CM has been used in efforts to experimentally analyze how a period of initial smoking abstinence may lower relapse risk (Alessi, Badger, & Higgins, 2004; Chivers, Higgins, Heil, Proskin, & Thomas, 2008; Lussier, Higgins, & Badger, 2005; Yoon, Higgins, Bradstreet, Badger, & Thomas, 2009). Sustaining abstinence through the initial weeks of a smoking-cessation effort is associated with a substantial increase in the likelihood of achieving longer term abstinence (Kenford et al., 1994). Similar to the relationship discussed earlier between early and later abstinence from cocaine, relatively little experimental analysis of the mechanisms involved in that relationship has occurred, owing largely to the absence of reliable methods to experimentally manipulate smoking rates short of placing study participants in controlled environments (hospital setting). Controlled environments are less than ideal for this purpose because of the absence of the typical smoking-related environmental conditions in such settings.

CM has been successfully used to surmount this obstacle of experimentally manipulating smoking rates, and we use one such study as an illustration of studies using CM as a research tool. In this study (Yoon et al., 2009), 28 daily cigarette smokers not currently seeking to quit long term were invited to participate in a 2-week protocol in which they might be asked to abstain from smoking for part or all of the study duration. Participants were randomly assigned to one of two study conditions: In one condition (14C), daily payment was made contingent on biochemically verified abstinence from smoking for all 14 days, and in the other condition (1C), daily payment was independent of smoking status on Days 1 to 13 and contingent on abstinence on Day 14 only. At the end of Day 14, all participants completed a 3-hour smoking-preference session during which they could make a total of 20 discrete-trial choices between earning two puffs on their preferred brand of cigarette or a small amount of money ($0.25 per choice). As anticipated, smoking abstinence was significantly greater in the 14C condition than the 1C condition across the initial 13 days of the study, but not on Day 14 when participants in both study conditions received abstinence-contingent reinforcement. In the smoking preference test, significantly fewer participants in the 14C condition (3 of 13; 23%) ever chose the smoking option than in the 1C condition (10 of 15; 66%). Additionally, the rate of choosing the smoking option differed significantly between the two conditions, with participants in the 14C condition choosing the smoking option an average of only 0.77 times ($SD = 0.61$) compared with those in the 1C condition, who chose the smoking option an average of 3.73 times ($SD = 0.94$). These significant differences in choice of the smoking option in the smoking preference session suggest that changes in the relative reinforcing effects of smoking may be one mechanism contributing to the differences in relapse risk commonly seen between those who do and do not sustain abstinence during the initial weeks of a smoking-cessation effort.

Another example of using CM as a research tool comes from a recent trial by Mueller et al. (2009), who used it to manipulate smoking rates to examine the potential contribution of individual differences in neuropsychological functioning to relapse vulnerability in a laboratory model of smoking abstinence. We found still other recent examples of voucher-based CM being used as a research tool in the pharmacotherapy literature, indicating that the intervention is increasingly being used to control the potential confounding influence of other drug use in evaluating the efficacy of new pharmacotherapies (Carroll & Rounsaville, 2007). We anticipate this area will be another one of growth in the CM literature.

Combining the intervention with pharmacotherapies. In addition to controlling the potential confounding influence of other drug use in evaluating pharmacotherapies for SUDs, voucher-based CM is being used in pharmacotherapy studies in at least three other ways. Some studies have focused on examining the relative efficacy of voucher-based CM versus a particular pharmacotherapy (Glenn & Dallery, 2007), others have investigated combined effects of CM plus pharmacotherapy (Poling et al., 2006), and still others have focused on whether CM can enhance compliance with pharmacotherapies known to be efficacious but for which adherence is problematic (Mooney, Babb, Jensen, & Hatsukami, 2005). Eight of the 10 trials we identified along these lines generated results supporting the efficacy of the CM intervention, but in terms of any type of synergistic effects of combining CM and medications, the results from this emerging and potentially very important area of investigation are quite mixed.

Perhaps the clearest finding in this area was a study that showed that the efficacy of voucher-based CM for cocaine abstinence among opioid-dependent patients enrolled in substitution therapy was dependent on patients' receiving an adequate dose of the medication (Oliveto et al., 2005). In this trial, patients who abused cocaine and opioids were stabilized on varying doses of levo-alpha-acetylmethadol (LAAM), a long-acting opioid medication similar to methadone, and assigned to one of four experimental conditions: low-dose LAAM combined with abstinence-contingent vouchers, low-dose LAAM combined with noncontingent vouchers, high-dose LAAM combined with abstinence-contingent vouchers, or high-dose LAAM combined with noncontingent vouchers. Abstinence from cocaine and opioids was greatest in the condition combining abstinence-contingent vouchers with high-dose medication.

The trial by Poling et al. (2006) suggested that combining bupropion therapy with voucher-based CM for treatment of cocaine dependence may facilitate the medication's efficacy. The results were somewhat ambiguous, but should they prove to be replicable, they could offer great promise for combining CM and pharmacotherapy. Overall, this area of investigation currently lacks any readily discernible programmatic direction but certainly appears to have great potential.

Extending the intervention to additional substance use disorders. Extension of voucher-based CM to new types of SUD is only a small part of current voucher-based CM research efforts, with most of the important work on that topic having been done in the initial 10 years or so after the introduction of this treatment approach (Lussier et al., 2006). Several studies identified in the current review might fall into this category, especially several on treating methamphetamine dependence. For example, Roll and Shoptaw (2006) conducted a small trial involving 18 outpatients dependent on methamphetamine. Study participants were randomly assigned to one of two different schedules of abstinence-contingent voucher schedules. One schedule was the prototypical schedule in which voucher value escalated contingent on each consecutive negative urine toxicology test and reset back to the initial low value if a drug test result was positive or if a participant failed to submit a scheduled specimen. In the other condition, voucher value escalated with each consecutive negative test, but there was no reset contingency for positive tests or failure to submit a scheduled specimen. Those assigned to the condition with the reset contingency submitted a significantly greater percentage of drug-negative specimens across the 12-week study period than those in the condition without the reset contingency (80% vs. 30%) and achieved a significantly longer duration of continuous abstinence ($M = 6.7$ weeks, $SD = 3.2$, vs. $M = 2.8$ weeks, $SD = 3.6$). Thus, this punishment contingency appears to have an important role in the efficacy of the prototypical voucher-based CM intervention.

Positive outcomes have been achieved in other trials assessing the efficacy of voucher-based CM in treating mixed samples of patients dependent on cocaine and methamphetamine enrolled in methadone (Peirce et al., 2006) or drug-free (Petry, Peirce, et al., 2005) community treatment clinics. When analyses from these latter studies were limited to only methamphetamine patients, the positive effect of CM on abstinence from drug use remained statistically significant (Roll et al., 2006). These findings are a welcome development considering how highly toxic methamphetamine is at the level of individual health and community stability. We know of at least one instance in which a public health office in a large urban center used voucher-based CM in an effort to address problems associated with risky drug and sexual behavior among gay and bisexual men dependent on methamphetamine (Strona et al., 2006).

CONCLUSIONS

The voucher-based CM approach to treatment of SUDs has developed in many exciting directions during the past two decades and has come to represent an important part of evidence-based treatments for SUDs and for other public health problems. The high level of efficacy achieved with this intervention across the many varied applications described in this chapter underscores the fundamental importance of the basic principle of reinforcement and related processes to understanding and treating SUDs and related health problems.

The material reviewed in this chapter has also shown that more research and development is needed to identify ways to further increase the effectiveness of voucher-based CM so that the intervention can succeed with even more patients. Even in applications such as promoting smoking cessation among pregnant women (e.g., Heil et al., 2008), in which the outcomes achieved with voucher-based CM far exceeded those achieved with any other treatment for that problem (Lumley et al., 2009), only about 40% of those treated had a successful outcome. Clearly, room for improvement exists. In many instances, the most likely option for achieving improvements will be offering a higher magnitude of reinforcement, because those with more severe levels of baseline drug use are usually those who fail to respond. The empirical evidence showing that increasing reinforcement magnitude increases the proportion of patients who respond to voucher-based CM is extensive (Higgins et al., 2007; Lussier et al., 2006; Silverman et al., 1999). Reinforcement magnitude is not the only option, however. Other options such as shortening the delay to reinforcement delivery and combining the intervention with efficacious pharmacotherapies merit thorough examination as well. Results from the Dutra et al. (2008) meta-analysis underscore the potential benefit of combining CM with other behavioral or cognitive–behavioral therapies, which is another topic worthy of further investigation.

Developing methods to sustain treatment effects over time will also remain an important priority. Strong evidence has shown that treatment effects achieved with voucher-based CM can extend well beyond the treatment period, especially when the initial treatment response is robust (Higgins et al., 2000, 2007; Higgins, Heil, Solomon, et al., 2004). That said, there is also no question that relapse rates are high with this treatment, as they are with all treatments for SUDs, and devising methods to improve longer term outcomes must remain a priority. Also important is the need to develop long-term or maintenance CM interventions. The importance of maintenance interventions has long been recognized in opioid substitution therapies for opioid dependence, self-help, and therapeutic-community interventions for SUDs generally (see Galanter & Kleber, 2008), and it is coming to be recognized regarding the use of nicotine replacement and other pharmacotherapies for smoking cessation (Steinberg, Schmelzer, Richardson, & Foulds, 2008). We see no reason to anticipate that voucher-based treatment for SUDs will be an exception to that pattern.

Dissemination of this treatment approach into community settings will remain an important priority. This treatment approach may be a better fit with single-payer health care systems such as in the United Kingdom, where the practical question of who will pay for the incentives that is so much at the forefront of dissemination discussions within the United States is at least less relevant if not totally inapplicable. Of course, health care systems exist within the United States, such as the Veterans Affairs system, in which that practical question may be less relevant as well, and we look forward to progress in the dissemination of this treatment approach into those systems. Integrating voucher-based CM into compensated work therapy programs appears especially promising in that regard (Drebing et al., 2005, 2007). Also important are efforts discussed earlier that are focused on integrating voucher-based CM into corporate efforts to improve employee health (Volpp et al., 2009). The positive influence of voucher-based CM research on policies and practices around the use of contingencies to promote behavior change in the U.S. drug court system is also important to recognize in assessing dissemination of this treatment approach. The same appears to hold for influencing at least some practices within the conditional cash transfer movement (Higgins, 2010). All of these efforts will benefit from careful cost-effectiveness studies, which are only beginning to emerge in the CM literature (e.g., Knealing, Roebuck, Wong, & Silverman, 2008; Sindelar, Elbel, & Petry, 2007).

As is clearly shown in the research reviewed in this chapter, voucher-based CM interventions represent an orderly and evolving evidence-based set of procedures that are based on fundamental principles of behavioral science (Higgins, Heil, & Lussier, 2004). As such, the further improvement and development of these procedures can be guided by the basic scientific principles on which the interventions are based. The broad success the field has achieved to date in applying these basic principles to treat SUDs across populations, drugs, and settings should give great confidence that researchers can continue to develop and improve CM interventions to address the costly and devastating consequences of SUDs. Likewise, the positive results obtained more recently using CM to treat medication noncompliance (Volpp, Loewenstein, et al., 2008), obesity (Volpp, John, et al., 2008), and physical inactivity (Finkelstein et al., 2008) suggest great potential for this treatment approach to also make substantive contributions to treating other public health problems in which behavior is a proximal cause. Overall, we are quite optimistic about the future of this treatment approach in promoting health-related behavior change.

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Chapter 20

BEHAVIORAL APPROACHES TO BUSINESS AND INDUSTRIAL PROBLEMS: ORGANIZATIONAL BEHAVIOR MANAGEMENT

William B. Abernathy

Applied behavior analysis is based on B. F. Skinner's operant learning principles. Skinner's seminal work in this regard was *Science and Human Behavior* (Skinner, 1953). Applied behavior analysis encompasses many settings and types of applications, especially clinical and educational applications. Organizational behavior management (OBM) is a subfield of applied behavior analysis that focuses on applications in the workplace. I begin this chapter with a broad-strokes summary of the outcomes of OBM projects as reported in two literature reviews and a new review conducted for this chapter. Next, I provide a brief history of OBM, the learning principles underlying OBM applications, the OBM implementation process, performance analysis strategies, the organizational behavior systems perspective, and future directions and collaborations for OBM.

ORGANIZATIONAL BEHAVIOR MANAGEMENT RESULTS

Balcazar, Hopkins, and Suarez (1986) reviewed articles for the period 1974 through 1984 and found 69 OBM applications in organizational settings. The articles were found in four journals: *Academy of Management Journal, Journal of Applied Behavior Analysis, Journal of Applied Psychology,* and the *Journal of Organizational Behavior Management*. All projects measured individual performance. Of the articles, 41% reported consistent performance improvements in all individuals. Another 49% reported mixed effects in which some individuals' performances improved and others' did not. The remaining 10% of the articles reported no effect.

Of these articles, feedback alone was the most common OBM application. Examples of feedback include supervisor vocal comments, written narratives, and graphic feedback. Performance improved more when the feedback was graphic and delivered by supervisors or managers. Feedback was most effective when combined with rewards, goal setting, or both.

Alvero, Bucklin, and Austin (2001) replicated and expanded Balcazar et al.'s (1986) review by analyzing OBM projects in 68 organizational settings on the basis of articles in the *Journal of Organizational Behavior Management* for the period 1985 through 1998. Consistent effects were found in 58% of the projects, mixed effects in 41%, and no effects in 1%.

Combining both reviews, the most frequently used method was feedback alone. Feedback was most commonly provided by the supervisor or manager. Individual feedback was used most, but group feedback yielded the most consistent results in both reviews. In the Balcazar et al. (1986) review, graphic feedback was the most common and yielded the most consistent results. In the Alvero et al. (2001) review, written feedback was most common, whereas a combination of written and graphic feedback yielded the most consistent results. In the first review, feedback was most often provided daily, and the most consistent results were obtained with daily or weekly feedback. In the second review, feedback was most commonly delivered weekly and produced more consistent positive results (80% of studies) than daily feedback (71%). In Alvero et al., monthly

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feedback also yielded consistent results in 80% of the studies reviewed.

For the purpose of this chapter, I reviewed a sample of 68 OBM studies published in the *Journal of Organizational Behavior Management* from 1984 to 2009. Studies selected were conducted in organizational settings and reported improvement statistics. Table 20.1 shows that across all 68 studies, the OBM interventions improved performance by a median of 54.5%. The settings for the interventions included 33 in manufacturing, 24 in retail, and 11 in not-for-profits. The types of interventions included 16 based on antecedent stimuli (e.g., training), 28 with feedback only, one that arranged nonmonetary consequences, and 23 that arranged monetary consequences. As in the prior reviews, feedback was generally effective in improving performance.

In a chapter in the book *Organizational Change* (Abernathy, 2001), I examined 2,195 performance measures in client organizations that began using feedback and performance pay. He found a composite trend of a 33% increase over a 12-month period. The composite was created by converting the raw data for each measure to standard scores, then averaging the standard scores.

More recently (Abernathy, 2010), I compared 68 project baseline performances in a medium-sized bank with performance levels at the end of 90 days. Target measures were selected by manager–subordinate teams from previously developed performance matrices. Examples of these measures included percentage of days balanced, percentage of accounts past due, accounts opened per hour, and percentage of audits completed on time. The intervention consisted of an incentive pay plan linked to the performances specified in the matrices. In addition, each team member was awarded $100 if performance on a target measure improved at least 30% over baseline. The results are depicted in Figure 20.1. On average, performances improved by 58%, with no performances deteriorating at the end of the 90-day intervention. Thus, across three literature reviews, and in the analyses depicted in Figures 20.1 and 20.2, varied types of evidence have supported the position that OBM interventions are effective in improving employee performances.

BEGINNINGS OF ORGANIZATIONAL BEHAVIOR MANAGEMENT

The beginnings of OBM are often traced back to Owen Aldis's 1961 article "Of Pigeons and Men," in which he made the case for applying operant psychology principles to the workplace. In 1969, Walter Nord expanded the case for OBM in his article "Beyond the Teaching Machine: The Neglected Area of Operant Conditioning in the Theory and Practice of Management." One of the first articles to describe an actual application of OBM in business was authored by Brethower and Rummler (1966).

In the same era, the application of operant principles to training and instruction led to the founding of the National Society for Programmed Instruction, now the International Society for Performance Improvement, with more than 1,000 members. Much of this early performance-based employee training was developed at the University of Michigan between 1961 and 1969 (Dickinson, 2001). Rummler left the University of Michigan in 1969 to found the consulting firm Praxis Corporation with Tom Gilbert, who later authored *Human Competence: Engineering Worthy Performance* (Gilbert, 1978).

TABLE 20.1

Summary of Percentage Gains by Project Intervention

Intervention	No. of studies	Average (%)	*SD* (%)	Minimum (%)	Maximum (%)
Overall	68	90.4	110	1.8	625
Antecedents	16	78.1	110	1.8	418
Feedback	28	120	133	3.0	625
Nonmonetary	1	89			
Incentive pay	23	63.3	69.6	3.0	300

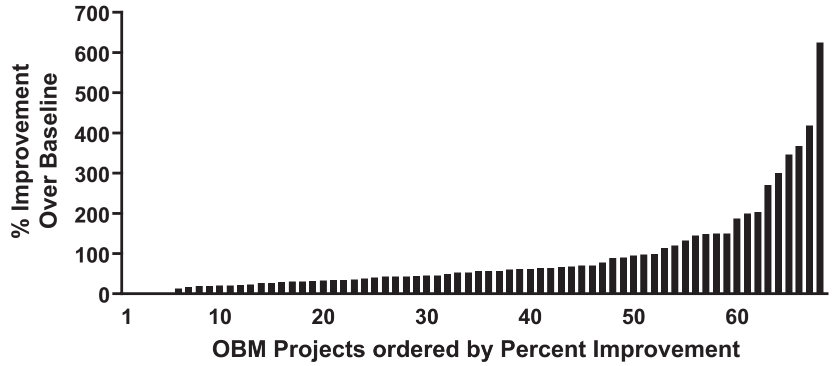

FIGURE 20.1. Baseline-to-intervention percentage improvements in 68 organizational behavior management (OBM) projects. From "A Comprehensive Performance Analysis and Improvement Method," by W. B. Abernathy, 2010, *Performance Improvement, 49*, p. 15. Copyright 2010 by the International Society for Performance Improvement. Adapted with permission of John Wiley & Sons, Inc.

Dale Brethower introduced the behavior systems perspective with his 1972 book *Behavioral Analysis in Business and Industry: A Total Performance System*. Paul Brown founded the consulting firm Instructional Design Associates, Inc., in 1971. He provided OBM-oriented management workshops at IBM and coauthored the book *Behavior Modification in Business, Industry and the Government* (Brown & Presbie, 1976).

In 1972, Aubrey Daniels, a clinical psychologist, and Fran Tarkenton, quarterback of the Minnesota Vikings and owner of Learning Foundation, founded Behavioral Systems, Inc. Their early work was with Milliken Textiles and other southern textile firms and focused on employee attendance and turnover. In 1978, Daniels founded Aubrey Daniels and Associates, which is now Aubrey Daniels International.

In 1973, Ed Feeney founded Edward J. Feeney and Associates, a consulting firm for businesses. Feeney was a sales manager for Emery Air Freight and attended a University of Michigan workshop on the management of behavior change. Feeney then implemented OBM programs throughout Emery Air Freight. Feeney's (1976) seminar workbook was titled *Behavioral Engineering and Systems Training*. These applications were reported widely, including in *Business Week* ("Where Skinner's Theories Work," 1972); *Organizational Dynamics* ("At Emery Air Freight," 1973); and in the film *Business, Behaviorism and the Bottom Line* (CRM Productions, 1972). Frederiksen and Johnson (1981) have argued that Feeney likely "opened the door for the widespread application of OBM" (p. 193). Examples of the work of Feeney and his consultants can be found in the handbook *Industrial Behavior Modification* (O'Brien, Dickinson, & Rosow, 1982).

In 1977, the *Journal of Organizational Behavior Management* was first published by the previously mentioned consulting firm Behavioral Systems, Inc., with Aubrey Daniels serving as editor. In 1982, the Organizational Behavior Network was founded, and in 1988 the first conference devoted exclusively to OBM was held in cooperation with the Florida Association of Behavior Analysis.

BASIC LEARNING PRINCIPLES AND ORGANIZATIONAL BEHAVIOR MANAGEMENT: MEASUREMENT, FEEDBACK, AND CONSEQUENCES

As an applied psychology, OBM is unique in that all of its principles and practices can be directly traced to the operant psychology of B. F. Skinner (1953). OBM is conceptually and methodologically grounded in behaviorism and the science of behavior.

Performance Measurement

In OBM, the dependent variable is observable employee behavior. Skinner (1938) recommended that the basic measure of behavior be its frequency or rate, although measuring duration, computing latency, and reporting other dimensions of observable behavior in the workplace have also become common.

Behavior versus results. A critical performance measurement issue in OBM relates to what Skinner (1953) termed the *free operant*. In Skinner's original work with animals, response rate was not recorded. Rather, the rate of bar-press switch closures was recorded. The topography of the rat's response (e.g., pressing with the right paw, left paw, or chin or sitting on the bar) was typically not recorded—only the actual closure of the switch. Skinner referred to this class of functionally related, but topographically distinct, responses as an *operant* because they operate on the environment to produce a common result (in this case, the switch closure).

This distinction between operants, or response classes, and specific responses is a key measurement issue in the workplace. In most cases, the results of an employee's performance are more important to the organization than are the details of the behavior that produced the result. Edward J. Feeney's (1976) *Behavioral Engineering and Systems Training* recommended that results should be defined as a "noun followed by a past tense verb" (p. 20). For example, *letter typed, machine repaired,* or *call completed* are results that should be measured rather than the behaviors of typing, repairing, or calling.

Measuring results avoids targeting behaviors that may have unintended effects and may not ultimately produce the desired result. For example, a banking client wanted to increase the number of customer accounts opened by new accounts clerks (a result). The bank's management thought the clerks could best improve sales by increasing their use of cross-selling techniques. For example, when a customer opened a checking account, the clerk would suggest also opening a savings account. As new account clerks focused on these specific behaviors (rather than on results), the use of cross-selling techniques increased, but the number of new accounts opened declined at several branch banks. With the emphasis on the behavior of cross-selling, many clerks ignored established customers and others who appeared unable to open multiple accounts.

A second example was in bank collections. The result of interest was to reduce the delay in collecting payments on outstanding loans and credit cards. Management thought the problem was that the collectors were not making enough phone calls. This focus on the specific behavior thought to underlie the result led management to measure the number of calls made by collectors each month. As a consequence, the collectors began to call friends and family rather than customers with past due accounts. Needless to say, this increase was not accompanied by a decrease in the number of days that loan collections were outstanding. Table 20.2 is excerpted from Daniels and Rosen (1983) and summarizes the distinctions between behavior and results measures.

There are exceptions to the principle of measuring results. For example, behaviors must be directly

TABLE 20.2

Distinguishing Results From Behaviors

Behavior	Results
What people are doing	What people have produced
What you see people do when they are working	What you see after people stop working
Must see people working	Not necessary to see people working
Tends to be expressed in present tense, verbs ending in *ing*	Tends to be expressed in the past tense by noun–adjective pairings: "document filed"
Cue words: *by, through, to*	Cue words and phases: *in order to, so that, to achieve, to be able to*
Commonly used terms: *input, process, activity, means*	Commonly used terms: *output, result, outcome, achievement, ends*

Note. From *Performance Management: Improving Quality and Productivity Through Positive Reinforcement* (p. 80), by A. C. Daniels and T. A. Rosen, 1983, Tucker, GA: Performance Management Publications. Copyright 1983 by Aubrey Daniels International. Adapted with permission.

measured when prevention is the goal. Much of the excellent OBM work in the area of safety involves counting safe behaviors (in which a checklist is used to identify and quantify specific response topographies, e.g., lifting a heavy object with a straight back) rather than counting the resulting accidents or injuries (see review by Grindle, Dickinson, & Boettcher, 2000). One could measure pilot safety by the number of airplane crashes, but a more reasonable approach would be to monitor pilot behavior via a preflight checklist.

A second exception is behavioral style. Administrators of an organization may want customer service agents to greet people with specific behavior topographies such as greeting them by name, smiling, or making eye contact. Salespeople may be expected to use techniques that have proven effective in the past or that comply with company policies. Under these conditions, measures of ongoing behavior would be preferable to measures of the results of those behaviors.

Measure actionable results. Another critical measurement issue in workplace settings is to measure results that are actionable by the employee. Measures become less controllable by the individual employee as more variables influence the result or as more employees are involved in producing the result. Profit is generally a poor performance measure because it is made up of several income and expense items, many of which a specific employee's behavior may have little or no influence on. In addition to the individual employee, all other employees in the organization have some influence on this measure, which significantly decreases the contingent relationship between the employee's behavior and the result.

Balanced measurement. A final measurement issue is balanced measurement, as popularized by Kaplan and Norton (1996) in their influential book *The Balanced Scorecard: Translating Strategy Into Action*. Balancing addresses problems associated with one-dimensional performance measurement plans. If feedback and recognition, or especially monetary incentives, are made contingent on one performance dimension, performances on other dimensions may deteriorate. For example, measuring productivity may cause quality or safety to suffer. Conversely, exclusively measuring error rates may result in a decline in production.

A solution is balanced measurement, in which management, supervisors, employees, or all of these identify potential conflicting behaviors and include them in a performance scorecard (Kaplan & Norton, 1996). An example of one such approach is the performance matrix (Felix & Riggs, 1986) shown in Figure 20.2. Unlike other scorecard formats, the matrix mathematically balances multiple performances by assigning a percentage weight to each. The weights are expressed as percentages (summing to 100%) and reflect the relative importance of each measure in the overall performance of the employee or unit. Balance is also ensured by capping the percentage scores that may be earned for any measure. For example, if the deadlines-met goal for the month was 95% and the employee completed 100% of the deadlines assigned, he or she would still receive only the percentage score indicated in the weight column of the performance matrix (40% in Figure 20.2). Capping prevents an employee from focusing on one performance and driving it above the goal to allow him or her to ignore other performances.

PERFORMANCE FEEDBACK

Although the concept of feedback is not used much in operant psychology, the term is common in OBM. *Performance feedback* refers to information that follows a performance and describes the level or

Measure Name	Base	Goal	Weight
Items / Hour	20	40	15%
Accuracy %	90%	100%	25%
% Deadlines Met	80%	95%	40%
Safety Checklist %	70%	100%	20%

FIGURE 20.2. Sample performance matrix.

quality of the performance. Positive feedback may serve as a discriminative stimulus that may occasion the performance under similar conditions in the future because it describes the performance that is likely to produce reinforcement. It may also strengthen the behavior on which it is contingent. When feedback strengthens the behavior on which it is contingent through the process of reinforcement, the positive feedback is probably functioning as a generalized or conditioned reinforcer, because positive feedback is often followed by back-up reinforcers such as public recognition, preferred job assignments, preferred work shifts, annual performance reviews, promotions, and pay. The reinforcing value of feedback probably depends on the feedback's being followed by other reinforcers. If this fails to occur, then positive feedback is likely to lose its reinforcing effect. If this interpretation is correct, then providing employees feedback that is not linked to primary reinforcers will ultimately fail to sustain performance.

Immediacy of Feedback

The immediacy of feedback is a key concern for organizational behavior analysts. Many organizations provide formal feedback to employees only once a year through annual performance reviews. In basic and applied research, reinforcers are generally more effective when they occur immediately after the behavior. In contrast, if feedback is viewed primarily as a prompt for future reinforcers, then feedback can be effective even when somewhat delayed. I studied feedback across 2,195 performance measures in eight organizations (Abernathy, 2011). Figure 20.3 shows these organizations' composite monthly performance trends for the first 12 months after performance matrix feedback was provided to individual employees. These composite measures were developed by converting all measures to standard scores and averaging them. Organizations A, D, E, G, and H in Figure 20.3 provided feedback to employees on a monthly basis, whereas Organizations B, C, and F provided feedback quarterly. Although the study was not randomly controlled, these findings suggest that monthly feedback was superior to quarterly feedback in its impact on employee performance trends.

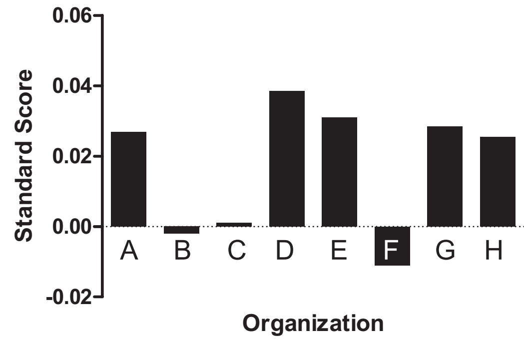

FIGURE 20.3. Effects of monthly versus quarterly performance feedback on 12-month standard score trends. From *Pay for Profit: Creating an Organization-Wide Performance System* (p. 173), by W. B. Abernathy, 2011, Atlanta, GA: Performance Management Publications (ISBN 0-9655276-1-1). Copyright 2011 by Aubrey Daniels International, Inc. Adapted with permission.

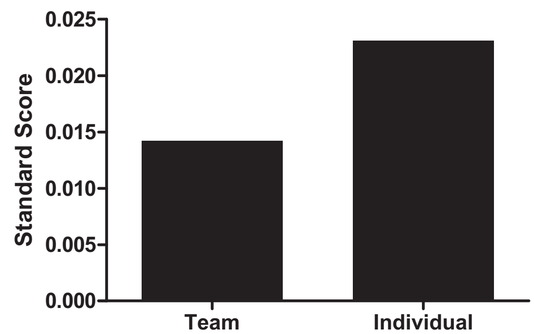

FIGURE 20.4. Effects of providing feedback to teams or individual employees. Twelve-month standard score trends are shown. Adapted from *Pay for Profit: Creating an Organization-Wide Performance System* (p. 183), by W. B. Abernathy, 2011, Atlanta, GA: Performance Management Publications (ISBN 0-9655276-1-1). Copyright 2011 by Aubrey Daniels International, Inc. Adapted with permission.

Individual Versus Team Feedback

Figure 20.4 (Abernathy, 2011) shows a comparison of performance improvements when feedback was provided about the team's collective results versus results produced by individual employees. Again, the constraints of conducting research in organizational settings do not allow for randomized controls, but these findings suggest that providing feedback about individual employees' performance has a bigger impact than does providing feedback based on team performance.

Performance Consequences

Skinner's (1938) operant psychology is grounded in the general theory of selectionism (see Chapter 10, this volume). Unlike cause-and-effect models that focus on motives and attitudes that goad the individual into action, selectionism finds that behavior is controlled by events that occur after the behavior. According to the operant account, voluntary behavior is not driven or elicited but rather emitted and then selected by the environment through its consequences. Behavior that produces positive consequences is selected by the environment, behavior with no consequences is not selected by the environment, and behavior with aversive consequences is selected against. This selectionist philosophy is equally at home in the free market economy (e.g., A. Smith, 1776) and in evolutionary biology (e.g., Darwin, 1859).

Taking a selectionist approach to behavior means the OBM technician will be especially interested in determining the consequences of employee behaviors. If target performances (e.g., completing tasks more quickly) have no consequences (e.g., management never acknowledges them) or aversive consequences (e.g., fellow employees chastise the employee for making them look bad), then improvement techniques that do not alter these consequences (e.g., training, work methods improvements) may fail to sustain performance or prove only partially successful.

As outlined in Table 20.3, Skinner (1938) organized the consequences of behavior into four categories: positive reinforcement, negative reinforcement, positive punishment, and negative punishment. Each consequence is defined operationally in terms of whether the event is added or removed after the behavior and whether the performance increases or decreases as a consequence of this operation.

Negative reinforcement. A key mission of many OBM practitioners is to transition organizations from a reliance on negative reinforcement (coercion; "do it or else") to the use of positive reinforcement. Although most people think of wages and salary as positive reinforcers, Skinner (1953) suggested that they might actually function as negative reinforcers. Hourly wages and monthly salaries do not meet the definition of positive reinforcement because they are not paid contingent on employee performance. They are paid on the basis of a predetermined time period (e.g., a paycheck every 2 weeks). The "dead man rule" applies: If an employee died, and no one informed payroll, he or she would still receive a paycheck.

According to Skinner's (1953) analysis, employees do not work to receive a wage or salary; they work to avoid losing it. The employee need not experience this directly. The contingent relation may be stated in a contract or observed from the consequences of other employees' poor performance. Many managers do not see a problem with negative reinforcement. "If they don't perform, we fire them!" is an all-too-common response to the recommendation that the organization arrange positive reinforcement contingencies to manage employees.

The case for businesses to transition from negative to positive reinforcement is good. First, in business settings dominated by negative reinforcement (i.e., avoiding getting fired), management fails to measure performance regularly or precisely. Instead, management emphasizes time spent working rather than results. When a company begins discussing traditional compensation arrangements, it is amazing how much the conversation concerns time: overtime, undertime, time clocks, time logs, time in grade, vacation time, sick time, compensatory time,

TABLE 20.3

Consequences of Behavior (Skinner, 1938)

Term	Action	Effect
Positive reinforcement	Event added	Responding increases
Negative reinforcement	Event removed	Responding increases
Positive punishment	Event added	Responding decreases
Negative punishment	Event removed	Responding decreases

and so on. Little attention is given in these meetings to discussing actual employee performance. A slogan that describes this issue is "If you pay for time, you get time. If you pay for results, you get results."

In a time-based wage and salary system, the employee learns to fill the day and look busy in an attempt to avoid a host of aversive consequences (e.g., being yelled at by the boss, being fired). As I often tell clients, however, "Busyness isn't business." For example, a banking client of mine was experiencing long delays in processing credit card applications. The management of the area was unwilling to consider performance pay, so we suggested that when all the credit cards scheduled for processing in a given day were completed, the employees could go home and still receive a full day's pay. Management initially objected that this practice would be too expensive until it was pointed out that the compensation cost per card would be the same. Management reluctantly agreed to try the plan, and it was subsequently explained to a group of somewhat skeptical employees.

On the following Monday, all the cards were processed by noon, and everyone went home (i.e., efficient credit card processing was reinforced). This continued for a month, and the delay in card processing was cut by two thirds with a reduction in overtime pay. At the end of the month, despite its success, management terminated the program, arguing that the employees had been intentionally filling their days to keep their jobs and receive overtime. This observation was correct, but management blamed the employees rather than the faulty reinforcement system for it.

A second issue, created by the use of negative reinforcement–based wage schemes, relates to behaviors that are natural responses to aversive control (recall that negative reinforcement involves escape from or avoidance of aversive events). These reactions to aversive control include aggression, unsanctioned instances of escape and avoidance, and emotional responses (Azrin, Hutchinson, & McLaughlin, 1967). Possible aggressive responses include complaining, lawsuits, conflicts, sabotage, and theft. Unsanctioned escape and avoidance may be evidenced by failures to carry out orders, absenteeism, tardiness, extended breaks, and leaving early. Emotional responses such as fear or anger may interfere with customer interactions or precision and creative work. Murray Sidman (1989) discussed problems associated with negative reinforcement in his book *Coercion and Its Fallout*.

A third issue, created by an exclusive reliance on negative reinforcement, is poor performance. When a performance standard is adopted, it is in the employee's best interests to meet the standard but not to exceed it. Meeting the standard allows the employee to avoid aversive events, but exceeding the standard leads to no further gain (i.e., no positive reinforcers) and may often result in aversive events (e.g., management may increase the standard, and fellow employees may chide the employee for making them look bad). A similar process occurs if after employees achieve a goal, it is increased. Daniels and Daniels (2004) have referred to these phenomena as *losses of discretionary effort*.

A final issue with negative reinforcement is expense. Managing through negative reinforcement requires a high level of expensive direct supervision, whereas pay for results requires less. In a negative-reinforcement workplace, the supervisors must spend their time directly observing employees to ensure they are performing while on the clock. By contrast, paying employees for results may be used without ever observing the ongoing performance, making it perfect for employees who work at home or in distant locations. The result of managing through positive reinforcement is often that managers may supervise more employees, thereby reducing management expenses (Van Fleet & Bedian, 1977). For example, Lincoln Electric, a manufacturer of arc welders in Cleveland, Ohio, was founded with a performance pay system rather than a wage and salary system. Lincoln Electric's managers' supervision span of control averaged 100 employees per manager (Jackson & Schuler, 2003).

Positive reinforcement. One example of positive reinforcement in organizational settings is performance pay. There is much confusion in the business world about performance pay. Many business managers believe that the annual pay raise (merit increase) is performance pay. However, most raises are annual and typically determined by subjective, after-the-fact appraisals based on the manager's recollection of the employee's performance. As such, these appraisals are often based on more recent performance or on employee attitude rather than results. Likewise, annual bonuses are also thought to be examples of performance pay. However, these payments are delayed and fail to prescribe in advance what the employee must do to earn them. Profit sharing is sometimes viewed as performance pay, but it is an annual group plan whose measure is largely out of individual employees' control except in very small organizations. Studies of profit sharing in larger organizations have found no convincing relation between profit sharing and employee productivity (Binder, 1990).

Examples of effective performance pay plans include piece rates, commissions, and goal sharing. Piece rates and commissions pay for each unit of production or sales. Goal sharing establishes goals for one or more measures. If the goal, or in some cases a percentage of the goal, is achieved, the employee receives a payout.

Unfortunately, many organizations are unwilling to attempt the transition from salaries to performance pay. This unwillingness may be because (a) managers do not fully understand the benefits of positive reinforcement, (b) the wage and salary system is more familiar, or (c) the performance measures and tracking system required to implement a performance pay system are viewed as too difficult to develop and implement. The reasons for this resistance may also be personal. In my experience, managers are more resistant than workers to adopting performance pay systems; perhaps because they are already receiving a good salary, they have more financial risk than their subordinates. Moreover, managers may experience a loss of personal discretionary control in the transition from subjective evaluations and negative reinforcement toward objective measurements and positive reinforcement.

When there is resistance from nonmanagement employees, it often comes from those subjectively judged by management to be good performers. These employees (e.g., those who get by on a good attitude toward management) may worry that their status will fall if objective measurement of their performance reveals that they are not as good as the subjective evaluations of management had previously indicated.

Partly because some organizations are resistant to performance pay, many OBM projects use nonmonetary positive reinforcers. Another reason is that some early OBM practitioners objected to using money as a positive reinforcer. As mentioned earlier, in the 1970s Edward J. Feeney was one of the pioneers in applying behavior analysis to the workplace. As a consultant with Edward J. Feeney and Associates at that time, I was instructed that money was not to be used as a positive reinforcer, only supervisor recognition. The latter, it was argued, was always accessible to management, which ensured that positive reinforcers would be delivered immediately.

Today, many OBM consultants provide manager training in behavioral principles (e.g., operant conditioning). The training focuses, in part, on how managers can use nonmonetary reinforcers to manage their subordinates. Nonmonetary reinforcers used in OBM have included supervisor and peer recognition, public postings of performance, recognition awards, and preferred work assignments or shifts, to name a few (see Nelson & Spitzer, 2003).

Merchandise is frequently used as a more tangible reinforcer. Many plans use vendors that provide gift catalogs with point requirements listed for each gift. The employee earns points for improvements or goal accomplishment that are then exchanged for gifts. In other cases, employees are given time off with pay for good performance. An important issue occurs in the use of nonmonetary positive reinforcement. If the organization continues to use negative reinforcement as the primary means of compensating employee performance, it may prove difficult to sustain performance with nonmonetary programs because the behaviors reinforced by the negative reinforcement may compete with those that are positively reinforced. Moreover, the negative reinforcement allows the manager to revert back to conventional practices that do not require continuous performance measurement or feedback.

Leveraged pay. A key issue in performance pay is whether it should be in addition to base pay (wage or salary) or should replace some or all of the base pay. Many plans add incentive pay on top of the employee's wage or salary. This approach has several drawbacks. First, payroll expense may increase without a concomitant increase in profits. This is especially the case with safety, customer service, and other measures that may have no immediate impact on profitability. As a result, the incentives offered may be minimal and, therefore, may have a limited impact on performance. Second, when incentives are added to base pay, the employees continue to receive market-comparable pay whether they participate in the incentive plan or not. The effort–reward ratio may be insufficient to encourage participation if the incentive amount is negligible.

A different approach to performance compensation is leveraged pay. In a leveraged pay system, a portion of each employee's pay is indexed to personal performance and organizational profitability. As a result, employee pay becomes more of a variable expense that increases only with organizational profitability. The economist Martin Weitzman (1984) pointed out that indexing pay to profit increases the organization's survivability, increases employee pay over competitors in good business cycles, and reduces the need for layoffs in poor business cycles. In Abernathy (2011), I described a performance pay system that indexes performance pay opportunity to organizational profitability while distributing the opportunities on the basis of individual and small-team performances.

ORGANIZATIONAL BEHAVIOR MANAGEMENT IMPLEMENTATION PROCESS

I have used the OBM process enumerated next in more than 170 organizations in seven countries representing a diverse array of sizes and industry types. The process closely mirrors the typical process used in OBM:

1. Conduct performance management workshop.
2. Develop performance measures.
3. Identify critical improvement results and behaviors.
4. Link positive consequences to performances.
5. Conduct a performance analysis.

1. Conduct Performance Management Workshop

Performance management workshops are usually presented onsite or at the consulting firm's headquarters. Workshops typically last between 1 and 5 days and focus on a behavioral approach to managing employee performance. Specifically, the workshops cover techniques for identifying and measuring important outcomes, how to set up a feedback system, goal setting, managing the consequences of performance, and dealing with unwanted performances.

Workshop materials are often customized to the client's requirements and supplemented by standard instructional materials. For example, at the Aubrey Daniels consulting firm, the basic materials are presented in *Performance Management: Improving Quality and Productivity Through Positive Reinforcement* (Daniels & Rosen, 1983) and in the later revised version (Daniels & Daniels, 2004). In some cases, the OBM consultant follows up the workshop by observing managers' interactions with subordinates and coaching them on better applications of the techniques.

Performance management focuses management's attention on three events in the sequence of employee performance: events happening before the behavior (antecedents), the behavior, and events after the behavior (consequences). Daniels and Rosen (1983) referred to this as an *A–B–C analysis,* and it is known more broadly in behavioral psychology as the *three-term contingency*.

Antecedents. Absent, infrequent, or poorly constructed prompts from the supervisor are often a performance constraint for subordinates. Antecedents prompt behavior, guide behavior, and allow for more precise behavior. They inform the employee as to the who, what, when, where, how, and sometimes why of a performance. A three-term contingency analysis suggests that antecedents derive their ability to influence performances from their close association with consequences. Thus, the employee may have a wonderful set of instructions but never follow them because doing so does not result in positive reinforcement.

A second type of antecedent discussed in performance management workshops is a performance goal. Goals for the employee may be set as part of a manager's performance coaching. These goals may change as the coaching process continues. As with any antecedent, a goal's ability to influence performance is determined by the association between meeting the goal and the consequences of doing so. Thus, the most effective goal-setting techniques will tie goal accomplishment to performance evaluations or performance pay. In these instances, the goal is typically set by management and is not negotiated. Unlike a performance coaching goal, goal setting done in connection with performance evaluation or pay is usually consistent across performances and job positions. Goals may be statistically derived on the basis of performance variability. Examples are the performance improvement potential (PIP) analysis, in which the top performance becomes the goal. The goal may also be defined as a standard deviation or some percentage above historical performance. Goals may also be defined using a top-down approach in which the sum of the goals contributes to the achievement of a higher level goal of the organization.

Feedback. Feedback may be provided by the supervisor through performance postings, coaching of individual employees, team meetings, or all of these. Feedback may also be self-reported by the employee, who manually collects and organizes the data. Ineffective performance feedback from the supervisor may be a key constraint on employee performance. Issues may be that feedback is absent, delayed, not actionable, imprecise, or negative (tells the employee what he or she is doing wrong rather than what he or she needs to do to improve). As mentioned previously, feedback may serve as an antecedent that signals possible reinforcement or may function directly as a social reinforcer.

Consequences. Ineffective use of performance consequences may also be a critical performance constraint. Consequences delivered by the supervisor may be absent, aversive, delayed, or unpredictable and can be social, nonmonetary, or monetary. In some cases, simply removing aversive or conflicting consequences improves performance. In other cases, reducing the delay and improving the certainty of the consequence is the solution.

2. Develop Performance Measures

In Abernathy (2011), I performed a cluster analysis on 2,195 objective client organizations' performance measures and found that they could be usefully partitioned into seven measurement categories. The categories were sales, expense control, productivity, cash flow, regulatory compliance, customer service, and special projects. Measures for these categories can be defined for the organization and cascaded down through management to workers. Alternatively, measures for the categories can be defined for a specific job position targeted by survey findings, PIPs, or the manager's personal objectives.

All measurement categories may not apply to a given organization or job position. Moreover, some categories may require two or more measures to accurately reflect the category. Measurements in a category may be a simple count of the result or behavior per period of time (rate). In a few cases, variations in the topography of the behavior are counted. The percentage of accuracy, duration, latency, and turnaround time of the behavior or result are also potential measurement dimensions.

In many cases, a measure may be expressed as a ratio when differences in the opportunity to perform exist. Percentage of accuracy ([outputs − errors] / outputs) is typically a better measure than the number of errors. For example, employee A has made 10 errors this month, and employee B has committed five errors. Which employee is the better performer? Given only this information, one would say that B was the better performer. However, one then finds that employee A processed 100 outputs, and employee B processed 20. Employee A's accuracy is $(100 - 10)/100 = 90\%$, whereas employee B's error rate is $(20 - 5)/20 = 75\%$.

Results may be expressed in dollars, volumes, ratios, percentages, standard time, delays, or other formats. In some cases, ratios may be a poor measurement choice. For example, a measurement system was requested for bank loan officers. The bank was having trouble securing profitable loans. Therefore, management preferred using the average income percentage per loan as a performance measure for the officers. The problem with this ratio, or any ratio, is that it is not sensitive to volume. For example, one loan officer might make two loans that total $1,000 and produce an income of $100, and another officer might make 10 loans for $10,000 that produce an income of $500. The income percentage of the first loan is $100 / $1,000, or 10%. The income percentage on the second loan is $500/$10,000, or 5%. The income from the second loan portfolio is $500 − $100, or $400 more than the portfolio with the higher percentage income. Which is more important to the bank—the percentage income or the total income? The answer might depend on the bank's funds availability.

Other alternatives would be to track both the percentage income per loan and the total loan income. These two measures would be included in the loan officer's scorecard or performance matrix with appropriate weights attached to each result. Alternatively, total net income could be tracked, which is influenced by both the dollar volume of the loan and the percentage income of the loan. Loan net income is simpler to track and leaves the strategy for increasing it up to the individual loan officer. The officer can focus on high-volume, low-income loans or lower volume, high-income loans.

The point of these examples is to illustrate that designing or selecting a measure for a results pinpoint includes many considerations and that measuring different aspects of a result will likely drive different employee behaviors. Many organizational incentive plans have failed to produce the desired results simply because the behavior or result measure was defined incorrectly. Table 20.4 summarizes the characteristics of good performance measures.

TABLE 20.4

Summary of Characteristics of Good Performance Measures

Good measures	Poor measures
Objective	Subjective
Results	Activities
Individual or small team	Group
Actionable	No action likely
Related to strategy or profit	Related to job description or local problem
Balanced	Unbalanced
Aligned	Conflicts with other measures
Immediate feedback	Delayed feedback
One element	Composite
Reported by third party	Self-reported

3. Identify Critical Improvement Results and Behavior

In the sections that follow, I describe four techniques for identifying critical improvement opportunities: (a) an organization-wide performance measurement system, (b) an organization-wide management practices survey, (c) calculation of performance improvement potentials, and (d) determination of critical improvement opportunities by the manager.

Organization-wide measurement system. In this strategy, an organizationwide performance measurement system is implemented before any improvement projects. Projects are then selected from the matrices on the basis of declining trends or subgoal performances. As mentioned previously, one strategy for measuring the many components of these performances is to design and implement organizationwide performance matrices using the method of cascading objectives proposed by Kaplan and Norton (1996; see Figure 20.5). First, an organizational scorecard (matrix) is developed by the executive team that lists the organization's two to seven key objectives for the coming year. These objectives are then stated for the entire organization as performance measures with goals and priority weights. These measures then serve as a guide for designing the executive team's measures. This phase is followed by developing the executive team's subordinate's measures and so on down through the organization to the worker. Once baseline data have been collected, the measures with the most deficient levels or trends are targeted for improvement. The advantages of this approach are that it is objective, it will reveal linked and dependent performances, and everyone will participate. The disadvantage is the time and effort involved in an organization-wide initiative.

Organization-wide management practices survey. A second strategy for identifying performances in need of improvement is to have all employees in the organization complete a management practices survey (Abernathy, 2010). The survey asks employees to rate the effectiveness of a variety of management practices. Practices that are rated low are targeted for

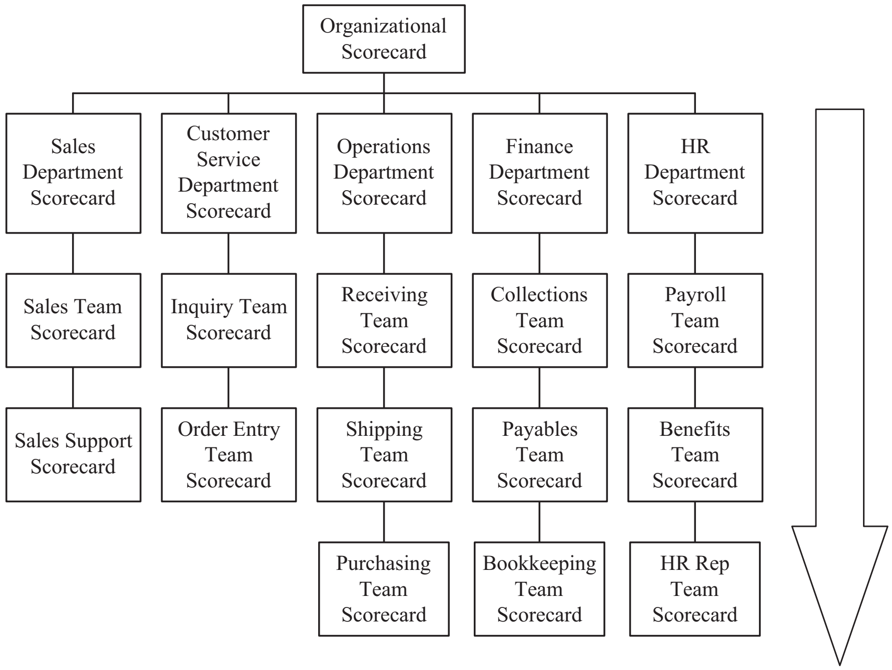

FIGURE 20.5. **Method of cascading objectives. HR = human resources.**

performance improvement projects. Although this strategy minimizes time and effort compared with the cascading strategy just discussed, it is based on perceptions rather than actual data. It will also likely miss critical linkages and dependencies across job positions. For example, the manager may be concerned with better scheduling in the department, but changing the schedule may affect other performances in the department or in other departments.

Performance improvement potential. A third improvement identification strategy was developed by Tom Gilbert (1978). Target performances are identified through the computation of the PIP, which is the exemplar (best) performance divided by the average performance. For example, if the exemplar performance is 20, and the average performance is 10, the PIP is 20/10 or 2.0. The underlying assumption is that the exemplar's performance is a reasonable potential because it has actually been achieved by someone in the job. PIPs may be computed for all performances in a job position, department, or organization, and the highest PIP ratios are targeted for improvement.

Manager determination. A final strategy is to allow managers trained in performance analysis to meet with subordinates to identify a target result and measure. Although this strategy minimizes the costs associated with the other methods, the disadvantages are the manager training time and expense. Another potential issue is that managers and their subordinates may select results or behaviors that can be improved easily rather than those that are of high value to the organization. As with the management practices survey discussed earlier, this technique may also miss the linkages and dependencies across job positions.

4. Link Consequences to Performance

Positive consequences should be made contingent on performance to both improve and sustain it. As previously discussed, these reinforcers may be social, tangible, or monetary. Examples of social reinforcers are praise and recognition. Social reinforcers likely function best when they are linked to tangible or monetary reinforcers. Examples of tangible reinforcers are time off, lunches, and merchandise. As discussed previously, the effectiveness of monetary reinforcers can be enhanced by leveraging base pay.

On the basis of her review of the literature, Dickinson (2005) suggested that "the critical determinant of performance is the contingent relationship between pay and performance, rather than the amount or percentage of incentive pay" (p. 22). Because pay cannot practically be immediately delivered after most performances, the solution has been to introduce immediate feedback that informs the employee of the forthcoming amount of performance pay.

Dierks and McNally (1987) reported an application with bank proof operators. They introduced daily supervisor feedback that increased the item-processing rate from 980 items per hour to 1,650 items per hour (net of errors). However, with a change in supervisors, the new supervisor failed to calculate and distribute the feedback. Performance dropped almost to its original level. To prevent this problem in the future, performance pay was installed, and the rate increased to 2,300 items per hour for a 3-year period. The final program was a pay-per-item (piece rate) plan that replaced the hourly pay. Performance rose to 3,100 items per hour, where it remained for 12 years until the bank was acquired. Both piece rate and its analog, sales commissions, have the advantage of providing immediate earnings to the employee, thus combining feedback and monetary reinforcement.

5. Conduct a Performance Analysis

Performance analysis is a procedure for determining the causes of performance deficiencies. Several procedures have been used throughout OBM's evolution. I present many of these performance analysis procedures here because each brings important insights to the task of determining the cause of underperformance.

Behavior engineering model. In the behavioral engineering model, the OBM consultant uses the six cells shown in Table 20.5 to identify probable causes of employee underperformance. Three of the cells relate to the employee's environment, and three relate to the individual. The environment and individual cells are organized with respect to the antecedent stimulus, behavior, and consequence issues discussed earlier.

Gilbert (1978) recommended that the environment cells be considered before the individual cells when attempting to determine the probable cause of underperformance. Therefore, an examination of missing or incomplete antecedents (instructions and guides), behaviors (resources, tools, processes), and consequences (incentives) would precede an analysis of individual knowledge, selection procedures, or employee motives.

When Dean (1994) asked approximately 1,000 participants from business and industry to identify which one of Gilbert's (1978) six cells was the biggest obstacle to their optimal performance, 75.6% of the participants selected one of the three environmental cells. This finding is interesting because it indicates that training, employee selection, and general employee motivation are perceived as less common performance constraints than are information (prompts), resources, and incentives. This finding

TABLE 20.5

Gilbert's (1978) Behavior Engineering Model

Source	Stimulus	Behavior	Consequences
Environment	Information: Job descriptions, guides, feedback	Resources: Tools, time, materials, access, staffing, processes	Incentives: Monetary and nonmonetary incentives, career development, consequences for poor performance
Individual	Knowledge training	Capacity: Selection procedures, flexible scheduling, job aids	Motives: Workers' willingness to work for available incentives, recruitment process

Note. From *Human Competence: Engineering Worthy Performance* (p. 88), by T. F. Gilbert, 1978, New York, NY: McGraw-Hill. Copyright 1978 by John Wiley & Sons, Inc. Adapted with permission.

tentatively supports OBM's primary focus on the environment rather than the individual employee's capabilities and personal motivation.

Performance analysis flowchart. Mager and Pipe (1984) developed a decision tree to assist the performance analyst in determining the causes of a deficient performance. The key decision points in the decision tree are much abbreviated in Figure 20.6. The order of the questions supports the previous view that environmental performance constraints should be addressed before factors related to the individual.

Vantage analysis chart. The vantage analysis chart (J. M. Smith & Chase, 1990) was designed to help performance engineers analyze organizational systems in an orderly fashion. The vantage analysis chart has six different vantage points from which to analyze an organization: philosophical, social, organizational, departmental, individual outcomes, and individual activities. It is used to demonstrate how performance engineers can (a) target their investigations to gather information at all vantage levels, (b) use the information to analyze problems, and (c) develop interventions consistent with the values at all levels of vantage.

PIC/NIC analysis. Daniels and Daniels's (2004) PIC/NIC analysis prompts the consultant to consider three characteristics of effective consequences. First, and for reasons discussed in detail earlier, positive (P) consequences are preferred over negative (N) consequences. Second, any consequence, be it positive or negative, will be more effective if it is delivered immediately (I) rather than after a delay. Finally, consequences are more effective when they are certain (C) rather than probabilistic. Thus, performances are least likely to reach optimal levels when consequences are negative, future, and uncertain. Behaviors with many antecedents (prompts) are more likely to occur than behaviors with few antecedents.

Opportunity–capability–context analysis. The first step in this analysis (Abernathy, 2009) is to

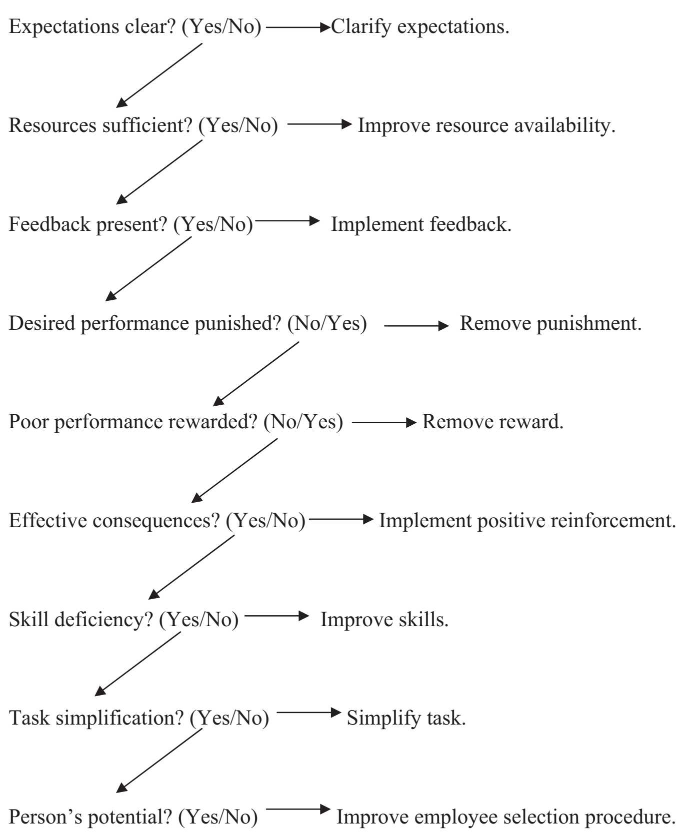

FIGURE 20.6. **Performance analysis decision tree.**

define organizational measures for each of the seven measurement categories previously described. The historical trends of these organizational measures are computed. Declining trends, or trends consistently below goal, determine which categories should receive further analysis. The trends of lower level (division, department, job position) measures in the category are then reviewed for declines, or being consistently below goal, to pinpoint target measures for improvement projects.

The second step is determining the constraints that are causing the target performance's declining trend or suboptimal level. These constraints are categorized as a lack of opportunity to perform, capability issues, or context issues (see Figure 20.7). The constraint categories are considered in order from left to right, because if there is no opportunity to perform, capability is irrelevant, and if there is no capability, then context is irrelevant. Once the constraint category is determined, the most appropriate method within the category is selected. For example, if capability is the targeted constraint category, then the subcategories competence, resources, and processes are examined. If it is determined that worker competence is the constraint, then either worker selection or worker training methods are improved.

The preceding performance analyses are conducted to pinpoint what factors are constraining the target performances. Analysis methods have varied from simply asking the supervisor what the problems are to more formal analyses, such as described earlier. Once the analysis is completed, a solution that removes the constraint is designed and implemented.

The design, implementation, and administration of projects are termed *performance management*. OBM solutions have focused on Daniels and Daniels's (2004) antecedents and consequence of the behavior, Gilbert's (1978) environmental stimulus and consequences, Mager and Pipe's (1984) feedback and consequences, Harless's (1994) environmental and motivation and incentives, and Abernathy's (2009) context constraints.

ORGANIZATIONAL BEHAVIOR SYSTEMS MANAGEMENT

Organizational behavior systems management is an alternative perspective and methodology to conventional OBM. OBM tends to focus on the individual employee and the specific job context, whereas organizational behavior systems management examines the total organizational contingencies. Two of the earliest presentations of this perspective were those of Dale Brethower (1972) in *Behavioral Analysis in Business and Industry* and Harshbarger and Maley (1974) in *Behavior Analysis and Systems Analysis*.

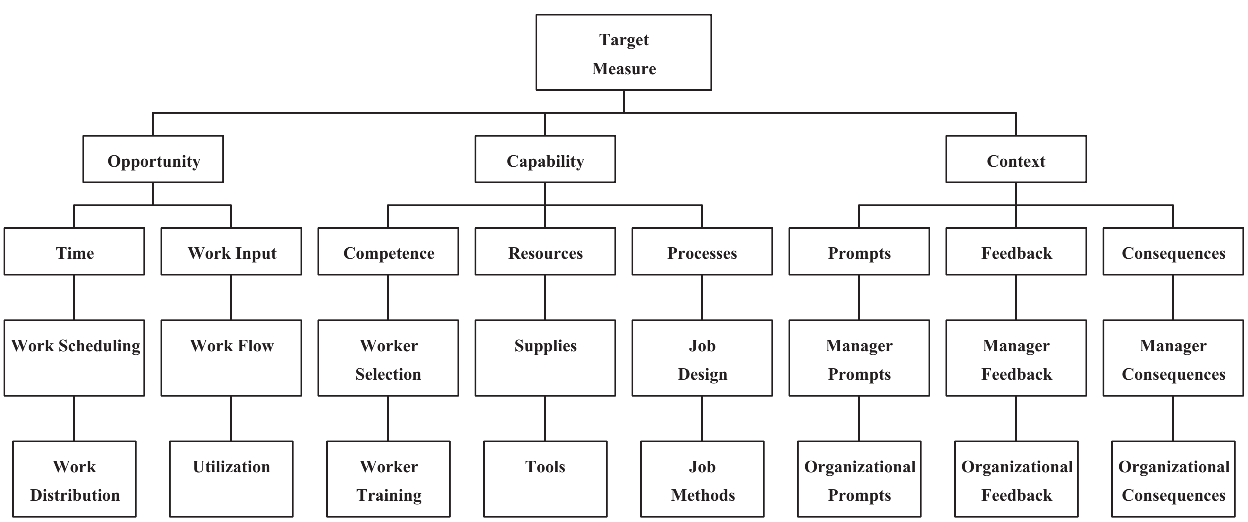

FIGURE 20.7. Performance constraint analysis. From "A Comprehensive Performance Analysis and Improvement Method," by W. B. Abernathy, 2010, *Performance Improvement, 49*, p. 9. Copyright 2010 by the International Society for Performance Improvement. Adapted with permission of John Wiley & Sons, Inc.

Other behavior system advocates have been Krapfl and Gasparato (1982), Senge (1990), Rummler and Brache (1995), Kaplan and Norton (1996), Mawhinney (2001), Redmon and Mason (2001), Malott (2003), and Abernathy (2007).

Behavior systems have been described laterally as inputs that are necessary for processes (e.g., employee performance) that produce the company's outputs (Brethower, 1972; Brethower & Rummler, 1966; Krapfl & Gasparato, 1982; Malott, 2003; Rummler & Brache, 1995). In other cases, behavior systems have been described vertically as job performances that drive department performances, which then drive organizational performances (Kaplan & Norton, 1996). Figure 20.8 illustrates how both perspectives can be integrated (Abernathy, 2011).

The integrated behavior system model considers the lateral work processes of an organization and its vertical management hierarchy. The ultimate concern of management is with the organizational outputs. If one of these outputs is deficient, the source is traced to a department or departments and ultimately to one or more job positions. The lateral inputs of the department or job may constrain the employees' opportunity to perform.

Human resources functions affect the organizational behavior system. These functions include organizational management structure, job definitions, orientation and training, performance evaluation, promotion and termination policies, and compensation. The performance analyst must ensure that these functions are aligned with employee, departmental, and organizational performances objectives.

If an organization is to successfully adopt and implement OBM principles, it must provide a management structure that supports a new reliance on positive reinforcement. This is best accomplished by a transition from a traditional closed, hierarchical management system (Figure 20.9) that relies on direct supervision and negative reinforcement to an open, network system (Figure 20.10) organized more as self-managed teams that are in direct contact with the consequences of their performances.

CONCLUSIONS

In this chapter I have outlined a general OBM implementation process that includes setting up performance management workshops, developing performance measures, identifying improvement opportunities, linking consequences to performance, and conducting a performance analysis. Five issues have been explored and are recapped in this concluding section of the chapter: (a) OBM effectiveness, (b) issues with the three-term contingency, (c) performance analysis and improvement, (d) behavior systems, and (e) OBM training.

Organizational Behavior Modification Effectiveness

OBM is rooted in the operant learning principles of B. F. Skinner (1938) and grew out of applied behavior analysis to become an effective behavioral technology in the 1970s. OBM has demonstrated positive results in 41% to 58% of the applications reviewed from 1974 through 1999 (Alvero et al., 2001; Balcazar et al., 1986). I found a median

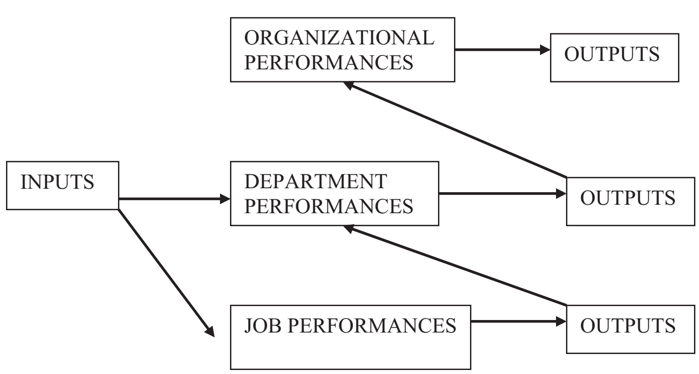

FIGURE 20.8. **Integrated behavior system model.**

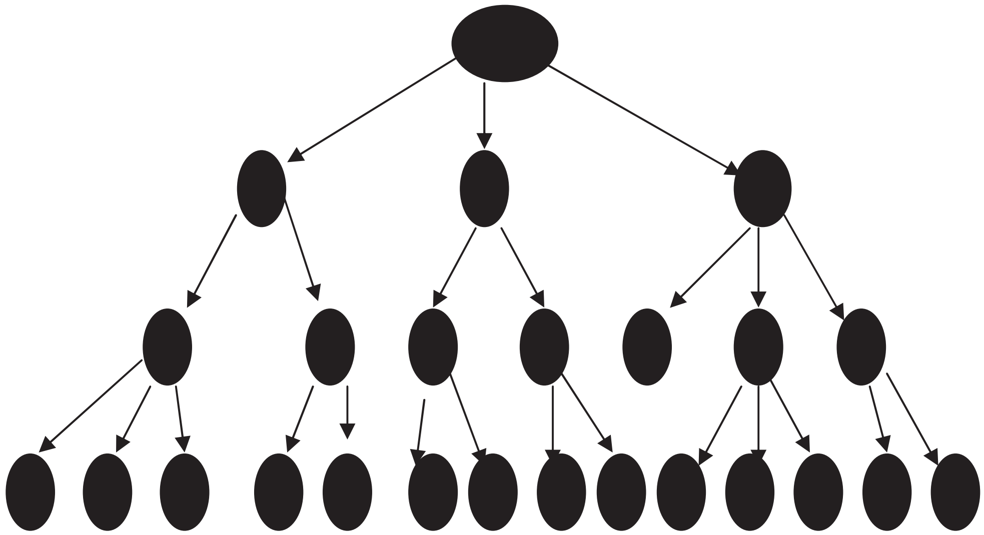

FIGURE 20.9. **Closed, hierarchical behavior system.**

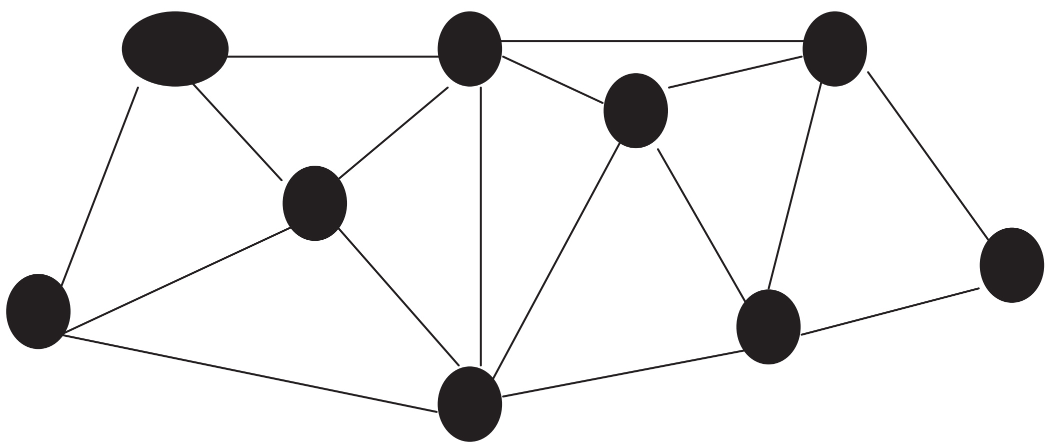

FIGURE 20.10. **Open, network behavior system.**

improvement of 54.8% across 68 studies from 1984 through 2009. These findings indicate that OBM projects are generally quite effective in improving employee performances in organizational settings.

Issues With the Three-Term Contingency

The three-term contingency (antecedents–behaviors–consequences) has been used in many, if not most, applications. Antecedents have included behavior checklists, instructions, and guides, and consequences have included feedback, social reinforcers, tangible reinforcers, and performance pay. The most common method used in OBM has been the introduction of performance feedback (Alvero et al., 2001; Balcazar et al., 1986). Feedback is typically provided as vocal comments by the manager but may be graphic or written.

Behavior may be measured directly, or the result of the behavior may be measured. With some exceptions (e.g., safety, customer service), I recommend measuring results first. If this proves ineffective, then the behaviors that produce the result should be measured. When results are measured, they should be actionable for the employee and balanced to ensure improvement in one result is not detrimental to other dimensions of the result (e.g., quality vs. quantity) or other related results (e.g., sales vs. collections).

Feedback has been a common technique in OBM partly because it can be applied immediately and targeted to individuals more so than other types of consequences. However, its effective delivery depends on the cooperation of the manager over long periods of time, which may not always occur (Dierks & McNally, 1987). Moreover, if feedback does not reliably predict backup reinforcers (money, time off, promotions, etc.), it may be able to improve performances in the short term but prove unable to sustain them over the long term.

An important consideration for OBM technologists is that many traditional wage and salary compensation systems tend to rely more on negative reinforcement to manage employee performance than on positive reinforcement. As a result, managers attend to exceptions or errors rather than to improvement or performance at goal. A reliance on managing exceptions and negative reinforcement allows the organization to manage employees without objectively measuring or consistently tracking employee performances. This culture must be overcome before OBM applications can be truly effective over the long term. As a result, most large-scale OBM interventions include, or should include, manager training in operant principles. Moreover, the compensation system should transition from conventional wages and salaries to pay for performance to change the culture of exceptions and sustain the performance improvement initiative.

Performance Analysis and Improvement

Several performance analysis models were presented. Most of the models have in common an expansion of improvement interventions beyond the three-term contingency model. For example, Gilbert (1978) referred in his behavior engineering model to job description, tools, materials, staffing, employee scheduling, processes, employee selection, and job training; Abernathy (2010) added work flow, work distribution and cross-training to this list.

Two disciplines that provide these additional tools are industrial–organizational psychology and industrial engineering. Bucklin, Alvero, Dickinson, Austin, and Jackson (2000) conducted an extensive comparison of the disciplines of OBM and industrial–organizational psychology. They concluded that OBM and industrial–organizational psychology both focus on improving organizational effectiveness, but their strengths and weaknesses differ. OBM tends to offer solutions to specific problems, whereas industrial–organizational psychology is more expansive and conducts research on varied and complex organizational topics (e.g., job analysis, employee selection techniques, survey research). OBM could also benefit greatly from sharing the techniques of industrial engineering, for example, work standards, workflow, work processes, work scheduling, staffing, and quality assurance.

Organizational Behavior Systems Management

Ludwig Von Bertalanffy (1950) was an early proponent of general systems theory, which has since been applied in several academic fields such as archeology, anthropology, political science, biochemistry, ecology, and economics. Applications have included telecommunications, computer science, control systems, electronics, environmental engineering, and many others. With the emergence in OBM of the behavior systems perspective (Brethower, 1972; Harshbarger & Maley, 1974; Krapfl & Gasparato, 1982; Malott, 2003; Mawhinney, 2001; Rummler & Brache, 1995), a collaboration between systems engineering and OBM could prove quite valuable.[1] A first step would be to apply correlational techniques such as factor analysis, spectral analysis, and neural network analysis to organizational systemwide data. Such analyses would assist in identifying critical behavioral interactions across departments as well as hierarchical levels of the organization.

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[1] A partial list of universities that offer advanced degrees in applied behavior analysis and OBM can be found on the OBM Network's website (http://www.obmnetwork.com).

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CHAPTER 21

CONTRIBUTIONS OF BEHAVIOR ANALYSIS TO HIGHER EDUCATION

Dan Bernstein and Philip N. Chase

U.S. higher education early in the 21st century is in the midst of a crisis of confidence. Governments are reducing funding while simultaneously increasing demands for accountability for student performance. Students and their families are questioning the escalating costs of higher education, which are higher than the base rate of cost-of-living increases, and asking what intellectual or employment value is added from the time, effort, and money spent on an education. Employers have asked governments to ensure that graduates of public institutions be skilled in communicating, problem solving, quantitative analysis, leadership, and teamwork. Even leaders in the academic community have questioned the values and practices of colleges and universities. There are concerns about the quality standards used in giving credit and degrees, with academic critics asking whether current teaching methods are evidence based. The balance of energy put into teaching and research is under constant scrutiny.

In his widely read 2005 book *Our Underachieving Colleges: A Candid Look at How Much Students Learn and Why They Should Be Learning More,* former Harvard president Derek Bok argued that few coherent educational goals are broadly met and no public data on learning make institutions accountable for their work. He further asserted that the contingencies on institutions do not favor documentation of learning or continuous inquiry into effective learning and teaching:

> Neither faculties nor their deans and presidents feel especially pressed to search continuously for new and better ways of educating their students, nor do they feel compelled to offer the very best education possible in order to avoid losing large numbers of applicants or suffering other consequences that matter. (Bok, 2005, p. 34)

Although a few educators have asserted that the overall complaints are unwarranted (e.g., Berliner & Biddle, 1995), the broad consensus is that all is not well in higher education.

As behavior analysts interested in education, we have noted that very little national conversation on higher education has drawn on behavior-analytic work in education to frame possible solutions, and the same has been true in schools of education and the precollege community (Deitz, 1994). In this chapter, we explore that observation and suggest what interested behavior analysts might do to provide high-quality and useful guidance to address the perceived problems. First, we review the major behavior-analytic conceptual and empirical contributions to higher education; these contributions are the big ideas with plenty of evidence demonstrating their empirical validity and utility in educational settings. Then we describe the challenges to and aspirations for higher education articulated in public policy and academic circles, setting the context for the question of why behavior-analytic work is not central to the conversation. We offer three broad observations on the lack of connection: wide divergence in the kind of performance valued, differences in the methods used and evidence offered, and lack of alignment on philosophical assumptions and cultural practices. We end by identifying steps that

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could be taken should any behavior analysts in higher education want to be players in the continuing national conversation on future directions in higher education. We believe that our students and our institutions would benefit greatly from inclusion of the skills and evidence from the behavior-analytic community.

HISTORICAL AND CONTEMPORARY BEHAVIOR-ANALYTIC CONTRIBUTIONS TO EDUCATION

We have identified some issues behavior analysts face in addressing problems in higher education by examining three significant behavioral innovations in higher education: programmed instruction (Skinner, 1968), the personalized system of instruction (Keller, 1968), and precision teaching (Lindsley, 1992). An important lesson we draw from reviewing these innovations is that evidence per se is not enough; as noted by Deitz (1994), evidence is needed on outcomes valued by the culture and the relevant communities of practice. As pragmatists, behavior analysts need to seek practices that work successfully for the culture; the successes achieved will survive only if the culture values them. Gathering evidence congruent with current educational values and goals is central to the thesis of this chapter.

Programmed Instruction

One of the best known behavioral solutions to problems in higher education is programmed instruction (PI). PI addresses a classic question in teaching groups of students: How might students learn at different rates without interfering with each other's learning? PI takes a materials engineering approach to this problem, with instructional materials arranged in steps, with questions and feedback presented at the end of each step. Progress to the next step is contingent on correct responding at the current step. The development of PI materials and their implementation may be characterized by (a) defining the field of coverage to be taught; (b) collecting terms, laws, principles, and cases; (c) making presentations clear and interesting; (d) providing small, achievable steps; (e) assessing student performance objectively; (f) basing progress on success; (g) reinforcing immediately via confirmation; and (h) fostering learning at one's own pace (Sulzer-Azaroff, 2004). PI is perhaps best illustrated by the text *Analysis of Behavior* (Holland & Skinner, 1961), designed for students to learn the concepts of behavioral psychology. The book is divided into frames, a brief presentation of content that requires the student to fill in a blank in the text. The student confirms his or her answer by turning a page to see the correct answer. A range of students showed superior learning using *Analysis of Behavior* (see Holland, 1965). Critical to PI's success was its strong, evidence-based tradition.

Markle (1967) suggested that a curriculum becomes a program of instruction when one demonstrates its effectiveness, and her chapter is an early argument for evidence-based practices. Markle detailed three levels of evaluation: developmental, validation, and field testing. *Developmental evaluation* is an intensive investigation in which a few conveniently chosen students use the program (i.e., the instructional materials) and are engaged by the teacher or designer with frequent queries about the material. Frequent evaluation of what students can say and do results in changes in the program. Validation investigates how well the curriculum meets its own goals under controlled circumstances. Validation expands the sample of students who successfully learn from the program, and it often compares the curriculum under development with either control (baseline) or alternative conditions. Field testing investigates how effective the curriculum is in a variety of settings and with a variety of students; it tests the generality of the program's effectiveness. In Markle's view, PI was defined by evidence of effectiveness, and her three stages of evaluation parallel modern requirements for the kinds of evidence recommended, for example, by the What Works Clearinghouse of the U. S. Department of Education (What Works Clearinghouse, 2008).

PI was successful in that programmed books, manuals, and other instructional material appeared on such diverse topics as chess, reading, and Hebrew (Adler, 1974; Castberg & Adler, 2004). Romiszowski (1974) reported that from 1957 to 1966, the number of published programs in the United Kingdom increased from around zero to close to 700. Goren (1963, 1983) produced a program for teaching bridge based on his syndicated column, and a number of programs were written for the health sciences. Programs taught medical terminology (Dennerll, 1993), rapid interpretation of electrocardiograms (Dubin, 2000), and patient assessment (e.g., Mechner, 1974, 1975). Behavior analysts also developed successful programs on neuroanatomy (Sidman & Sidman, 1965) and behavior analysis (Holland & Skinner, 1961).

Research and reviews of the literature have revealed the success of these programs. For example, Kemp and Holland (1966) conducted a unique review that compared programs that had undergone an independent test of effectiveness before comparison with other methods of instruction. Holland and Kemp (1965) devised an experimental method for determining how efficiently a programmed curriculum produced learning. They measured the percentage of programmed frames (the small achievable steps of a program) that could be eliminated without changing student learning. As did Markle (1967), they insisted that the defining feature of a program was that it had been shown to work. Kemp and Holland reviewed 12 studies comparing programs of instruction with other methods, and their review showed that programs with the fewest superfluous frames produced more learning than other methods of instruction. When each component of the program was essential to learning, the results were superior.

PI was also in concert with other educational movements such as Bloom's (1968) concept of mastery learning. Given Bloom's (1956) influential analysis of cognitive, psychomotor, and affective objectives, many educators used the goals of mastery as their criteria for successful interventions. The goals of PI were more consistent with criterion-referenced assessment than were normative assessment methods such as curve grading. Other educators expanded the use of teaching machines into audiovisual instruction and the beginnings of computer-assisted instruction. The acceptance of a systems model of teaching skills needed for the military spread to teaching other skills that were useful in many walks of life (Anderson, Faust, Roderick, Cunningham, & Andre, 1969). The systems model of defining achievable objectives, conducting task analyses, assessing entry skills, providing direct instruction, and collecting data to inform systematic changes in each of these components became synonymous with the science of education. These movements in education were not tied tightly to the work of behavior analysts, but the results were congruent with research on PI.

Over the years, however, many applications of PI lost the critical component of demonstrated effectiveness (Markle, 1967). Instead of testing and refining programs on the basis of data, PI came to be defined by its form: breaking material into small steps with immediate feedback for student responses (e.g., Orlich, Harder, Callahan, & Gibson, 2001). Markle (1967) argued that this form-based usage unnecessarily limited the definition of a program, offering examples of programs with large steps whose effectiveness, nonetheless, had been empirically demonstrated. Although Markle's model of evaluation stands as central to a behavior-analytic view of effective instruction, still to be demonstrated is whether PI produces complex problem solving, critical analysis, application to novel contexts, and evaluative synthesis—the kinds of higher level learning that most educators are interested in seeing from their students in college classrooms.

Personalized System of Instruction

From the late 1960s through the 1980s, personalized system of instruction (PSI) was also widely recognized in educational culture at large. It was characterized by these features: (a) mastery learning based on criterion-referenced grading, (b) emphasis on the written word as the main means of conveying information, (c) lectures and demonstrations used to motivate the students, (d) peer proctors providing immediate consequences for the students' performance in the class, and (e) students working at their own pace rather than a standard pace set by the instructors' presentation of course materials (Johnson & Ruskin, 1977).

PSI was also adopted in many fields, and college texts appeared with PSI or Keller Plan study guides, multiple versions of tests (for mastery testing), and descriptions of how to fit the content of the text into a PSI course. As with PI, PSI was found to be successful for teaching in many college classrooms (Buskist, Cush, & DeGrandpre, 1991; Johnson & Ruskin, 1977; Kulik, Kulik, & Cohen, 1979).). PSI was also shown to have positive long-term effects on student performance. For example, in comparison with a lecture course, even students with high GPAs performed significantly better on a 2-year follow-up test after a PSI course (Du Nann & Weber, 1976), and a PSI class demonstrated a remarkable 35% retention after 5 years (Ellis, Semb, & Cole, 1998). Meta-analyses of empirical evidence demonstrated that students learned more from PSI classes than from lecture classes presenting the same material (Kulik, Kulik, & Bangert-Drowns, 1990). The practice of using criterion-referenced grading rather than normative performance as in grading on a curve was central to the method's learning advantages. Also as with PI, PSI was used in diverse settings and for different topics (Sherman, 1982), including philosophy classes (Ross & Semb, 1982), teacher helping skills (Fawcett, Matthews, Fletcher, Morrow, & Stokes, 1982), bank training (Tosti & Jackson, 1982), reading in middle school (Reid, Archer, & Freidman, 1977), and elementary school spelling (Dineen, Clark, & Risley, 1977; Klishis, Hursh, & Klishis, 1982).

Johnson and Ruskin (1977) provided a comprehensive review of how PSI contributed to several related forms of behavioral instruction in higher education. In Ferster's (1968) interview technique, students demonstrated mastery in oral interviews in addition to written quizzes and tests. J. Michael's (1967) group remediation was not mastery based but instead maximized performance through the use of points contingent on timely quiz performance. Once students passed a quiz, they were freed from other course responsibilities during the week. Malott and Svinicki (1969) used daily quizzes along with a "doomsday contingency" in which students not reaching mastery by the end of each week were either dropped from the course or received an F. Finally, Lloyd and Knuzen's (1969) behavioral menu–point system had students engage in a professional psychology activity, such as observational research, and if their work did not meet high quality standards, they were required to redo it.

When PSI gained popularity, it suffered from the same problems of quality control as did PI, but it encountered new problems as well. For example, many students waited until the end of the semester to take the required quizzes, so an atypically large number of students in PSI classes were held over to the next semester through incompletes, which created a record-keeping nightmare that administrators quickly rejected. When PSI classes then held students accountable for finishing in a semester, an atypical number of students failed, producing bimodal distributions with many As and many Fs and Ws. These unconventional grade distributions, especially in large introductory courses, were targeted by administrators for contributing to students dropping out of colleges and universities. When PSI researchers lowered the failure rates with several changes in the grading contingencies, for example, by pacing students early in the semester, the resulting atypically high grade distributions were also criticized because these courses contributed to grade inflation.

Informal discussions among behavior analysts also suggested that the substantial effort required to create a PSI course contributed to its gradual disappearance from higher education. Although we know of no formal evidence on this question, Keller once mentioned to Philip N. Chase that when he was originally developing PSI, his job was only to teach. His job was not to secure grants, not to help manage the department's finances, not to provide data to administrators on how well the department was doing, not even to publish unless there were research findings worth communicating to one's peers. The multitasking that is so much a part of modern faculty life has put a higher cost on time spent in teaching-related activities.

Precision Teaching

Precision teaching (PT) was a third major form of behavioral instruction that appeared during the 1960s and 1970s, and it was defined as "basing educational decisions on changes in continuous self-monitored performance frequencies" (Lindsley, 1992, p. 51) displayed on logarithmic graphs that visually highlight increases and decreases in the rates of responding. Although mostly used with children in regular and special education settings, PT has also been used and evaluated in college classrooms (e.g., Johnson & Layng, 1992; Johnston & Pennypacker, 1971). As with PI and PSI, PT is a method of obtaining precise information on whether a student is learning, and it can be combined with several other strategies and procedures, including PSI (e.g., Johnston & Pennypacker, 1971). On the basis of its emphasis on data, advocates of PT characterized it by a number of recommended practices (Lindsley, 1992): (a) Student performance is practiced in sessions designed specifically for the student; (b) practice is rapid, errorful, daily, and completed during 1-minute timings; (c) aims or goals are provided for the student; (d) performance is counted by the learner and charted on standard celeration (the rate of change over time) charts; (e) performances occur under well-specified and unique conditions; and (f) consequences are provided for performance. In addition, PT has led to integrated decisions about remediation that start with analysis of the components that make up targeted responding and include adding steps (slices) of curriculum for students to demonstrate fluency (Johnson & Layng, 1992). PT's definitions of performance have also led to the concept of learning channels that specify the sensory modality of the stimulus condition (i.e., see, hear) and the kind of response made (e.g., say, write, point). Finally, PT includes performance outcomes that indicate whether fluency has been achieved: behavior that maintains over time, that endures under situations that are less than ideal, that occurs under a range of appropriate situations, and that can be combined with other behavior when the need arises (Chase, 2003; Johnson & Layng, 1992).

A comprehensive review of empirical evidence on PT reported mixed support (Doughty, Chase, & O'Shields, 2004). On the positive side, studies have demonstrated a strong positive correlation between high rates of accurate performance and improved retention of similar kinds of performance. On the negative side, little evidence has shown that the procedures recommended in PT result in gains that are independent of other confounded and powerful variables, including amount of practice and rate of reinforcement. This reading of the data is controversial (see Binder, 2004; Chase, Doughty, & O'Shields, 2005), but the review recommended additional research to disentangle confounded variables and to empirically evaluate some of the claimed benefits of PT that have heretofore been based on interpretation or extrapolation. In particular, more research needs to evaluate whether training to fluency improves accurate responding over time and generalization to skill use in different contexts and problem solving situations (called *adduction* by Johnson & Layng, 1992). Demonstrating these effects directly in academic skills typical of college-level education would also be valuable.

Interteaching

Beyond the three major historical contributions of behavior analysis, we have identified two contemporary lines of behavior-analytic work that continue to inform the design of higher education. The first of these, interteaching (Boyce & Hineline, 2002), is a method of college instruction that addresses the logistical problems with PSI that may have interfered with its continued influence (Eyre, 2007; Saville, Zinn, Neef, Van Norman, & Ferreri, 2006). Interteaching involves at least eight components: (a) The instructor provides a preparation guide with questions to focus the students' reading and prepare them for discussions about the readings; (b) the students prepare answers to the questions and come to class; (c) the students divide into small groups, usually dyads and triads, to discuss the readings; (d) the instructor moves around the class facilitating the discussions, answering questions, and monitoring the quality of the discussions; (e) at the end of the discussions, the students fill out an interteaching record to identify material that is difficult or of significant interest to them; (f) the instructor collects these records and prepares a lecture for the following class meeting that focuses primarily on the material identified by the students; (g) the instructor prepares and administers frequent tests; and (h) the test items are clearly connected to questions in the preparation guide.

Saville et al. (2006) recommended that the instructor also establish grading contingencies related to the quality of the discussions, for example, providing bonus or quality points toward grades on the basis of how well all members of the group perform on the tests.

In one evaluation, Saville, Zinn, and Elliott (2005) set-up a lab-based comparison of interteaching with lectures, reading alone, and a control. Interteaching students performed better than students from the other groups. Saville et al. (2006) further studied interteaching with a classroom-based comparison of interteaching and lectures. These two studies both showed better performance by students in the interteaching conditions and preference by students for interteaching over lectures. In addition, studies of similar behavioral innovations emphasizing active responding in lecture and discussion classes (e.g., guided notes, response cards, choral responding) show improvements (Heward, 1994).

Interteaching, although developed by behavior analysts, has many similarities to teaching methods developed by other educators over the past 20 years. *Active learning* is a catch phrase in many teaching communities, and terms such as *think–pair–share* are used to describe practices similar to the small-group discussions based on preparation guides. Frequent assessment of students' understanding is common across higher education, often aided by in-class technology in the form of personal communication devices. Peer-guided discussion of answers has become the active learning norm in many large science classes, pioneered by Mazur (1997), but expanded on by many others. The 1-minute paper promoted by Angelo and Cross (1993) serves the same function as the interteaching record. None of these parallel developments diminishes the quality of the practices built into interteaching, but they suggest that this method shares developments that are not uniquely derived from PI, PSI, or other behavioral teaching insights. This lack of uniqueness may be one reason why interteaching has not emerged as part of the national conversation about teaching higher education.

Advocates of interteaching have noted that it addresses several issues raised by typical results produced by PSI. A course taught with interteaching techniques is paced by the instructor's presentation of material, so procrastination is reduced. Unlike PSI, a typical number of intertaught students finish the course during each semester, avoiding the atypically large number of PSI students who fail. Because students cannot repeat unit tests, an intertaught course also results in a more conventional grade distribution, eliminating the need to justify an unusually high grade distribution to skeptical administrators and colleagues. Interteaching also does not require instructors to develop multiple versions of tests and answer keys, complex record-keeping systems, and other management and test security concerns needed for a large mastery class.

Saville et al. (2006) claimed that interteaching is less time consuming for the instructor than are other methods of behavioral instruction, and requiring less time and less effort would predict higher rates of adoption of interteaching. At the same time, interteaching moves away from some of the benefits of PSI, PI, and PT described earlier. For instance, the mastery requirement promoted by Keller (1968), Bloom (1968), Lindsley (1992), and Skinner (1968), with its criterion-referenced measures and repeated testing on alternate, comparable examinations, is essential to greatly enhanced learning (Kulik et al., 1990). There is little benefit to a student or to a curriculum if most students complete a foundational course with a large deficit in the material they have learned. Because interteaching adopts traditional norm-referenced grading, many students will not be prepared to succeed when they need the skills and knowledge in either application or in subsequent education. No one would want to get on a plane with a pilot who received a C in a curve-graded course on landings or navigation. The major conceptual advance brought to higher education by Keller's rejection of curve (normative) grading seems to be abandoned by interteaching and other nonmastery forms of behavioral instruction. Sacrificing the goal of mastery as a way to save time or avoid conflict with colleagues over grades is certainly a practical strategy, but it should be acknowledged as stepping away from one of the major historical contributions behavior analysis has offered to higher education.

Our review of published work has not uncovered a comparison of interteaching and PSI to see whether interteaching sustains the high levels of learning that have been repeatedly demonstrated by PSI programs. We would particularly encourage a comparison of the number of students who actually master material in mastery courses such as PSI and non-mastery courses such as interteaching. We would also like to see a comparison of the efficiencies of both approaches. Such comparisons might be difficult because the efficiency of a PSI course is only seen in later iterations of a course because the cost of initial preparation is amortized over multiple offerings. The analysis should also include the time of instructors of subsequent courses who may be saved the effort of reteaching material from a prerequisite course taught in mastery format.

We should note that by design more interaction is likely among students and more rapport with the instructor is likely in interteaching than in PSI courses. Many students consider face-to-face time central to their experience, despite evidence that learning is not dependent on that component of traditional courses (Lovett, Meyer, & Thille, 2008). The traditional PSI format views class meetings as an optional activity for motivating students, but few students regularly engage in that option. If faculty teaching is evaluated by student satisfaction, many instructors will choose a method such as interteaching that maximizes the opportunity for personal relations. Perhaps PSI would fit well into the current notion of hybrid courses that are taught with complementary online and face-to-face methods. The mastery component serves the delivery of content and the live class component works on higher order problem solving and building intellectual community.

Computer-Aided Personalized System of Instruction

A direct derivative of PSI that has also undergone systematic evaluation is computer-aided personalized system of instruction (CAPSI), developed by Pear and associates at the University of Manitoba (Kinsner & Pear, 1988; Pear & Kinsner, 1988; Pear & Novak, 1996; but also see other evaluations of using computers to assist in the implementation of PSI courses such as Crosbie & Kelly, 1993). CAPSI incorporated computer technology to improve the administration of a mastery-based course and to facilitate delivery of feedback. As described by Crone-Todd (2007), CAPSI incorporates the principles of PSI by focusing on (a) small units of study, (b) study guides to direct learning in each unit, (c) self-pacing, (d) mastery demonstrated on tests based on the study questions, (e) review of test performance by the instructor or two peer-reviewers to determine whether mastery is met, and (f) feedback on each question.

Several evaluations of CAPSI at the University of Manitoba (Kinsner & Pear, 1988; Pear & Crone-Todd, 1999; Pear & Kinsner, 1988; Pear & Novak, 1996) have compared CAPSI with conventional lecture-based teaching and reported enhancements in student progress through the course, results of final exams, final grade distributions, and student satisfaction with CAPSI. To our knowledge, comparisons have not been made between CAPSI and regular PSI. Because mastery learning outperforms lecture (Kulik et al., 1979, 1990; Kulik & Kulik, 1991) and mastery is involved in both PSI and CAPSI, how much the use of computers per se adds to learning is not clear.

On one hand, CAPSI clearly reduces the administrative load for PSI instruction, making it more likely that instructors will choose this method. Even if CAPSI is only as good as PSI in learning, its efficient delivery of personalized mastery learning makes a contribution. On the other hand, using computer-scorable student responses may limit CAPSI to simplistic educational goals. In principle, a PSI course can include complex material covering the full range of Bloom's (1968) taxonomy, and human graders can provide reliable scoring and feedback on a wide range of open-ended questions (Bernstein, 1979). The CAPSI research has been conducted with items covering a narrower range of intellectual skills, although Crone-Todd (2007) attempted to define more complex learning that can be incorporated into CAPSI. To the degree that educational goals include understanding beyond recall and recognition, computer-scored items still impose limits on what can be accomplished.

Summary of Behavioral Instruction

Behavior analysts design and implement instruction through an empirical, iterative process of evaluation that has involved extensive data on individual performance with direct manipulation of precisely defined interventions. Although precise algorithms are unlikely to ever be determined, research has produced a few common rules despite the differences across multiple disciplines, varying levels of courses, and idiosyncrasies among instructors and students. Next, we present a brief overview of the general prescriptions common to most forms of behavioral education.

Attention to managing the contingencies. The single biggest idea is the importance of managing consequences, because contingencies with immediate, frequent, and contingent consequences change behavior most effectively. For example, in CAPSI the instructor and two peers review test performance and provide feedback on all answers, and interteaching includes feedback from the instructor and fellow students during dyadic discussions and from the instructor after test performance. PI provides small, achievable steps assessed objectively and with immediate confirmation. Grading contingencies directly incorporate reinforcement and punishment. For example, J. Michael's (1967) group remediation differentially rewards those who pass quizzes on the first attempt, and Malott and Svinicki's (1969) daily quiz system delivers points as intended positive reinforcers and uses avoidance of doomsday contingencies as intended negative reinforcers.

Component–composite analysis. PI, PSI, PT, interteaching, and CAPSI also share a part-to-whole strategy of synthesizing complex intellectual performance. Although often criticized for producing simplistic student objectives, behavior analysts have asserted that complexity is best understood in terms of the interactions of many simpler events. As applied to education, behavior analysts start with a complex, targeted, composite system and break it down into its simpler components. This analysis suggests effective strategies for synthesizing more complex responding.

Practice makes perfect–active responding. A third feature of behavioral instruction is providing multiple opportunities for individual students to practice performances the instructor deems important. Programs, study and discussion guides, 1-minute timings, dyadic discussion groups, and weekly quizzes all ensure that students are actively engaged. Research within behavioral instruction has also shown that frequent, distributed, and cumulative practice facilitates student mastery of the content (see Mayfield & Chase, 2002).

Measurable behavior. Behavior analysts presume that understanding learning requires observable, measurable behavior. Behavioral instruction incorporates measurement systems that adequately determine whether students have met the objectives of a course. Behavioral instruction often goes beyond measuring percentage correct accuracy. For example, PT and some forms of computerized behavioral instruction include measures of time (e.g., latency, speed, rate and celeration). In addition, many behavioral educators have called for measures of retention, endurance, application, and problem solving (Chase, 2003; Johnson & Layng, 1992).

The learner is always right. All forms of behavioral instruction focus on individual characteristics of the learner such as age, gender, previous courses completed, course prerequisites, scores on pretests, and exceptional characteristics. This focus on the individual typically leads to individual pacing and attention to individual success at meeting mastery criteria. Mastery criteria function as quality control that drives implementation of procedures leading to individual success, as opposed to ranking students by their degree of failure.

Behavior-analytic teaching in context. The emphasis of this chapter is to put these behavioral practices into a context of higher education as a whole. How has the evidence from behavioral practices in higher education influenced the higher education community? We have both have worked with educators in many disciplines who are focused on students' achievement of valued outcomes for their disciplines. As with Wolf's (1978) call for social validity, it is crucial that behavior analysts work with their communities to achieve desired educational goals, use acceptable teaching procedures, and produce satisfactory results. We now turn to describing some of these other conversations in a constructive effort to help the behavior-analytic community in higher education examine how its research and procedures can affect that larger conversation. We believe that behavior analysis can inform the best ways for students to achieve the educational outcomes being discussed in higher education in general, and we offer some possible avenues for that cooperation.

NATIONAL CONVERSATION ON EFFECTIVE HIGHER EDUCATION

Many associations and free-standing critics have questioned the assumptions of current practice and challenged universities to demonstrate that students achieve shared critical educational goals. Both legislatures and paying families are disturbed by the percentage of students who do not complete their studies; overall, only 63% of students entering college complete a bachelor's degree within 6 years (Berkner, He, & Forrest Cataldi, 2002). At public institutions, the 6-year degree rate ranges from lower than 50% in open-admission schools to rates higher than 80% at schools with stricter admissions policies and specific retention programs. Highly selective research universities and liberal arts colleges often have a 95% bachelor completion rate at 6 years (Education Trust, 2009).

A federal commission appointed by former Secretary of Education Margaret Spellings questioned whether current practices yield sufficient intellectual skills in students to merit the time and resources devoted to the enterprise (U.S. Department of Education, 2006). In response to that challenge, the Association of Public and Land-grant Universities championed voluntary public reporting of comparable data on standardized measures of student intellectual skill as well as costs and completion rates (McPherson & Shulenberger, 2006). These aligned voices want public accountability for both results and costs, in time and in resources. Together they promote standardized testing in postsecondary education, resulting in a "no college student left behind" mentality. Berliner and Biddle (1995) disputed claims of declining work by educational institutions, citing the increase in students with lower high school achievement now attending college. This response acknowledged increased variation in performance, but it shifted sole responsibility away from higher education institutions, implying that expecting the same results with very different students is not reasonable.

A second community within liberal arts colleges and selective universities questions the products of educational programs. The Association of American Colleges and Universities' (AAC&U's; 2002) Greater Expectation report called for both fundamental skills (e.g., writing, numeracy, collaboration, critical reading) and flexible problem-solving skills. Whether for citizenship or workplace or leading a fulfilling life, this position argues that education includes but is also more than knowing things about a field. The AAC&U Liberal Education for America's Promise project captured a national consensus about appropriate goals and measures for undergraduate education (AAC&U, 2007), setting out 15 areas for student development. As shown in Exhibit 21.1, some of these topics are familiar to all (e.g., critical thinking, written communication, quantitative literacy), and a few have a more contemporary sense

Exhibit 21.1
Association of American Colleges and Universities: Liberal Education Goals

Knowledge of human cultures, and the physical and natural world
Through study in the sciences and mathematics, social sciences, humanities, histories, languages, and the arts

Intellectual and practical skills, including
- Inquiry and analysis
- Critical and creative thinking
- Written and oral communication
- Quantitative literacy
- Information literacy
- Teamwork and problem solving

Personal and social responsibility, including
- Civic knowledge and engagement—local and global
- Intercultural knowledge and competence
- Ethical reasoning and action
- Foundations and skills for lifelong learning

Integrative and applied learning, including
- Synthesis and advanced accomplishment across general and specialized studies

(e.g., creative thinking, information literacy, intercultural knowledge and competence). The goals need to be practiced across the curriculum in progressively challenging projects, and AAC&U expects them to be demonstrated through their use in new settings and complex problems.

Hundreds of faculty members served on task forces convened by AAC&U to create "metarubrics" for each goal, identifying the component skills within each area and describing levels of performance from novice to advanced skills and understanding. AAC&U and the Association of Public and Land-grant Universities currently share a federal grant to compare students' learning measured by standardized tests with learning measured with standardized rubrics. Although they differ in definition and measurement, both groups promote student performance well beyond remembering and repeating information provided in courses. Both organizations raise the bar on what it means to offer a satisfactory college education, and they call for public descriptions of student learning.

A third community asserts that contemporary college teaching has become static, relatively uninformed, and insensitive to its outcomes. Led initially by the now-defunct American Association for Higher Education, this community argued that teaching is not merely the distribution of knowledge but is itself a form of intellectual inquiry into successful practice. Ernest Boyer (1990), president of the Carnegie Foundation for the Advancement of Teaching, promoted the term *scholarship of teaching and learning*. Carnegie founded an Academy for the Scholarship of Teaching and Learning devoted to making faculty inquiry into successful learning a priority for all institutions, including those with a substantial research mission.

In the scholarship of teaching and learning model, instructors function as scholars when they teach, including being clear about goals, informed about instructional practices, and committed to examining evidence of learning for identifying best practices (Glassick, Huber, & Maeroff, 1997). In this view, faculty members should implement the latest evidence-based methods in promoting learning, and graduate education would include preparation in scholarly teaching as well as in discovery research. In its strongest version (e.g., Bernstein et al., 2009), excellent teaching is a form of discovery that engages intellectual inquiry in the same ways as substantive research in a field. This approach speaks directly to Bok's (2005) complaint cited earlier; these are faculty who are constantly engaged in continuous improvement of methods, driven by public evidence of learning.

The scholarship of teaching and learning community favors experiential learning in which students participate actively in the discovery and integration of their understanding of a field. The National Research Council commissioned and the National Academy of Sciences published a volume called *How People Learn* (Bransford, Brown, & Cocking, 1999) that summarizes the most widely held view of best practices in education. This review draws heavily on models of expertise, the distinction between novices and experts, and intellectual skill development tracked over time with descriptive standards of increasing expertise and understanding. Despite different interpretations of cognitive science (e.g., Willingham, 2009), the industry consensus is that the richest learning (in the AAC&U sense, or see Wiske, 1998) occurs when students engage in frequent and open-ended responding that engages consequences. When students merely receive information and conclusions to be rehearsed and remembered, less is remembered, and intellectual performance is less readily generalized to novel contexts. Given the substantial amount of direct lecturing in U.S. higher education, this assertion is an implicit criticism of the entire enterprise.

Many discipline-based examples have demonstrated the power of well-designed activities that generate discovered understanding rather than deliver conclusions from experts. In physics, for example, Finkelstein and Pollock (2005) stopped having teaching assistants solve problems on the board in physics discussion sections and instead had them facilitate student groups in solving a sequence of hands-on exercises exploring the same principles. When compared on typical exams and nationally standardized tests of conceptual understanding, the students who discovered the solutions in teams greatly outperformed the students who were shown the correct solutions. Beichner and Saul (2004) eliminated lectures and had instructors facilitate group collaboration on carefully designed physics problems. These "studio physics" students performed better on shared, traditional examinations than students in lecture sections. Those who showed the biggest gains were the top students in engineering, but the hands-on group approach also reduced failure rates among female and ethnic minority students to the same level as the whole class average. The conceptual understanding that emerges from this instruction matches the desired learning goals identified in Exhibit 21.1, including inquiry, analysis, and problem solving through teamwork.

Alignment of Behavior Analysis With the Perceived Challenges

Given that many people have called for more effective learning by a larger and more diversely prepared student population, one would expect to find university instructors embracing the lessons from relevant behavior-analytic research oriented toward enhancing achievement. Bok (2005) in particular called for analysis of systemic institutional contingencies on teaching and learning of the sort behavior analysts routinely perform. For example, the status of lectures in higher education is certainly in flux, and many behavioral educators have replaced lectures with individual or group active learning. PI and PSI deemphasize lectures because they are impermanent, not individualized; fail to sustain attention; and do not foster frequent student activity (Johnson & Ruskin, 1977; Keller, 1968; Skinner, 1963). Schwartz and Bransford (1998), however, demonstrated that lectures work well when learners already have a foundation of knowledge in a field; they argued that active learning is best for novice learners, but lectures are a good complement as learning advances. Behavioral research on rule-governed and contingency-shaped behavior also concluded that instructions (lecture) and shaping (active learning) are effective at different points on the continuum of learning and combine well to produce generalization (R. L. Michael & Bernstein, 1991). These findings are not surprisingly backed up by research on variation and novelty in student performance (Chase & Danforth, 1991) and generalization of learning (Stokes & Osnes, 1988). Interteaching combines lectures with high levels of student activity, and accordingly it is a behavioral method that may appeal to a general higher education audience.

Perhaps the biggest opportunity for behavior analysis to make a difference would be through widespread implementation of programmatic mastery learning. The fundamental features of small steps, iterative measurement, expert feedback, and required cumulative mastery have their greatest impact on students who typically fall in the broad middle of academic achievement. Highly motivated and well-prepared students learn a lot in many educational contexts, but mastery instruction generates gains in learning among a wide range of students by supporting different rates of progress with multiple iterations of practice, measurement, and feedback. Families and public officials have urged all students to seek education beyond high school, but increased enrollment of weaker students has contributed to poor rates of retention and degree attainment. Mastery programs of instruction, with a track record of broadly successful learning, should be the optimal solution for this pressing concern.

The leading research reviews (e.g., Bransford et al., 1999; Donovan & Bransford, 2005), however, have not cited behavior-analytic work as central to learning in higher education. One widely cited book (Wineburg, 2001) identified the behavioral tradition in education as the wrong way to teach and one that has finally been abandoned. Interestingly, even Bloom's (1968) version of mastery teaching rarely has been mentioned. Along with others (e.g., Buskist et al., 1991; Deitz, 1994), we have identified for consideration three possible reasons behavioral contributions are ignored—differences in the response forms that have been evaluated, differences in research methods and evidence, and differences in worldview and cultural assumptions. In each case, we suggest ways in which interested behavior analysts can usefully participate in the national dialogue on effective instruction in higher education.

Generation of Complex Response Forms

The evidence reported from behavioral instruction in higher education has not systematically addressed outcomes valued within higher education. In general, leaders in higher education have focused on liberal education skills (see Exhibit 21.1; AAC&U, 2007). Bloom (1956) proposed an early taxonomy of types of cognitive behavior; it ranges from simple comprehension and memory through application and analysis to integration, synthesis, and evaluation. In a book on deep understanding (Wiske, 1998), authors converged on the notion that deeply learned ideas and concepts are remembered without rememorizing, and they are used in contexts in which they were not taught (and without prompting from an instructor).

Other researchers have proposed dynamic models of informed or expert thinking that can be flexibly used in many contexts. Mislevy, Steinberg, Breyer, Almond, and Johnson (2002) developed simulation models of professional practice that can be used both to teach complex expert performance and to provide learners with opportunities to demonstrate flexible understanding. For example, dental hygienists use an interactive simulation to interpret diagnostic data, formulate treatment, and adjust treatment on the basis of changes in data. Iterative opportunities to practice and receive feedback on simulation performance prepare students for assessment of diagnostic and treatment skills. Jonassen (1997) and others taught and measured learning using explicitly ill-structured problems that do not clearly specify what skills or knowledge are needed for their solution. Jonassen argued that true generalization is only demonstrated when it is not obvious what specific portion of the students' intellectual skills are relevant.

Behavior analysis has addressed complexity and generalization. Although the language and conceptual framework are different, the strategy for synthesizing a generalizable repertoire is similar to those identified by Stokes and Baer (1977) for producing generalized social and interpersonal skills. Complexity from a behavior-analytic perspective results from combining simpler component performances. Tiemann and Markle (1990), for example, elaborated conceptual tools for developing instruction that synthesizes complex repertoires from component skills. Similarly, behavior analysts have conducted basic research on complex behavior that includes stimulus generalization, response generalization, concept formation, and relational responding (Alessi, 1987; Chase, 2003; Shahan & Chase, 2002). Johnson and Layng (1992) defined *fluency* as encompassing complexity inherent in application and problem solving, and others have developed and tested definitional schemes for measuring complex behavior (Crone-Todd, 2007; Johnson & Chase, 1981; Semb & Spencer, 1976). Given that this conceptual and basic empirical work could be directly useful for instructional design, why is it so rarely cited or built on?

As suggested by both Wolf (1978) and Deitz (1994), behavior analysts need to ensure that the behavioral literature on higher education has demonstrated that students have achieved the complex and flexible repertoires valued in contemporary higher education. Our review did find several evaluations of the effect of behavioral practices on complex college student performance (e.g., Gardner, 1972; Kritch & Bostow, 1998; Lloyd & Knutzen, 1969; Mayfield & Chase, 2002; Miller & Weaver, 1976; Neef, McCord, & Ferreri, 2006; Ross & Semb, 1982; Stewart, Carr, Brandt, & McHenry, 2007). There are also behavioral studies of staff training with complex performance as dependent variables (e.g., Ducharme & Feldman, 1992; Fleming & Sulzer-Azaroff, 1992; Isaacs, Embry & Baer, 1982; Iwata, Wong, Riordan, Dorsey, & Lau, 1982). Mostly, however, our examination of the behavioral literature revealed studies of quizzes and tests in which students defined procedural terms and named key studies. These performances seem more accurately defined as component skills, not composite skills (cf. Tiemann & Markle, 1990), and they meet knowledge-level objectives, not analysis, synthesis, and evaluation (cf. Bloom, 1956). Even well-conceived and valuable work to develop a definitional system of higher order learning with high interobserver agreement (Crone-Todd, 2007) had only items at the knowledge and comprehension levels of Bloom's (1968) taxonomy, and it required only pervasive imitation, as defined by a model of hierarchical complexity (Commons & Miller, 1998). Knowledge, comprehension, and imitation do not cover the skills that have been discussed by the Carnegie Academy for the Scholarship of Teaching and Learning, AAC&U, Association of Public and Land-grant Universities, and American Association for Higher Education. Certainly, there are behaviorists measuring complex and flexible outcomes, but absent more published demonstrations in college settings of developing the intellectual repertoires valued in higher education, the general higher education community has little reason to look to behavior analysis as a source of useful ideas for instruction.

Behavior analysts have countered these criticisms in the past by pointing out that little evidence exists that other approaches have addressed complex and flexible performances. For example, Johnson and Chase (1981) examined eight studies on the levels of objectives met in college classrooms, and 50% to 90% of the objectives could be completed simply by copying from the text or other study materials provided to the student (also see Semb & Spencer, 1976, for similar results). Things have not improved much simply by the passage of time; King, Newmann, and Carmichael (2009) discussed a shortage of authentic intellectual work, and the AAC&U (2007) LEAP Report identified low-level measures as a problem endemic to all of higher education.

Rather than defend low-level responding, however, behavior analysts need to demonstrate that behavioral strategies, innovations, and tools produce the complex performances called for by the higher education community. The intellectual tools of behavior synthesis have been successful in generating complex repertoires within behavioral safety, organizational behavior management, developmental disabilities, and autism spectrum disorders. If behavior-analytic research synthesized students' complex intellectual repertoires to highly flexible criteria, the educational audience would be more interested in our work. From our perspective, behavior analysts in higher education could build systematically from conceptual and basic work on complex learning to create a technology of complex higher education performance.

Methodological Barriers

In addition to differences in response form, behavior-analytic research uses different methods than other research in higher education. Behavior analysts study problems with a part-to-whole approach designed to understand fundamental processes, and they also give priority to systematic single-subject experimental manipulations to study phenomena of interest. Both of these methodological preferences present challenges in reaching the larger higher education audience. In the first instance, measuring complex behavior is indeed difficult (cf. Atkins, 1969; Ebel, 1969), but too much emphasis on evaluating very simple behavior may reduce the utility of the results for some audiences. Showing that students remember the name of an author or the definition of a procedural term when under stress is not considered very useful to many in higher education. It does not even help to show that "name that author" fluency correlates with skills such as doing surgery and building better bridges. Laboratory research showing that behavioral concepts account for both simple learning and more complex learning (Chase, 2003; Johnson & Layng, 1992) has also been insufficient to convince a broad audience outside basic learning science.

As discussed by Deitz (1994), educators are not typically interested in a conceptually extrapolated relation between retention of component skills and extension, application, and problem solving. Educational audiences want empirical demonstration that higher level outcomes are achieved on a broad scale using methods that have previously been explored only in laboratory or limited contexts. Only when sustained learning of component skills supports more valued responding will it matter to the higher education audience, thereby demonstrating social validity for behavior analysts' work (Wolf, 1978). Until relations between behavioral methods and high-level outcomes are demonstrated and replicated by internally valid studies conducted in realistic and typical higher education contexts, behavior analysts will continue to have little audience outside behavior analysis.

The second methodological preference, single-subject designs, creates a similar issue for many educators. Single-subject experiments are powerful because they can be evaluated on four straightforward criteria: reliability of measurement, replicability of procedures, internal validity (elimination of alternative explanations), and external validity (generality of results across contexts). For example, functional analysis of problem behavior (Iwata, Dorsey, Slifer, Bauman, & Richman, 1994) uses single-subject experimental logic to test attention as a reinforcer. If a higher incidence of a behavior occurs when attention is contingent on the behavior than when attention is withheld, attention functions as a reinforcer. If the measures are reliable, the procedures can be reproduced, and the results occur over relevant conditions of generality, such simple experimental logic has allowed behavior analysts to solve significant problems.

In contrast, the current gold standard for experimental evidence used by educators is a randomized clinical trial. Although the same criteria are used to evaluate randomized clinical trials (e.g., reliability, replicability, internal validity, and external validity), single-subject methods are often referred to as *quasi-experiments* because they do not include random selection of participants and random assignment of those selected to conditions. Sidman (1960), Johnston and Pennypacker (1980), and others have described difficulties with the inferential tactics of randomized clinical trials, and this chapter is not the place to repeat these problems. The lack of emphasis on group methods for evaluating educational practices, however, has separated behavior analysts from the rest of the evidence-based education community.

Basic and applied studies of the environmental determinants of behavior have clearly benefited from a focus on individual behavior and not populations. An individual provides the right unit of analysis for determining whether a consequence functions as a reinforcer, but some behavior analysts in higher education study the aggregated behavior of populations. For example, a curriculum designer might reasonably evaluate a lesson by identifying the percentage of students who answer questions correctly within 1 second. Single-subject experiments eliminate plausible alternative explanations for changes in behavior, but conducting repeated single-subject experiments to test external validity is not efficient and is rarely done. One reason behavior-analytic studies on complex learning have been ignored by other educators is the lack of replication of effects on complex responding across many college students, with a range of content and different instructors. A behavioral educator interested in fluency could repeat an experimental analysis of a lesson using random assignment to conditions across an appropriate range of students, reporting the percentage of students in each condition who met the time and accuracy criteria. As an example of Markle's (1967) third stage of evaluation (field testing), this kind of study would integrate controls for threats to internal and external validity and should meet the criteria of communities looking for evidence from randomized clinical trials.

Such a synthesis of methodologies may provide consumers of evaluations maximum information if evaluation reports include a distribution of the results of individuals rather than a mean, even in studies done with groups of participants. Studies should describe and discuss the overlap (or lack thereof) in the performance of individuals in the varying conditions and focus less on statistical inference of whether the samples come from a common distribution (e.g., Bernstein, 1999). Using this method, one would visually represent all the performances that make up the group data on different teaching methods and ask how much leverage does one get by teaching as in group A or B? How much spread is there? As researchers do in single-subject experiments, they examine the overlap in the distribution of responding between treated and untreated behavior rather than ask simply whether the means are different (rejecting the null hypothesis). Visual inspection of the pattern of individual results, in combination with quantitative descriptions, is a powerful way to combine one's interest in individual participants with the practical need to do research with larger numbers and a wider range of participants.

Philosophical and Cultural Assumptions

Evidence alone may not convince educators, community members, and students to consider behavioral innovations in higher education. Philosophical clashes have also kept behavior analysts and others in education from talking and investigating each other's educational innovations. Some cognitivists do not read articles presenting powerful behavioral explanations of phenomena simply because they appear in sources they find unappealing; they miss out on the data generated from an unwelcome perspective. Similarly, behavior analysts sometimes reject data from research on cognitive learning because of their explicit assumptions of agency and the causal role of active cognition. Research reports sometimes use their results to promote those models of humanity, and it is convenient to discount procedures and data that support an untenable philosophical position.

Behavior analysis's emphasis on identifying the environmental influences of observable behavior ties behavioral education philosophically to a pragmatic (Lattal & Laipple, 2003), mechanistic (Marr, 1993, 2003), and selectionist (Donahoe, 1991, 2003) worldview. These philosophic influences are evident in the strong emphasis on measuring success. As repeated throughout this chapter, the concepts of behavior analysis applied to education work through continued testing and evolution of these concepts using the experimental criteria of prediction and control, the applied criteria of efficiency and efficacy, and the interpretive criteria of uniformity and parsimony.

To gain high levels of prediction and control, to demonstrate efficiency and efficacy, and to interpret changes in performance as being a result of changes in environmental manipulations, behavioral education has embraced part-to-whole instruction that defines complex performance in terms of the product of simpler component performances. This perspective has placed behavioral education at odds with gestalt or constructivist perspectives that emphasize holistic, relevant, and complex behavior. Holistic approaches start instruction with examples of behavior at a level of complexity represented by relevant tasks and deemphasize analysis of component skills. The criticism of the part-to-whole approach has focused primarily on the simplicity of behavior that students learn from behavioral instruction. Holistic critics have asserted that overly analytic, precise programming of component skills does not lead to adaptive composite behavior because the instruction stays at the level of the components. The philosophic assumptions of behavioral education lead to increased attention to evaluation and accountability, but when the evaluated and accountable learning is not complex learning, those interested in complexity will not pay attention.

Behavioral instruction also violates long-standing traditions in higher education. For example, research on both PI and PSI challenged the primary role of lectures in communicating what students need to learn (Johnson & Ruskin, 1977; Keller, 1968; Skinner 1963). Faculty members rely on oral traditions to inform their teaching rather than professional research and literature, and behavioral methods run contrary to those community traditions. Most educators received much of their undergraduate education through lectures, and imitation of that history makes lecturing the de facto model of exemplary teaching (Johnson & Ruskin, 1977). In addition, many classrooms are designed for lectures, so it would be costly to stop using lectures as the primary teaching method. Because the clientele for education are unaware of evidence-based instruction and focus instead on factors such as the selectivity of admissions (Bok, 2005), there are no competing contingencies that would favor behavioral instruction.

Much remains to be learned by considering an extension of the familiar dictum "The pigeon is always right." In this case, even a bird described in cognitive language is showing relevant behavior. As reviewed earlier, extraordinary research on college teaching has demonstrated powerful effects that influence most participants, and behavior analysts would be better off learning from it than objecting to its intellectual origins or assumptions. Paying attention to these phenomena may spawn behavioral investigations into the possible sources of the effects, but it should also generate new practices in the courses that are taught, regardless of the frame of reference that gave rise to the procedures.

NEXT STEPS FOR BEHAVIORAL EDUCATIONAL PRACTICES

> We are on the threshold of an exciting and revolutionary period, in which the scientific study of man will be put to work in man's best interests. Education must play its part. It must accept the fact that a sweeping revision of educational practices is possible and inevitable. When it has done this, we may look

> forward with confidence to a school system which is aware of the nature of its tasks, secure in its methods, and generously supported by the informed and effective citizens whom education itself will create. (Skinner, 1968, p. 153)

We think many opportunities exist for behavior analysts today because people respond positively to our science. This older quotation from Skinner (1968) suggests, though, that we have been on this threshold before. As Neuringer (1991) warned, we need to be humble about what we know and do not know. Part of this humility involves being as skeptical of our own work as we are of others (Chase, 1991). Our review suggests that educational practices derived from behavior analysis could generate additional learning and contribute more to the development of a well-educated society than is presently the case. Having said that, we need to recognize the limits of laboratory demonstrations, extrapolation to higher education from other findings, and interpretation of empirical findings. Although data support PI, PSI, PT, and other forms of applied behavior analysis in higher education, we can ask what a behavior analyst might do next to encourage discussion and adoption of the results of behavior analysis's body of work on education.

We believe this state of affairs will change when more behavior-analytic researchers create and report teaching innovations that generate complex and flexible responding (i.e., deep understanding) of the kind valued by postsecondary educators. If the methods yield a substantially greater percentage of students who achieve deep understanding than do conventional lectures or than does typical active learning derived from constructivist educational principles, then communities will adopt them. Behavior analysts' work would be especially valuable if behavioral methods could yield higher rates of retention and successful completion of critical, challenging courses among student groups who have traditionally performed below average on those measures.

Behavior analysts interested in higher education should work to demonstrate the power of "shovel-ready" methods that are readily transportable on a large scale into existing educational settings, and they should operate within existing physical space and business models. Going public with additional laboratory studies that require special support and tightly regulated conditions will not advance the agenda; claims about higher order thinking or flexible and complex repertoires must be based on field-based evidence rather than extrapolation from controlled studies under optimal conditions. Markle's (1967) model of evaluation provides the steps needed to generate a range of evidence that meets these criteria, including evidence of successful instantiations within the constraints of field contexts. Successful implementation will only change practice if there is an advantage in learning without a high density of behavioral specialists on site or other expensive support. Technology cannot change behavior if it is not adopted, so adoption strategies must be part of the plan.

The development of such examples needs to arise from examination of findings throughout the educational literature, including those with large-scale group data or those derived from competing conceptual models. Practitioners need to look for phenomena that are of shared interest to all communities and then use controlled settings to find methods to synthesize those valued and complex repertoires in students with a wide range of incoming talent, experience, and skill. Following Markle's (1967) model, those synthesis procedures must be adapted and developed further for use in regular school settings, including using conventional group comparisons as evidence (noting our earlier comments on analysis and presentation of group data). The metaphor for this work should be creating a plug-in software program that adds functionality to an existing application rather than developing an entirely new system of education or institution. After the plug-in has demonstrated its utility in the real space of an existing institution, with all the limits and impediments that come with it, the evidence gathered will make a much better argument for the more radical suggestion of scrapping the larger system and building a new one (a totally new application).

We advocate a clear focus in the practices and tactics of behavior analysts in higher education. Rather than identifying performances that mirror or parallel the responses that they study in laboratories, behavior analysts should look within the broad community of higher education for examples of its goals for learners in many contexts (e.g., those in Exhibit 21.1). Once those flexible and generalizable responses have been identified, behavior analysts need to use their best conceptual and empirical tools to synthesize those repertoires in realistic settings. This work will of necessity include a wide variety of methods, including strategies such as PSI that focus on evidence from individual learners and strategies like problem-based learning in which groups of learners are the unit of analysis. Researchers can always disaggregate data to examine and learn from the evidence provided by individual learners, but contemporary higher education is not based on tutorials. When suitable exemplars of complex and flexible responding are synthesized, opportunities for experimenting with changes in the overall model of educational delivery will be greater.

The contributions of behavior analysis to the practice and conceptualization of higher education are many and significant. Within certain boundaries, astonishing demonstrations of effective education have indicated the value and power of behavior analysis as a tool for synthesizing intellectual skill. At the same time, the larger community has moved in a different direction, following work derived from other conceptual systems that aim to generate more complex and flexible intellectual responding. The broad existence of that model has failed to generate excellent results on a broad scale (with a large percentage of the population), leading to general dissatisfaction and a great opportunity to demonstrate effective instruction. Behavior analysis in education could take advantage of that opportunity if its practitioners will use their analytic and synthetic skills to generate the responding that is valued by the community and under the conditions set by that community.

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CHAPTER 22

BEHAVIORAL GERONTOLOGY

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According to U.S. Census Bureau data (Grayson & Velkoff, 2010), the older adult population (i.e., those age 65 or older) in the United States is expected to reach 70 million by 2030 and 88 million by 2050. In 2008, 38% of the U.S. older adult population reported some type of disability, such as problems with hearing, vision, cognition, self-care, mobilization, or independent living (Administration on Aging, 2009). The same report said that approximately 4% of the older adult population lived in institutional settings, such as nursing homes, and the proportion increased dramatically with age (e.g., 15.4% of individuals older than age 85 were living in institutional settings). Of those living in institutional settings, as many as 80% exhibited problem behavior such as physical aggression, wandering, and disruptive vocalizations (Allen-Burge, Stevens, & Burgio, 1999). Clearly, older people represent a growing population in need of effective psychological and behavior support.

Our aim in this chapter is to provide guidance to behavior analysts and clinicians who work with older adults and who assist care staff or family caregivers in improving the quality of life of older adults, including those with problem behavior. We present the historical and conceptual context, including the behavior-analytic and geropsychology research traditions and associated crucial concepts. We follow this with a description of the current clinical context of working with older adults in long-term care settings, highlighting the burgeoning need for behavioral gerontology to be applied in this field.

The chapter is structured around specific topographies of problem behaviors that clinicians may confront in their work with older adults. For each behavior, we provide prevalence estimates (although we acknowledge that prevalence is difficult to accurately estimate because of inconsistent definitions and measurement methods used) and review the behavioral gerontology research. Within each problem behavior section, we highlight client behaviors to strengthen (or teach) because our experience has been that junior clinicians sometimes overlook the need for adaptive goals to increase positive aspects of an individual's functioning. For example, if the goal is to reduce disruptive vocalizations, then one may teach the elder in care an adaptive means by which to gain staff attention (e.g., use of a bell). Thus, reducing a problem behavior needs to be considered in conjunction with increasing other, usually more adaptive behavior.

Because of space limitations, we do not review the caregiver training literature, although we acknowledge this consideration is crucial when working with older adults. For example, Stevens et al. (1998) showed that a 5-hour in-service workshop and intensive on-the-job training not only increased nursing aides' knowledge of behavioral skills but also facilitated their use of the skills with older nursing home residents.

At least two research traditions have been instrumental in our current understanding of and strategies for managing problem behaviors in older adults. First, the behavior-analytic focus on functional analysis has placed an emphasis on determining the

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antecedent and consequent events that influence the probability of problem behavior (Hanley, Iwata, & McCord, 2003). Within this research tradition, behavioral interventionists manipulate environmental variables identified as causal by the functional analysis. By controlling these causal variables, problem behavior may be managed while adaptive responding is increased (Baker, Hanley, & Mathews, 2006).

The second research tradition is clinical geropsychology that, as does behavior analysis, adopts a person-centered model that identifies and manipulates causative environmental factors in its interventions. However, clinical geropsychology is focused on a broader range of diverse biopsychosocial and environmental causative factors, such as pain, discomfort, memory deficits affecting daily living, caregivers' lack of knowledge about the disease process, premorbid personality, depression, and anxiety. Clinical geropsychologists use a broader definition of a functional analytic approach to analysis and intervention. They have defined functional analysis as "a method of explaining a phenomenon, which involves the generation of hypotheses from both observable and/or unobservable data. It attempts to explain and predict the functions of a phenomenon, through an examination of the relationships that contribute to it" (Samson & McDonald, 1990, as cited in Moniz-Cook, Stokes, & Agar, 2003, p. 204). Corresponding interventions are designed to target each causative factor, such as dealing with physiological precipitants of behavior (e.g., discomfort), using spared memory in learning procedures, direct discussion or therapy with the individual, staff education in basic dementia skills, changing nursing care practices, and changing the physical, social, or sensory environment (e.g., Bird, Llewellyn-Jones, Korten, & Smithers, 2007; Burgio & Burgio, 1986; Moniz-Cook et al., 2003). Both of these research traditions believe the determinants of behavior can be multiple and that causes can vary across individuals and time, and both are explicit in designing treatments that address causal factors.

From the clinical geropsychology tradition, innovative and effective nonpharmacological treatments for challenging behaviors have increasingly been favored (Camp, Cohen-Mansfield, & Capezuti, 2002; Landreville et al., 2006; Moniz-Cook et al., 2003) and found to be efficacious (Bird et al., 2007; Moniz-Cook et al., 2003; Opie, Doyle, & O'Connor, 2002). Bird, Llewellyn-Jones, Smithers, and Korten (2002) showed that a range of individualized, psychosocial interventions targeted at causal factors can result in reductions of challenging behaviors and improvements in staff attitudes.

Behavior analysis and clinical geropsychology have influenced the development of behavioral gerontology, which is defined as "the small and recent field that combines the application of behavioral principles to important social problems within the multidisciplinary field of gerontology" and is focused on "empirically grounded interventions targeted at improving the lives of older adults" (Adkins & Mathews, 1999, p. 39). Behavior analysis has been applied to behavioral problems of older adults since the late 1970s. In a review of publication trends, Buchanan, Husfeldt, Berg, and Houlihan (2008) concluded that gerontological research published in behavioral psychology journals in the past 25 years has been stagnant. Despite this, behavioral gerontology has much to offer in preventive interventions, in addressing the psychological challenges of old age, and in informing clinical practice in managing challenging behavior, including dementia. The latter is of particular relevance because the use of psychoactive medication to manage problem behavior has been discouraged because of the side-effect load for older adults, such as increased risk of falls, extrapyramidal symptoms, sedation, and cognitive decline (Talerico, Evans, & Strumpf, 2002). Additionally, the Nursing Home Reform Act, passed as part of the Omnibus Budget and Reconciliation Act of 1987, stipulated that nonpharmacological interventions should be first-line responses to challenging behaviors associated with dementia.

During the past 25 years, the greatest proportion of behavioral gerontology research has focused on the need to increase the older person's engagement with the environment, social interactions, and positive health-related behaviors. To a lesser extent, research has focused on improving the older person's capacity to participate in his or her personal care such as bathing and dressing and improving mood, affect, and cognition. A small proportion of research has studied methods of increasing caregiver behavior-management skills. Researchers have studied various populations of older adults, including those with physical and cognitive impairments, healthy older adults, and older adults' caregivers. Research settings have been in clinics, adult day care centers, home environment, and residential aged care facilities (nursing home or hostel).

THE CRUCIAL CONCEPTS

The crucial concepts in behavioral gerontology are (a) an understanding of the idiosyncratic nature of behavioral problems because of the unique causative factors in each case; (b) the need for a thorough assessment of the individual and environment, including but not limited to a functional analysis; (c) the need for the case-specific adaptation of any interventions to target individual causal factors in each case; and (d) the need for flexibility in the clinical application of interventions.

The management of older adults' challenging behaviors must start with a comprehensive assessment, including a functional analysis that incorporates assessment of the environmental context and the caregiver's perception of the behavior. Essential components of management include the clear definition of the target behavior, the generation of hypotheses regarding the purpose of the behavior, the identification of causal and maintaining factors, and the development of a problem formulation, based on all the assessment information. The clinician can draw on the evidence base to assist with the design of interventions but must also be aware that clinical innovation is often necessary. If interventions are to have an impact, the clinician needs to develop a therapeutic relationship with the older person's caregivers because they are frequently an essential element in the implementation of interventions. Finally, the clinician must evaluate the effectiveness of interventions with reliable and valid measures.

THE CLINICAL CONTEXT

Behavior problems are prevalent among older adults (Brodaty et al., 2001; Snowdon, Miller, & Vaughan, 1996; Turner & Snowdon, 2009). An Australian report indicated that more than 90% of residents from a sample of 11 nursing homes manifested one or more challenging behaviors over the course of their dementia (Brodaty et al., 2001). Behavior problems such as wandering, inability to manage personal hygiene, resistance to assistance or care, and aggressive responding by older adults with dementia are the most common factor precipitating institutional care (Burgio & Bourgeois, 1992). These behavioral excesses are most problematic for caregivers, and therefore older adults who exhibit them are more frequently referred to specialist services than those who show behavioral deficits such as social withdrawal and inactivity (Plaud, Moburg, & Ferraro, 1998).

Dementia is frequently associated with mental health problems such as depression, psychosis, and a range of unique behavioral problems. These noncognitive symptoms and behaviors are referred to as *behavioral and psychological symptoms in dementia.* In the broadest context, *challenging behavior* denotes

> any behavior that is a barrier to a person participating in, and contributing to their community (including both active behaviors such as wandering, and passive behaviors such as withdrawal and inactivity); undermines, directly or indirectly, a person's rights, dignity or quality of life; and poses a risk to the health and safety of a person and those with whom they live and work. (McVilly, 2002, p. 7)

An audit of the reasons for referral of 26 individuals to a behavior assessment and intervention service found that physical and verbal aggression were the most frequent reasons for referral, followed by disruptive vocalization, resistance to care, intrusiveness, and chronic psychotic behaviors (responding to auditory hallucinations, or acting on delusional beliefs; Turner & Snowdon, 2009). Other less frequent behaviors included crawling on the floor, sleep disturbance, overeating, hoarding, pacing, spitting, inappropriate urinating and defecating, and throwing colostomy bags. Behavioral gerontology has much to offer in this context. We use the reasons for referral to the behavior assessment and intervention service team in the Turner and

Snowdon study (2009) for the topography of behaviors that follow.

BEHAVIORS

Aggression

The challenging behavior exhibited by older people that most frequently causes difficulty in care situations is physical aggression, defined as "destructive actions directed towards persons, objects, or self" (Whall et al., 2008, p. 721). Aggression is manifested in many ways and can include hitting, kicking, spitting, grabbing, punching, pinching, and scratching. Verbal threats and verbal abuse are common milder forms of aggression.

The exact prevalence of aggressive behavior among older adults is unknown, and wide ranges have been reported in the literature. Aggression is usually directed toward those in the immediate environment and may result in injuries to caregivers or other residents in nursing homes (Sloane et al., 2004). Elder aggression is the leading cause of staff stress and burnout (Burgio & Bourgeois, 1992; Burgio & Burgio, 1990). Sloane et al. (2004) reported that aggression is most likely to occur during bathing, and Whall et al. (2008) found that of four direct care situations, a shower or bath was the only care event significantly related to aggressive behavior.

Baker et al. (2006) demonstrated that the function of aggression in a 96-year-old woman with dementia was to escape from her toileting routine. The specific setting analysis revealed that aggression occurred in the bathroom but not in the recreational room, and antecedents to hitting were the presence of a caregiver in the bathroom, physical contact by the caregivers during toileting, and the task demand of sitting on the toilet. The usual consequences for hitting included the caregiver giving verbal reprimands, moving back to avoid being hit, and providing a break from the routine. Levels of aggression were measured in two experimental conditions and one control condition. The highest level of aggression was noted in the escape condition (41%), followed by the attention condition (18%). No aggression was observed in the control condition. Thus, the provision of escape was maintaining the behavior.

Whall et al. (2008) identified three background factors and one proximal factor as significant predictors of aggressive behavior in older adults with dementia. Background factors were being male, more advanced stage of dementia, and a past personality showing low agreeableness (as measured by the NEO Five-Factor Inventory). The total amount of nighttime sleep was the only proximal factor that was predictive of aggression, with those exhibiting aggressive behavior sleeping 30 minutes more per night than residents who did not. Whall et al. hypothesized that this was because the more aggressive group was more likely to receive psychoactive medication.

Because aggression frequently occurs during personal care situations, any intervention that aims to increase the older adult's participation in or independence with personal care could reduce aggressive behavior. Additionally, interventions that provide the reinforcer (e.g., escape) before the occurrence of aggression would also be expected to reduce aggressive responses. The studies reviewed next have addressed the effectiveness of such interventions.

A few studies have attempted to reduce the frequency of aggression through either increasing independence in personal care or reducing avoidance reactions solely through antecedent manipulation (Cohen-Mansfield & Jensen, 2006; Downs, Rosenthal, & Lichstein, 1988). The earliest of these tested the benefits of modeling therapies to improve older adults' tolerance for bathing. Behavioral approach to bathing was measured under two modeling conditions and a control condition. In the participant modeling condition, a group of four residents watched the researcher demonstrate the steps in helping a volunteer resident take a bath, including providing verbal descriptions of actions. In the filmed modeling condition, the group of four residents watched a film of the participant modeling. Bathing tolerance was operationalized as the number out of 31 hierarchical steps the individual took toward bathing. Significantly more bath-tolerance steps were taken in the participant modeling condition. This study provided encouraging early evidence that a social antecedent intervention such as a particular type of modeling could increase an older adult's approach to bathing.

Relatively few studies have focused on reducing aggression through identification of the function and subsequent manipulation of the consequences of aggression. Differential reinforcement of other behavior is a consequence manipulation in which a reinforcer is delivered after a specified period of time in which the problem behavior has not been emitted. In an early study using differential reinforcement of other behavior to treat aggression in six institutionalized elderly men, Vaccaro (1988) reinforced aggression-free 10-minute periods (staff attention served as the reinforcer). Concurrently, aggressive episodes resulted in a 10-minute time out (removal from the group). Using an A-B-A-B design, significant reductions in physical and verbal aggression were observed during the intervention phases. A surprising outcome was that the treatment effects generalized from the group setting to the ward environment at a 4-month follow-up, and staff reported improved interaction with these patients.

In contrast to Vaccaro's (1988) consequence manipulation, Baker et al. (2006) used a treatment informed by the results of a functional analysis to reduce physical aggression during toileting. Aggression proved to be maintained by escape from the toileting procedure used by staff. The intervention involved the provision of noncontingent escape; that is, the toileting procedure was briefly terminated for 10 seconds about every 30 seconds. In essence, the patient was allowed short breaks from the toileting routine on the basis of time, not her aggressive behavior. This function-based intervention almost completely eliminated aggression in this 96-year-old woman with dementia.

Personal Care

Given the correlation between aggression and personal care activities, several studies have targeted independent personal care for improvement. An important part of these interventions is teaching care staff to provide less hands-on intervention during personal care. Early research in this area used both antecedent and consequence manipulations in promoting independence in personal care. Rinke, Williams, Lloyd, and Smith-Scott (1978) used prompts and reinforcement to produce clinically significant increases in independent bathing and dressing among four elderly nursing home residents.

Numerous studies in the past 30 years have focused on caregiver training to promote residents' independence. Using both antecedent and consequence manipulation in the area of staff training, Engelman, Altus, Mosier, and Mathews (2003) found that with only 30 minutes training in the system of least prompts (adapted from Mathews & Altman, 1997), nursing assistants learned to provide graduated prompts and praise to facilitate residents' active participation during dressing.

In 2004, Sloane et al. conducted a randomized controlled trial to evaluate the effectiveness of person-centered showering, which provided choices, covering with towels, distracting attention, using bathing products recommended by family, and modifying the shower spray and a "towel bath" (an in-bed method of bathing), on bath-associated aggression, agitation, and discomfort. They found significant reductions in all measures of agitation and aggression in both treatment groups compared with the control group. Aggressive incidents declined by 53% for the group receiving the person-centered showers and by 60% for the towel-bath group.

Disruptive Vocalization

Behaviors that constitute disruptive vocalization (DV) are heterogeneous. DV is "verbal or vocal behaviors that are inappropriate to the circumstances in which they are manifested. . . . They disturb persons around the older person and may be an indicator of distress" (Cohen-Mansfield & Werner, 1997, p. 369). DV includes loud repetitive requests, self-talk, screaming, yelling, negative remarks, howling, continuous requests for attention and help, repetitious noises, groaning, singing, complaining, cursing, and threatening (Cohen-Mansfield, 1986; McMinn & Draper, 2005; von Gunten, Alnawaqil, Abderhalden, Needham, & Schupbach, 2008).

The prevalence of DV varies between 10% and 40% among nursing homes residents (Cohen-Mansfield & Werner, 1997; von Gunten et al., 2008). DV causes extreme emotional distress to care staff (Draper et al., 2000; Hallberg & Norberg, 1990; McMinn & Draper, 2005) and often leads to social isolation or chemical restraint. Nursing staff expressed more anger and frustration with, anxiety about, and a need to distance themselves from residents with DV than they did from those not displaying such vocalizations (Draper et al., 2000). Apart from its impact on staff, DV can also have a negative impact on other residents and can trigger reactive verbal and aggressive retaliation (Dwyer & Byrne, 2000). As with most challenging behaviors, multiple and interacting causal factors have been implicated in DV (Draper et al., 2000; Meares & Draper, 1999; von Gunten et al., 2008). It has been well established that DV is associated with severe cognitive, sensory, communication, and physical impairments; sleep disturbance; psychosis; anxiety; depression; pain; social isolation; and other agitated behaviors (Draper et al., 2000; Dwyer & Byrne, 2000; McMinn & Draper, 2005; von Gunten et al., 2008). Using naturalistic observations of five nursing home residents (ages 62–68 years) who screamed frequently, Cohen-Mansfield, Werner, and Marx (1990) found that DV was greatest when the resident was alone, in his or her own room, in the evening and at night. The frequency of DV increased when the resident was physically restrained and when involved in toileting and bathing activities.

DV may be a class of operant behavior maintained by consequences, such as caregiver attention. Consistent with this hypothesis, Buchanan and Fisher (2002) found the DV of two older adults was indeed maintained by attention. Using functional analysis, Dwyer-Moore and Dixon (2007) found that attention maintained the DV of one older adult, whereas escape from demands (questions or gross motor tasks) maintained it in another.

When a functional analysis reveals that DV is maintained by attention (e.g., Buchanan & Fisher, 2002), then a straightforward behavioral intervention would be to withhold attention for DV and to provide attention when socially acceptable vocalizations are emitted. Green, Linsk, and Pinkston (1986) successfully trained spousal caregivers of mentally impaired elderly partners in these differential reinforcement procedures. Using two husband–wife dyads, time-sampling frequency recordings, and an A-B-A-B-C single-case design, Green et al. found a decrease in the length of DV for one spouse and an increase in spontaneous verbalizations in the other. Similarly, Dwyer-Moore and Dixon (2007) used an A-B-A-B reversal design and differential reinforcement of appropriate vocalizations to decrease DV in a 90-year-old woman. The rate of DV decreased to 40% lower than baseline levels, with a concurrent 400% increase in appropriate vocalizations. However, implementing a differential reinforcement procedure in a nursing home setting may not be feasible. Care staff have a duty of care and are either unwilling to ignore DV or not able to consistently implement a treatment protocol that involves extinction of DV.

From a less functional approach, and using an independent groups design with 59 nursing home residents divided into a preserved language skills group and an impaired language skills group (as determined by the Functional Linguistic Communication Inventory) and analysis of covariance, Matteau, Landreville, Laplante, and Laplante (2003) found that severe language deficits were significantly associated with a higher frequency of DV. This finding supports the assertion made by McMinn and Draper (2005) that DV may serve a communicative purpose for impaired individuals to express unmet needs such as pain, discomfort, emotional distress, thirst, or hunger. If this is true, then improving or compensating for older adult communication may be an effective way to decrease DV. In a somewhat indirect evaluation of this hypothesis, Cohen-Mansfield and Werner (1997) compared the effects of (a) exposure to music, (b) exposure to a family-generated videotape, or (c) face-to-face social interaction. All three interventions reduced DV by clinically significant amounts but social interactions proved to be more effective (56% reduction) than either music (31% reduction) or the family video (46% reduction). The control group showed a 16% reduction in DV. Cohen-Mansfield and Werner asserted that DV is the result of material and social deprivation in the nursing home environment, but another possibility is that improved social interactions helped to meet some of the unmet needs that Matteau et al. and McMinn and Draper suggested set the occasion for DV. Future research should be conducted to more systematically evaluate these hypotheses.

Intrusiveness and Wandering

Wandering may be defined as high-rate purposeless pacing or ambulating into areas in which the individual may not be safe. Estimates of wandering among older adults range from 3% to 59% (Burns, Jacoby, & Levy, 1990). Wandering becomes intrusive when residents enter others' rooms and personal space, a behavior that may result in interpersonal conflict. Some incidents of wandering lead to the individual's becoming lost, injured, dehydrated, exhausted, or overexposed to the elements (Cohen-Mansfield, Werner, Culpepper, & Barkley, 1997). Wandering may threaten the individual's home placement.

Behavioral functions of wandering can include access to, or escape from, sensory stimulation. Access to attention or preferred items has also been found to be a motivating factor for wandering (Cohen-Mansfield et al., 1997; Heard & Watson, 1999). In other cases, wandering may result from loss of frontal lobe function, insight, or empathy, as occurs in frontotemporal dementia (Lough & Garfoot, 2007).

A functional analysis of wandering by Dwyer-Moore and Dixon (2007) revealed that the wandering of a 70-year-old man with dementia was maintained by attention. Wandering was put on extinction (no attention) and attention was provided noncontingently along with access to the patient's five favorite leisure items. This function-based treatment was shown to be effective, with an 85% reduction in wandering. Heard and Watson (1999) conducted naturalistic observations to identify a consequence that appeared to reinforce wandering in individual geriatric patients. They subsequently used differential reinforcement of other behavior in an A-B-A-B design. For two patients, attention appeared to maintain wandering, whereas access to tangibles or sensory stimulation appeared to reinforce wandering in two others. The differential-reinforcement-of-other-behavior procedure decreased wandering by 60% to 80%. This experiment was particularly significant because it showed that wandering with an apparent neurological basis was sensitive to differential reinforcement contingencies.

Less functional approaches to the treatment of wandering have taught older adults to discriminate safe from unsafe areas. Hussian and Davis (1985) used edible consequences to reinforce walking in safe areas that were marked by orange signs and punished (with loud noise) walking in unsafe areas marked by blue signs. Stimulus control was established by this discrimination training procedure, and people with dementia learned to walk in marked safe areas and to avoid unsafe areas. Hussian and Brown (1987) successfully used two-dimensional visual barriers (grid patterns on the floor) to reduce wandering. Feliciano, Vore, LeBlanc, and Baker (2004) reduced by 95% the entry of a 53-year-old woman with mental retardation, bipolar disorder, and dementia into a restricted area by using a visual barrier (at eye level).

Another antecedent intervention using spared memory to teach the person with dementia to associate an environmental cue with a desired behavior was described by Bird, Alexopoulos, and Adamowitz (1995). Using repeated retrieval trials to teach cued recall of a behavior, the researchers trained a 73-year-old woman with dementia who was intrusively wandering into other residents' rooms to associate a tangible environmental cue (a large red stop sign) with a behavior (stop and walk away; Bird et al., 1995). Similarly, Lough and Garfoot (2007) described a man in his mid-50s with frontotemporal dementia who was successfully taught to turn around when he arrived at strips of black and yellow security tape on the floor and a sign affixed to the door with the same colored tape, stating "Turn Around." He was instructed to stop at the line on the floor, read the sign aloud, and follow the instruction. The researchers reported that the intervention was successful after several practice sessions. In another instruction-based intervention, Provencher, Bier, Audet, and Gagnon (2008) successfully taught a 77-year-old woman with early dementia to find her way to three locations with an errorless-based learning technique that involved an individual training session consisting of a 30-minute learning phase and a 10-minute test phase, separated by a 10-minute break. Using an A-B-A design and multiple baselines across routes, Provencher et al. found a significant reduction in time taken to reach each destination and significantly fewer errors in route finding for two of the three destinations.

Although these interventions were entirely instruction based, with no specific consequences described by the researchers, operant conditioning may well have been implicated in some cases (e.g., the naturally reinforcing consequences of arriving at the desired destination).

Memory and Cognitive Problems

A primary symptom of dementia is memory impairment. Memory deficits commonly result in communication difficulties, social isolation, failure to take medication, repetitive questions, agitation, and topographical disorientation leading to difficulty in way finding.

Antecedent interventions that use residual memory of previously learned information and external memory aids as prompts have been found to be effective (Bird et al., 1995; Nolan & Mathews, 2004; Nolan, Mathews, & Harrison, 2001).

As an example of the latter, Nolan et al. (2001) used a simple environmental intervention to increase room finding by older adults with dementia. They placed two external memory aids outside the participant's bedroom (a photograph of the participant as a young adult and a sign stating his or her name). The memory aids quickly increased room finding to more than 50% and to 100% within a few days. Similarly, memory aids were used by Nolan and Mathews (2004), who placed a large clock and a large-print sign in the dining area, designed to aid in identifying mealtimes. The intervention significantly decreased residents' repetitive questions related to food and meal times.

Baltes and Lindenberger (1988, p. 296) described the nature of cognitive aging as "an ongoing dynamic between growth and decline," having continued plasticity accompanied by limits. This theory was incorporated into the theory of selective optimization with compensation and was significant for clinical practice because it emphasized and guided the search for the individual's potential in the face of limitations. As an example of a compensatory strategy, external memory aids called memory wallets have been successful in improving the quality of conversation (more meaningful and appropriate) between older people with dementia and their caregivers (Bourgeois, 1990; Bourgeois & Mason, 1996). The memory wallets had both written and photographic topic prompts about the older adult, his or her day, and his or her life. Treatment effects were maintained at 3- and 6-week follow-up. Bourgeois (1993) extended this work by improving conversations between two individuals with dementia when using memory aids in adult day care and nursing home settings.

Reality orientation (RO) was an early (circa 1950s) cognition-focused intervention defined as "the presentation and repetition of orientation information" (Spector, Orrell, Davies, & Woods, 2001, p. 378). RO can be of a continuous 24-hour nature (in which caregivers engage the older adult throughout the day) or of a classroom type (in which groups of older adults meet to engage in orientation-related activities). Studies from the 1960s to the mid-1990s using RO to improve the confused person's orientation to time, place, and his or her current situation produced equivocal results (for a summary, see Bird, 2000). Spector, Davies, Woods, and Orrell (2000) conducted a systematic review on the effectiveness of RO as a psychological intervention for people with dementia using evidence from randomized controlled trials. The review showed that people receiving RO improved significantly more than controls in both cognition and behavior. Currently, RO has been reconceptualized as a form of *cognitive stimulation,* defined as "engagement in a range of activities and discussions (usually in a group) aimed at general enhancement of cognitive and social functioning" (Clare & Woods, 2004, p. 387).

Several studies have evaluated memory training programs for older adults with early-stage dementia, and a Cochrane systematic review of randomized controlled trials of cognitive training found no significant results (Clare & Woods, 2004). However, cognitive rehabilitation interventions are more promising, in which *rehabilitation* is defined as helping "people achieve or maintain an optimal level of physical, psychological and social functioning in the context of specific impairments arising from illness or injury" (Clare & Woods, 2004, p. 393).

Disengagement

Nursing home residents are frequently unoccupied (Kolanowski, Buettner, Litaker, & Yu, 2006), despite the Omnibus Budget and Reconciliation Act of 1987 mandate that all facilities were to provide "activities designed to meet the interests, and the physical, mental, and psychosocial well being of each resident." For example, Bates-Jensen et al. (2004) found that in 15 sampled nursing homes (*N* = 451 residents), residents spent at least 17 hours per day in bed. Bates-Jensen et al. estimated that among residents with dementia, more than 60% of the day was spent alone and 49% the time was spent in null behavior (the resident was doing nothing; Schreiner, Yamamoto, & Shiotani, 2005).

Nursing home placement commonly leads to skill loss and dependency behaviors that are reinforced (with care) by staff (Baltes, 1987). Cognitive and physical impairments can lead to boredom, lack of appropriate stimulation of the remaining senses, increased risk of falls, and mental health problems such as depression and anxiety. The latter can result in the older adult, with or without dementia, disengaging from everyday life. Kolanowski et al. (2006) reported that level of engagement was correlated with agitation and apathy, depression among recently admitted residents, cognitive and sensory deficits, and physical impairments. When the residents' environment was arranged to maximize engagement with appropriate activities, cognitive and physical deficits continued to explain a significant amount of the variance in engagement.

Increasing the older adult's independence and capacity for engagement within the environment, including offering opportunities for choice of preferred activity, and facilitating improved social interactions and participation in cognitively appropriate activities can minimize problems associated with disengagement (Gallagher & Keenan, 2000a; LeBlanc, Cherup, Feliciano, & Sidener, 2006). Strengthening behaviors that are incompatible with depression and anxiety, such as providing meaningful roles within the setting, can also counteract the influence of associated withdrawal and avoidance (Skrajner & Camp, 2007). Research has found that facilitating engagement in well-designed and well-implemented activities can lead to increased positive affect and reduced behavioral symptoms (Feliciano, Steers, Elite-Marcandonatou, McLane, & Arean, 2009; Kolanowski et al., 2006; Schreiner et al., 2005). Additionally, participation in social activities has been associated with improved quality of life for residents in care facilities (Mitchell & Kemp, 2000).

Behavioral approaches to improving engagement have manipulated antecedents and consequences (mostly social), including the use of groups and education initiatives. A frequent antecedent approach is to use prompts to increase nursing home residents' engagement (Altus, Engelman, & Mathews, 2002; Brenske, Rudrud, Schulze, & Rapp, 2008; Engelman, Altus, & Mathews, 1999; McClannahan & Risley, 1975; Reitz & Hawkins, 1982). An early study by McClannahan and Risley (1975) found that nursing home residents increased their participation in activities from 20% to 74% when equipment, materials, and verbal prompts were provided; when the verbal prompts were removed, participation fell back to 24%. Of four prompting procedures evaluated, Reitz and Hawkins (1982) found personal invitations and staff prompts to be the most successful in increasing nursing home residents' activity attendance. Similarly, research by Engelman et al. (1999) found that increasing prompts and praise by nursing assistants increased the rate of engagement of five special care residents. More recent research by Brenske et al. (2008) showed that providing descriptive prompts increased activity attendance and engagement among six individuals with dementia. Using a reversal (A-B-A-B) design, the intervention involved a specific description of an available activity as part of the invitation to attend the activity room, such as "Are you sure you won't go? There will be crossword puzzles" (Brenske et al., 2008, p. 273). After the introduction of the descriptive prompts, presence in the activity room increased by 58% and activity engagement increased by 14%.

Several studies have focused more on programming for reinforcing consequences of engagement. Gallagher and Keenan (2000a) improved the quality of nursing home residents' social interactions by playing a quiz game after meals. Under this procedure, residents were more likely to respond to questions and to the answers provided by others. Relative to playing bingo (the usual after-meal activity), the duration of postmeal social interaction was extended. LeBlanc et al. (2006) used a preference assessment procedure to identify the benefits of providing choice-making opportunities for older adults. In a multielement design with multiple baselines across three participants, LeBlanc et al. provided choice-making opportunities throughout the day, in two blocks of 90 minutes. Compared with baseline, all three participants increased their engagement during the intervention times.

Positive reinforcement is a frequently used procedure for increasing resident attendance and engagement in social and recreational activities. For example, Bunck and Iwata (1978) found that the provision of tangible reinforcers significantly increased older adults' attendance at a special meal program; the tangible reinforcers were more effective than prompting procedures. Thompson and Born (1999) used verbal and physical prompts (contingent on nonparticipation) and social reinforcers (verbal praise) to increase participation in an exercise class in a day care center. Participants were four older adults with mixed disabilities (two had dementia, one had an acquired brain injury, and one had a stroke). Participation consistently increased across all exercises. Gallagher and Keenan (2000b) used lottery tickets (£20 gift voucher) as reinforcers for nursing home residents' engagement with activity materials (e.g., darts, board games, jigsaw puzzles, library books, skittles, and bowls). The reinforcement program substantially increased engagement, which did not return to baseline levels at 6-week follow-up. They suggested that residents may have sampled some of the naturally reinforcing consequences of exercising (e.g., improved flexibility and mobility).

Skrajner and Camp (2007) designed an engagement-promoting program in which older adults with dementia were trained to lead small-group activities for others with more severe dementia. This Resident-Assisted Montessori Programming was based on the Montessori method of "creating and presenting activities developed using models of rehabilitation and learning" (p. 28). Resident-Assisted Montessori Programming group participants demonstrated more constructive engagement and positive affect during group activity sessions than during regular activity programming. The Resident-Assisted Montessori Programming leaders also expressed great satisfaction with their roles.

Psychotic Behaviors

An estimated 1% of older adults (older than age 65) have schizophrenia (Bartels, Mueser, & Miles, 1997), and paranoia is the second most common psychiatric disorder in old age (Carstensen, 1988). Brink (1983) reported a 38% incidence of paranoia in a sample of community-dwelling older adults with Alzheimer's disease ($N = 39$). Rate estimates of psychotic disorders among nursing home residents with dementia range from 2.3% to 60.1% (Brodaty et al., 2003). These disorders cause distress and excess disability to the individual with the symptoms and stress to other residents and care staff (Brodaty et al., 2003).

Late-onset schizophrenia involves the onset of schizophrenia after age 40 and is sometimes known as *late paraphrenia* (Almeida, Howard, Levy, & David, 1995). Sensory deficits are strongly associated with paranoia in late-onset schizophrenia; an estimated 40% of patients with late-onset schizophrenia have hearing deficits (Bartels et al., 1997). Almeida et al. (1995) explored the psychopathological state of a sample of patients with late-onset schizophrenia and found a wide range of delusional ideas, most frequently involving persecution (83.0%) and reference (31.9%), that is, "when people mistakenly become convinced that neutral events, objects or people in the environment have special significance and contain personal relevance to the observer" (Startup, Bucci, & Langdon, 2009, p. 11). Of these patients, 83% reported hallucinations, most frequently auditory (78.7%), whereas shallow, withdrawn, or constricted affect was found in only 8.5%.

Paranoia is a common psychotic feature in dementia: A common example is the older woman with memory loss who claims that her purse has been stolen when she really has forgotten where she put it. This phenomenon is considered by some as a defense mechanism (in the Freudian sense) to protect against humiliation and inferiority (Brink, 1980). However, cognitive dissonance theory (Festinger, 1957) provides a viable alternative explanation, that it is an attempt to resolve or make sense of the inconsistent cognitions of the purse being gone and the woman not remembering.

Psychotic symptoms can also occur in delirium (an acute confusional state) and in situations in which the elderly person experiences acute illness such as pneumonia or a urinary tract infection. Awareness of the association between delirium and acute illness is important because the individual may need immediate medical treatment. Psychosis sometimes accompanies mood disorders in old age. In depression, it usually manifests as paranoia and delusions of poverty, whereas in manic states, it can manifest as delusions of grandeur.

Treatment and management of psychosis in older adults should address the pervasive and debilitating impaired social functioning, other functional impairments, and negative symptoms that are the hallmark of schizophrenia. Treatment goals could include reorienting the older adult to his or her current environment, increasing the person's capacity to engage in meaningful and constructive activity, and enhancing the person's social skills and ability to engage in social interaction within his or her environmental context.

Research into cognitive–behavioral therapy (CBT) over the past 10 years has reported improved quality of life for younger adults with schizophrenia, including improved psychosocial functioning, and reduced both positive psychotic symptoms (e.g., hallucinations and delusions) and negative psychotic symptoms (e.g., apathy, lack of emotion, poor social functioning; Granholm, Ben-Zeev, & Link, 2009; Penn et al., 2009; Zimmermann, Favrod, Trieu, & Pomini, 2005). Evidence has come from case series (Christodoulides, Dudley, Brown, Turkington, & Beck, 2008); from randomized controlled trials (Zimmermann et al., 2005), and from meta-analyses (Wykes, Steel, Everitt, & Tarrier, 2008). Wykes et al. (2008) reviewed 33 clinical trials using CBT for psychosis and found an effect size of 0.4 (95% CI [0.252, 0.548]). Most research has been conducted in the United Kingdom, where the National Health Service has recommended a minimum of 16 one-on-one CBT sessions for individuals with schizophrenia (National Collaborating Centre for Mental Health, 2009). In the United States, the Schizophrenia Patient Outcomes Research Team has recommended that CBT be offered as an adjunctive therapy to people with schizophrenia who continue to experience psychotic symptoms despite receiving adequate pharmacotherapy (Kreyenbuhl, Buchanan, Dickerson, & Dixon, 2010).

Abundant evidence has shown that CBT is as effective with cognitively intact older adults who are depressed or anxious as it is with younger populations (Hill & Brettle, 2005; Koder, Brodaty, & Anstey, 1996; Laidlaw et al., 2008), and it has been applied in the treatment of older adults with mild to moderate dementia, in both individual and group formats (Bird & Blair, 2007; Kipling, Bailey, & Charlesworth, 1999; Koder, 1998; Scholey & Woods, 2003). In one of the first case series ($N = 7$) of CBT interventions with concurrent dementia and depression, Scholey et al. (2003) found significant improvement on the Geriatric Depression Scale after eight individual CBT sessions; two of the patients showed clinically significant improvement. Koder (1998) suggested some modifications in the application of CBT with cognitively impaired elderly patients. These modifications included "simplifying material, using more structured techniques, and recognizing the critical role of the patient's caregiver in therapy" (Koder, 1998, p. 173). Laidlaw and McAlpine (2008) recommended that the clinician take account of contextual factors such as life span expectancies and chronic illness. Evidence has suggested that, depending on the degree of cognitive impairment, it may be possible to teach the elderly person relaxation strategies, to become aware of unhelpful thoughts and beliefs, and to challenge and replace them (Bird & Blair, 2007; Koder, 1998; Scholey & Woods, 2003). When it is not possible to work directly with the individual, researchers have recommended that clinicians enlist the assistance of the caregiver (Bird & Blair, 2007; Koder, 1998).

More recently, group-format CBT has been applied to the treatment of schizophrenia in older adults. Granholm et al. (2005) conducted a randomized controlled trial with a group of 76 middle-aged and older outpatients (ages 42–74) with chronic schizophrenia. They compared a treatment-as-usual group with a group that also received cognitive–behavioral social skills training (CBTSS) over 24 weekly group sessions. The CBTSS taught cognitive–behavioral strategies, social skills, problem-solving, and compensatory strategies for cognitive impairment. CBTSS participants showed significantly greater cognitive insight, defined as the capacity to evaluate "anomalous experiences with more objectivity" (Granholm et al., 2005, p. 520) and "reduced confidence in aberrant beliefs" (p. 524), as measured by the Beck Cognitive Insight Scale (Beck, Baruch, Balter, Steer, & Warman, 2004). Additionally, CBTSS participants performed social functioning activities significantly more frequently than those receiving treatment as usual, as measured by the Independent Living Skills Survey (Wallace, Liberman, Tauber, & Wallace, 2000) and the University of California, San Diego, Performance-Based Skills Assessment (Patterson, Goldman, McKibbin, Hughes, & Jeste, 2001). They also reported significantly fewer positive symptoms, as measured by the Positive and Negative Syndrome Scale (Kay, Fiszbein, & Opler, 1987).These improvements were maintained at 12-month follow-up (Granholm et al., 2007).

Behavior-analytic approaches to the treatment of psychotic behavior among older adults remain largely unexplored. In a single-case design, Brink (1980) reduced paranoid statements made by an 81-year-old woman by briefly confronting the veracity of the statements and then ignoring further paranoid statements. In another single-case design, Carstensen and Fremouw (1981) provided positive reinforcement for appropriate verbal behaviors over 14 individual sessions with a 68-year-old woman (Ms. B) displaying paranoid behaviors (verbally expressing her concerns that a staff member wanted to kill her). In response to Ms. B's expression of fear, staff were instructed to say that they understood that someone would be speaking with her about her fear and then to direct her conversation to another topic. They were also asked to initiate conversations with Ms. B at times when she was not verbalizing her fears. After treatment, staff reported that Ms. B's verbalizations of fear had been almost eliminated. However, no objective outcome measurements were reported.

In a multiple-baseline-across-behaviors design, Melin and Gotestam (1981) manipulated the physical environment in which geriatric patients with either dementia ($n = 19$) or schizophrenia ($n = 2$) took coffee. For the experimental group, chairs were placed around small tables, crockery and food were made available for self-service, staff members were not present during coffee time, the lighting was brightened, and the duration of coffee time was increased. Individuals in the control group were served coffee by the staff in the usual manner, sitting at the chairs along the walls. Similar changes were made at mealtimes. These changes significantly increased communication and table manners.

Other Relevant Research

Recent research has found that older people with psychotic symptoms benefit significantly from participation in group therapies designed to teach and improve social skills. Patterson et al. (2006) conducted a randomized controlled trial using their previously piloted group intervention, Functional Adaptation Skills Training, with 240 community-dwelling patients (ages 40–78) with a diagnosis of schizophrenia or schizoaffective disorder. The Functional Adaptation Skills Training intervention, a manualized behavioral intervention based on Bandura's (1989) social cognitive theory, targeted medication management, social skills, communication skills, organization and planning, transportation, and financial management. Participants met for weekly sessions of 120 minutes over 24 weeks. Patterson et al. (2006) found that relative to an attention-only control group, Functional Adaptation Skills Training participants showed significant improvement in their ability to manage everyday tasks, and in appropriate communication with others. However, no improvement in medication management occurred.

CONCLUSION

In this chapter, we have provided a brief overview of the historical, conceptual, and clinical context of behavioral gerontology. We reviewed psychosocial and behavioral approaches to the assessment and treatment of common behavior problems in old age. The research evidence presented here demonstrates that behavioral gerontology offers empirically supported individualized function-based interventions that improve the lives of older adults (Adkins & Mathews, 1999).

Having said this, the treatment strategies discussed here require further replication and extension as they are applied to treating behavioral and psychological problems faced by the older adult. Further research on the long-term effects of the function-based interventions developed by behavioral gerontologists is needed. These studies should provide detailed procedural information about functional analysis techniques and other forms of assessment, objective outcome measures, and adequate details about the interventions or combination of interventions so that replication is possible. Behavioral gerontologists need to pay more attention to assessing the social validity of their intervention outcomes (i.e., do patients, care staff, and family find the procedures and outcomes to be socially acceptable and important?). Such data will be useful if these interventions are to implemented widely in nursing homes or other institutional settings (Adkins & Mathews, 1999). Finally, clinicians conducting behavioral gerontology interventions must publish the results of their clinical work. In this way, we may begin to address the concerns of Buchanan et al. (2008) regarding the paucity of research in the field.

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