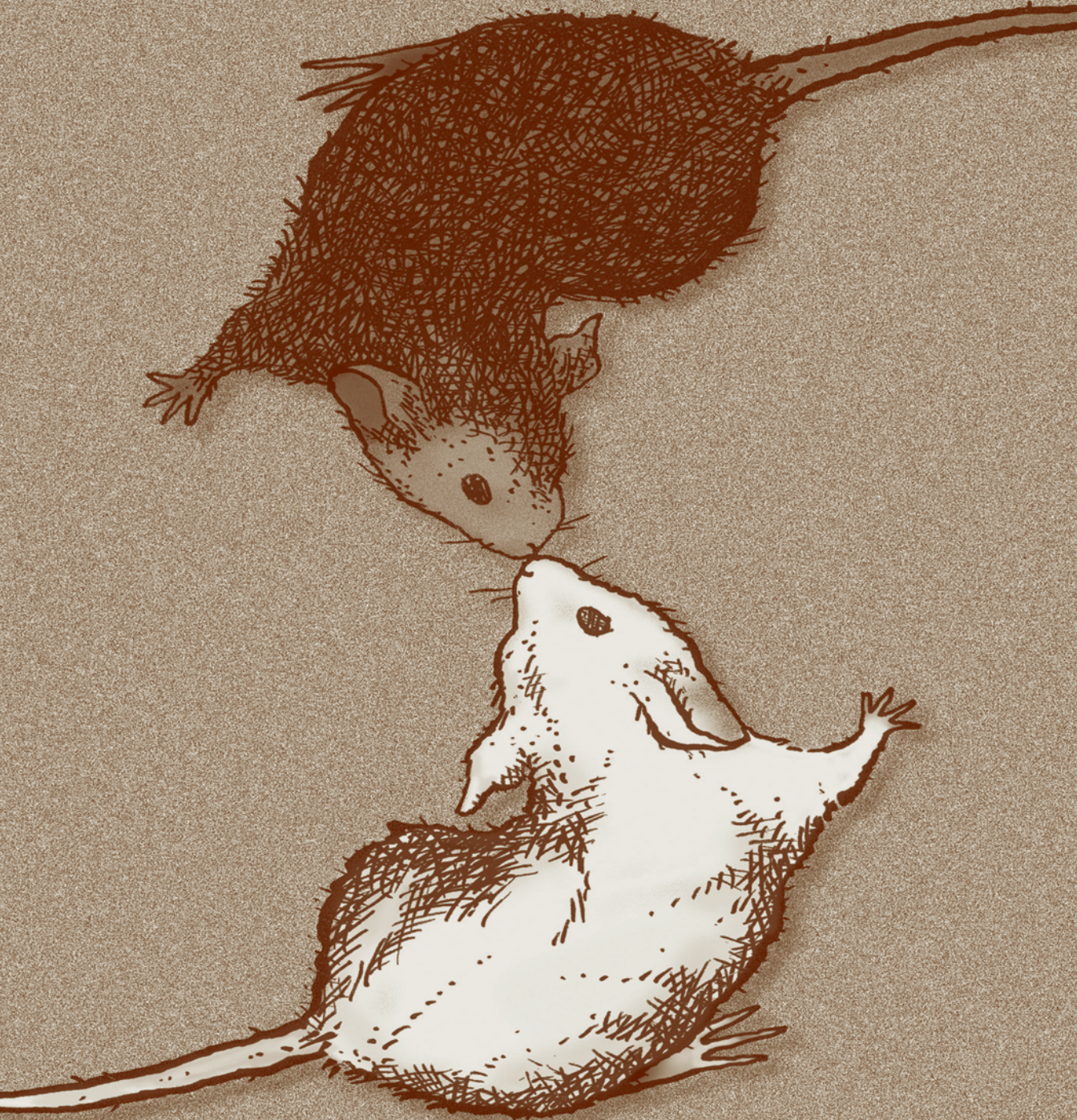Third Edition

BEHAVIOR ANALYSIS
AND LEARNING

W. David Pierce • Carl D. Cheney

Behavior Analysis and Learning

Behavior Analysis and Learning

Third Edition

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To B. F. Skinner

When an organism acts upon the environment in which it lives, it changes that environment in ways that often affect the organism itself. Some of these changes are what the layman calls rewards, or what are generally referred to technically as reinforcers: when they follow behavior in this way they increase the likelihood that the organism will behave in the same way again (Ferster & Skinner, 1957, p. 1)

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Foreword

This book updates and expands an excellent textbook on principles of learned behaviors, the first two editions of which were authored by David Pierce and Frank Epling. Sadly, Frank died before this third edition, and Carl Cheney now joins David in describing developments in contemporary behavioral theory and research. Both active researchers, Pierce and Cheney are adherents of a coherent theory pioneered by B. F. Skinner and known as experimental analysis of behavior. According to this view, to explain human behavior, we must understand the interactions between an individual and his or her environment. Behavior is lawful, and the laws involve relationships between responses, on the one hand, and environmental events on the other. Consequences of our actions help to determine our future actions. The power of this framework extends from simple conditioning preparations to imitation, language, psychopathology, and culture. This power is demonstrated throughout the text.

Covered are basic principles of Pavlovian and operant conditioning, weakening and extinction of learned responses, influences of intermittent reinforcement, conditioned reinforcement, biological influences, aversive consequences, stimulus control, and choice and preference. Much of the basic behavioral research has been done with nonhuman animal subjects, and there are important reasons for this. Environments can be controlled, as can the experiences of animal subjects. Studying the behavior of animals in isolated experimental environments provides us with a framework of information with which we can interpret more complex human behaviors.

Pierce and Cheney go well beyond the basics, however, and this third edition adds considerable new coverage. Experimental analyses are applied to imitation, verbal behavior, rule-governed behaviors, education, problem behaviors, and cultures. The breadth of this text is impressive, and the reader will gain a deep understanding and, I predict, an appreciation, of this field of study. A variety of adjuncts are provided to help the student master the subject matter. Study questions and quizzes are provided at the end of each chapter. Most helpful are pointers to Web sites containing simulations, instructional procedures, experimental procedures, and actual studies. Students motivated to go beyond the text will be assisted by these.

There are many reasons to study behavioral principles. Some readers will want to modify aspects of their own behaviors, and research on self-control is relevant. Some will apply behavioral principles to raising children and to educating them. Others will use principles of reinforcement when dealing with friends, family, or in business contexts. Some will want to become therapists, and basic findings throughout the text are related to possible applications. However, there may be no more important reason for learning about how environmental events influence our behaviors than that our long-term survival is at risk—the survival of our species and, indeed, life on earth.

In a paper written near the end of his career, B. F. Skinner asked why we are not acting to save the world. As Skinner wrote, overpopulation, overconsumption, destruction of natural resources, and destructiveness of weapons all threaten life on earth. To date, we have not successfully dealt with such threats, and he suggests that only by applying basic principles of behavioral influence will we succeed. These involve utilizing our knowledge to design relationships between behavior and consequences that benefit humanity as a whole, both

present and future. This clear and motivating text by David Pierce and Carl Cheney will provide the reader with the evidence, methods, and modes of thought that Skinner thought necessary for us to survive and prosper. After studying this text, the reader will be able to judge the adequacy and importance of Skinner's claim.

—Allen Neuringer
Reed College

Preface

We dedicate this book to the memory of W. Frank Epling. Frank was coauthor of the first two editions of *Behavior Analysis and Learning*; he was a great friend, a productive colleague, and an outstanding teacher. We have tried to make the 3rd edition as enjoyable and instructive as Frank would want it.

As with every revision, we have made several alterations in topics and presentation in response to user and reviewer comments and to the availability of added information from the literature. Reviewers have reported that although this is a basic experimental analysis text, they liked the inclusion of applied human examples. Most reviewers also appreciate the use of Mechner notation and diagrams to help depict complex contingencies of reinforcement. Users and reviewers indicated that they liked the biobehavioral emphasis (after all, behavior is a biological process), and the wide range of species examples. The pedagogical features remaining include the *Focus On*, and *On the Applied Side* sections, as well as the *Advanced Issues* on more difficult topics that are central to the experimental analysis of behavior. These features allow instructors to arrange either a basic introduction to behavior analysis and learning (by excluding complex material) or to provide a more detailed presentation of the area for specialized undergraduate or graduate courses.

In this edition we have updated all areas, topics and coverage as much as possible and created several new features. For reader/users we have added *Brief Quizzes; Study Questions* (with page numbers for answers), and *On the Web* listing of general information and specific topic web sites. We consider these additions, as all textbook writers currently do, to be a major resource for the student and we encourage instructors to incorporate web assignments whenever appropriate. Most students nowadays have access to computers, are computer fluent and expect to access information via this medium. We also suggest using the *Study Questions* to arrange social contingencies for learning the textbook material. Instructors can assign student partners or buddies who meet outside of class (perhaps over coffee) to discuss the study questions. We suggest that student pairs take turns at the roles of speaker and listener—the speaker providing the answers to study questions and the listener providing corrective feedback and reinforcement based on the textbook material.

For the instructor, we have altered the order of chapters and included some new ones. Given that this is primarily a book about operant conditioning, we integrated the two chapters on respondent conditioning from the 2nd edition into one. This new presentation is not meant to reduce the importance of respondent behavior and conditioning, but it may better suit instruction on classical and operant conditioning. We have added a new chapter on *Correspondent Relations: Imitation and Rule Governed Behavior* that reviewers and users requested and that is helpful to introduce the chapter on *Verbal Behavior*. We have increased the coverage and added new features of David Premack's work and have updated discussion of the Rewards and Intrinsic Motivation controversy as described at length in a recent book by Cameron and Pierce. The coverage and discussion of Tony Nevin's research and his conceptualization of behavioral momentum has been substantially increased. In addition, the section on behavior analysis and education has been extensively expanded in the chapter on *Applied Behavior Analysis*. We now address the works of Fred Keller (PSI) and Ogden Lindsley (Precision Teaching) as major contributions to the experimental analysis of behavior in educational settings. We also have enhanced our discussion of the ABC model for education of children with autistic behavior.

We have expanded the discussion of genetic and operant control of behavior using recent research with *Aplysia*. The interrelationship of phylogeny and ontogeny is emphasized throughout the book and especially in the last chapter on *Three Levels of Selection*. In this regard, we have retained and expanded the section on principles of selection and the biological context of conditioning. Animals are foremost the result of biological evolutionary processes and as such those processes contribute to how an animal reacts or comes to react to its environment. Behavior analysts recognize the essential nature of biological contributions and constraints while simultaneously emphasizing what can be done with arbitrary selective procedures to alter socially important behavior.

The organization of the book has changed to facilitate teaching what we consider to be a systematic analysis of behavior regulation. We recommend presenting and treating the material in the order in which it is presented; however, individual adjustments and adaptations are possible for personal considerations best left to the instructor. The introduction and the second chapter, presenting the experimental analysis of behavior, have been updated with the addition of more sources and more discussion. Following this, we address respondent contingencies and behavior as a basic paradigm; then the three-term operant model is introduced in terms of positive reinforcement and extinction. After basic operant processes are discussed, we address schedules of reinforcement—the major independent variable of behavior analysis. Next, we present the control of behavior using aversive procedures— allowing us to address three additional contingencies of positive and negative punishment and negative reinforcement (escape and avoidance). At this point in the book, all the basic contingencies have been covered.

We now focus on the interrelationship of operant and respondent contingencies and the biological context of behavior, showing that both operant and respondent processes often (if not always) work together, or in opposition, in complex interacting contingencies. After a consideration of complex operant-respondent contingencies, it is appropriate to address issues of stimulus control and the regulation of higher order behavioral processes such as conditional discrimination, remembering and concept formation. The research on stimulus control often is used as evidence of animal and human cognition, but we show that behavior analysts can study these processes from a natural science perspective, without reference to inferred cognitive processes or hypothetical mental events. Once the student is used to analyzing complex processes, it is easier to address the regulation of behavior on two or more concurrent schedules of reinforcement—the experimental analysis of choice and preference. In the 3rd edition, we have expanded the discussion of the matching law, addressed the research on optimal foraging, focused on behavioral economics and self-control, and tried to clarify the breadth and application of these areas of investigation. As the natural science of behavior becomes more mature, we expect an even greater emphasis on these areas of analysis, involving multifaceted contingencies. One example of these contingencies is conditioned reinforcement and the regulation of behavior by concurrent-chain schedules of reinforcement. In this edition, we have increased the coverage of concurrent-chain procedures and how these schedules of reinforcement are used to evaluate the delay-reduction hypothesis and other accounts of conditioned reinforcement.

Imitation and rule-governed behavior are important issues in the analysis of human behavior and we have created a chapter to introduce and adequately discuss these topics. Humans are quick to adopt the actions of others both from instructions and direct observation, hence, the critical variables in the management and utilization of these procedures are very important. Also, the analysis of the rule-governed behavior of the listener sets up the subsequent chapter on *Verbal Behavior* or the analysis of the behavior of the speaker. In the 3rd edition, we have presented a thorough introductory analysis of verbal behavior that

has been greatly revised for this edition. Although we have not devoted as much space as this critical topic deserves, nonetheless the basic rationale and fundamental components of Skinner's analysis are presented. The issues of private events and equivalence relations are discussed, as are several recent findings from the *Journal of Verbal Behavior*. The discussion of verbal behavior provided here should serve as a set of working principles as well as a solid foundation for continued study.

A unique feature of this edition is the revised and updated chapter on *Applied Behavior Analysis*. It is nearly impossible—at least we couldn't do it—to separate the basic analysis of behavior from testing and using those principles in applied situations. It is little wonder that Skinner's second book, *Walden Two*, was all about application, albeit fictionalized, of the principles reported in his first book *The Behavior of Organisms*. The utility and functionality of the principles of behavior are so compelling that suggestions for application immediately spring from even the naïve student when they first hear of reinforcement and extinction. Our discipline has become more recognized and appreciated from the visible effects on human behavior in applied situations than ever from the, possibly more important, but clearly more esoteric, findings from the laboratory. Starting with *The Psychiatric Nurse as a Behavioral Engineer* in 1959 (*JEAB* Vol. 2), application has been moving along with the development of the science. The separation of the two flagship journals of behavior analysis (*JEAB* and *JABA*) was mainly a convenience and in no way suggested, at least to us, a separation of philosophy or emphasis, certainly not in principles. Applied behavior analysis is part and parcel of the experimental analysis of behavior and therefore we emphasize it in this book, including a substantial chapter on application and *On The Applied Side* sections throughout the book.

We end the book, as in previous editions, by addressing three levels of selection: natural selection, selection by reinforcement, and selection at the cultural level by meta-contingencies. The three levels of selection are described and the commonalities among them elaborated as principles of nature. This issue bears careful and repeated mention, in our classes at least. It seems to require some repetition and time for many students to grasp the breadth and significance of what the point here is exactly. The utilization of virtually the same causal process to generate functional relations and explain behavior at vastly different levels of resolution should be impressive. *Selection by consequences* is the way the world works; it is also how one would build a behaving robot. Rather than a robot that contemplates different cognitive strategies, a functional AI (artificial intelligence) system would have few hard-wired actions except an ability to adjust its behavior based on consequences or feedback. The consequences of actions whether by a salivary gland, a political group, or a child asking for more ice cream are what influence subsequent actions of that organism or AI entity. Morphologies, vocal articulations, immunological processes are all changed by the consequences of these actions. The selection process is totally ubiquitous yet rarely or clearly pointed out to students.

Behavior analysis always has been an exciting scientific field, and we hope that we have communicated our own enthusiasm for the discipline in this book. By its very nature the study of why we do the things we do appeals to nearly everyone very quickly. Principles of behavior analysis and learning are having an impact in education, industry, therapy, animal training, medicine, clinical psychology and environmental protection as examples of only a few areas of successful application. For example, the BEHAVE.net Web site illustrates some of the range of species and problems to which a science of behavior has recently been applied. There is an explicit technology available to those who master the principles of behavior presented in this text. In many sections we have explored direct applications of behavior principles, and readers can use these principles to change their own and others behavior. However, our major focus has remained to present the fundamental

principles and procedures that form the foundation of the experimental, as well as, and in addition to the applied analysis of behavior.

Of course, many people have directly and indirectly contributed to this text. Our particular points of view began to take shape during our upbringing and were shaped and promoted by family, friends, teachers, and students. We thank them all for what we are today. And we blame them for any mistakes in commission or omission that appear in this book. What the heck, we can't think of everything!

—W. David Pierce
—Carl D. Cheney

CHAPTER 1
A Science of Behavior: Perspective, History, and Assumptions

IN THIS CHAPTER

1. Find out about learning, a science of behavior and behavior analysis.
2. Discover how the principle of selection by consequences extends to the behavior of organisms.
3. Delve into the early beginnings of behavior analysis and learning.
4. Investigate some of the basic assumptions of a science of behavior and learning.

Learning refers to the acquisition, maintenance, and change of an organism's behavior as a result of lifetime events. The **behavior** of an organism is everything it does, including covert actions like thinking and feeling. (See section on assumptions in this chapter.) An important aspect of human learning concerns the experiences arranged by other people. From earliest history, people have acted to influence the behavior of other individuals. Rational argument, rewards, bribes, threats, and force are used in attempts not only to promote learning but also to change the behavior of people. Within society, people are required to learn socially appropriate ways of doing things. As long as a person does what is expected, no one pays much attention. As soon as a person's conduct substantially departs from cultural norms, other people get upset and try to force conformity. All societies have codes of conduct and laws that people learn; people who break moral codes or laws face penalties ranging from minor fines to capital punishment. Clearly, all cultures are concerned with human learning and the regulation of human conduct.

Theories of learning and behavior have ranged from philosophy to natural science. When Socrates was told that new discoveries in anatomy proved that bodily movement was caused by the arrangement of muscles, bones, and joints, he replied, "That hardly explains why I am sitting here in a curved position talking to you" (Millenson, 1967, p. 3). About 2,300 years later, the philosopher Alfred North Whitehead asked the famous behaviorist B. F. Skinner a similar question. He said, "Let me see you account for my behavior as I sit here saying, 'No black scorpion is falling upon this table'" (Skinner, 1957, p. 457). Although there was no satisfactory account of behavior in the time of Socrates, a science of behavior is currently addressing such puzzling questions.

Human behavior has been attributed to a variety of causes. The causes of behavior have been located both within and outside of people. Internal causes have ranged from metaphysical entities like the soul to hypothetical structures of the nervous system. Suggested external causes of behavior have included the effect of the moon and tides, the arrangement of stars, and the whims of gods. Some of these theories of behavior remain popular today. For example, the use of astrological forecasts is even found in modern corporations, as demonstrated in the following passage taken from the January 1991 issue of the Economist.

Is astrology the ultimate key to competitive advantage? That is what Divinitel, a French company specializing in celestial consulting, claims. For FFr350 ($70) a session, the firm's astrologers offer advice on anything from the timing of takeovers to exorcisms. For the busy executive, Divinitel's galaxy of services can be reached via Minitel, France's teletext system. The firm is even planning a flotation on France's over-the-counter stock market in March 1991.

So who is daft enough to pay for this mystical mumbo-jumbo? About 10% of French business, according to a study by HEC, a French business school. A typical client is the boss of a small or medium-sized company who wants a second, astrological opinion on job applicants. The boss of one plastics company even uses Divinitel's advice on star signs to team up salesmen. ("Twinkle, twinkle," p. 91)

The trouble with astrology and other mystical accounts of behavior is that they are not scientific. That is, these theories do not hold up to testing by scientific methods. Over the last century, a scientific theory of learning and behavior has developed. Behavior theory states that all behavior is due to a complex interaction between genetic influence and environmental experience. The theory is based on observation and controlled experimentation, and it provides a natural-science account of the learning and behavior of organisms, including humans. This book is concerned with such an account.

Science and Behavior

The **experimental analysis of behavior** is a natural-science approach to understanding behavior regulation. Experimental analysis is concerned with controlling and changing the factors affecting the behavior of humans and other animals. For example, a behavioral researcher in a classroom may use a computer to arrange corrective feedback for a student's mathematical performance. The relevant condition that is manipulated or changed by the experimenter may involve presenting corrective feedback on some days and withholding it on others. In this case, the researcher would probably observe more accurate mathematical performance on days when feedback was presented. This simple experiment illustrates one of the most basic principles of behavior—the principle of reinforcement.

The principle of reinforcement (and other behavior principles) provides a scientific account of how people and animals learn complex actions. When a researcher identifies a basic principle that governs behavior, this is called an analysis of behavior. Thus, the experimental analysis of behavior involves specifying the basic processes and principles that regulate the behavior of organisms. Experiments are then used to test the adequacy of the analysis.

Experimental analysis occurs when a researcher notices that seagulls fly around a shoreline when people are on the beach, but not when the beach is deserted. After checking that changes in climate, temperature, time of day, and other conditions do not affect the behavior of the seagulls, the researcher offers the following analysis: People feed the birds and this reinforces flocking to the beach. When the beach is abandoned, the seagulls are no longer fed for congregating on the shoreline. This is a reasonable guess, but it can only be tested by an experiment. Pretend that the behavior analyst owns the beach and has complete control over it. The experiment involves changing the usual relationship between the presence of people and that of food. Simply stated, people are not allowed to feed the birds, and food is placed on the beach when people are not around. Over time, the behavior analyst notes that there are fewer and fewer seagulls on the beach when people are present and more and more gulls when the shoreline is deserted. The behaviorist concludes that people regulated

coming to the beach because the birds were fed, or reinforced, for this behavior only when people were present. This is one example of an experimental analysis of behavior.

Behavior Analysis

Although experimental analysis is the fundamental method for a science of behavior, contemporary researchers prefer to describe their discipline as *behavior analysis*. This term implies a more general scientific approach that includes assumptions about how to study behavior, techniques to carry out the analysis, a systematic body of knowledge, and practical implications for society and culture (Ishaq, 1991).

Behavior analysis is a comprehensive approach to the study of the behavior of organisms. Primary objectives are the discovery of principles and laws that govern behavior, the extension of these principles over species, and the development of an applied technology. In the seagull example, the underlying principle is called *discrimination*. The principle of discrimination states that an organism will respond differently to two situations (e.g., presence or absence of people) if its behavior is reinforced in one setting but not in the other.

The principle of discrimination may be extended to human behavior and social reinforcement. You may discuss dating with Carmen, but not with Tracey, because Carmen is interested in such conversation, whereas Tracey is not. In a classroom, the principle of discrimination can be used to improve teaching and learning. The use of behavior principles to solve practical problems is called **applied behavior analysis** and is discussed at some length in chapter 13.

As you can see, behavior analysis has a strong focus on environment–behavior relationships. The focus is on how organisms alter their behavior to meet the ever-changing demands of the environment. When an organism learns new ways of behaving in reaction to the changes that occur in its environment, this is called *conditioning*. The two basic kinds of conditioning are respondent and operant.

Two Types of Conditioning

Respondent Conditioning

A **reflex** is behavior that is elicited by a biologically relevant stimulus. When a stimulus (S) automatically elicits (→) a stereotypical response (R), the S → R relationship is called a reflex. This behavior and the reflex relationship had survival value in the sense that those animals that quickly and reliably responded to particular stimuli were more likely than other organisms to survive and reproduce. To illustrate, animals that startle and run to a sudden noise may escape a predator, and the startle reflex may provide an adaptive advantage over organisms that do not run, or run less quickly to the noise. Thus, reflexes are selected across the history of the species. Of course, different species of organisms exhibit different sets of reflexes.

Respondent conditioning occurs when a neutral or meaningless stimulus is paired with an unconditioned stimulus. For example, the buzz of a bee (neutral stimulus) is paired with the pain of a sting (unconditioned stimulus). After this conditioning, a buzzing bee usually causes people to escape it. The Russian physiologist Ivan Petrovich Pavlov discovered this form of conditioning at the turn of the 20th century. He showed that dogs salivated when food was placed in their mouths. This relation between food stimulus and salivation is an unconditioned reflex, and it occurs because of the animals' biological history. When Pavlov rang a bell just before feeding the dogs, they began to salivate at the sound of the bell. In this way, a new feature (sound of the bell) controlled the dogs' respondent behavior
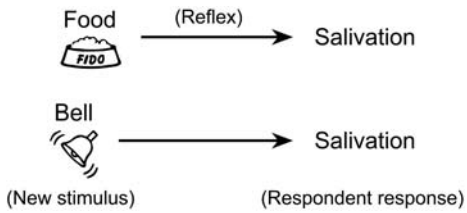
FIG. 1.1. *Simple respondent conditioning. In a reflex for a dog, food in the mouth produces salivation. Next, a bell rings (new stimulus) just before feeding the dog; after several pairings of bell and food the dog begins to salivate at the sound of the bell.*

(salivation). As shown in Fig. 1.1, a **respondent** is behavior that is elicited by the new conditioned stimulus.

Respondent conditioning is one way that organisms meet the challenges of life. A grazing animal that conditions to the sound of rustling grass by running away is less likely to become a meal than one that waits to see the predator. Almost all species on our planet, including humans, show this kind of conditioning. In terms of human behavior, many of our likes and dislikes are based on respondent conditioning. When good or bad things happen to us, we usually have an emotional reaction. These emotional responses can be conditioned to other people who are present when the positive or negative events occur (Byrne, 1971). Thus, respondent conditioning plays an important role in our social relationships—determining our friends as well as our enemies.

Operant Conditioning

Operant conditioning involves the *regulation of behavior by its consequences*. B. F. Skinner called this kind of behavior regulation **operant conditioning** because, in a given situation or setting (S^D), behavior (R) operates on the environment to produce effects or consequences (S^r). Any behavior that operates on the environment to produce an effect is called an **operant**. During operant conditioning, an organism emits behavior that produces an effect that increases (or decreases) the frequency of the operant in a given situation. In the laboratory, a hungry rat in a chamber may receive food if it presses a lever when a light is on. If lever pressing increases in the presence of the light, then operant conditioning has occurred (see Fig. 1.2).

Most of what we commonly call voluntary, willful, or purposive action is analyzed as operant behavior. Operant conditioning occurs when a baby smiles at a human face and is picked up. If smiling at faces increases because of social attention, then smiling is an operant and the effect is a result of conditioning. In a more complex example, pressing a sequence of buttons while playing a video game will increase in frequency if this response pattern results in hitting
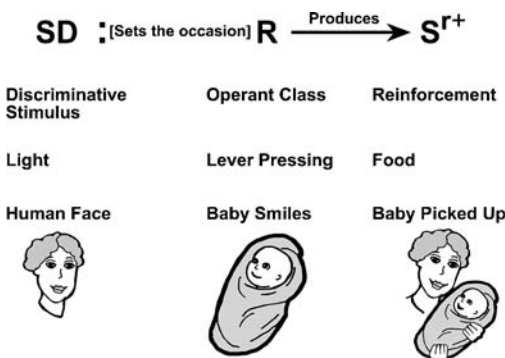
FIG. 1.2. *Simple operant conditioning: In an operant chamber, lever pressing produces food for a hungry rat. The consequences of lever pressing (presentation of food) increase its frequency in that setting. In another example, a baby smiles to a human face and is picked up. The consequences of smiling (social attention) increase the frequency of this behavior in the presence of human faces.*

a target. Other examples of operant behavior include driving a car, talking on the phone, taking notes in class, walking to the corner store, reading a book, writing a term paper, and conducting an experiment. In each case, the operant is said to be selected by its consequences.

Selection as a Causal Process

B. F. Skinner (1938) viewed psychology as the study of the behavior of organisms. In this view, psychology is a subfield of biology. The main organizing principle of contemporary biology is evolution through natural selection. Skinner generalized this to a broader principle of **selection by consequences**. Selection by consequences applies at three levels: (a) the selection of characteristics of a species (natural selection), (b) the selection of behavior within the lifetime of an individual organism (selection of operant behavior), and (c) the selection of behavior patterns (or practices) of groups of human beings that endure beyond the lifetime of a single individual (cultural selection). In all three cases, it is the consequences arranged by the environment that select for the frequency of genetic, behavioral, and cultural forms (see chap. 14).

Selection by consequences is a form of causal explanation. In science we talk about two kinds of causation: immediate and remote. **Immediate causation** is the kind of mechanism studied by physics and chemistry, the "billiard ball" sort of process, where we try to isolate a chain of events that directly results in some effect. For example, chemical reactions are explained by describing molecular interactions. In the study of behavior, an immediate explanation might refer to the physiology and biochemistry of the organism. For example, the bar pressing of a rat for food could involve the release of endogenous opiates and dopamine in the hypothalamus.

In contrast, **remote causation** is typical of sciences like evolutionary biology, geology, and astronomy. In this case, we explain some phenomenon by pointing to remote events that made it likely. Thus, the cause of a species characteristic (e.g., coloration) involves the working of natural selection on the gene pool of the parent population. An explanation of species coloration, for example, would involve showing how this characteristic improved the reproductive success of organisms in a given ecological environment. That is, natural selection for coloration explains the current frequency of the characteristic in population.

On the behavioral level, the principle of selection by consequences is a form of explanation by remote causation. When a rat learns to press a lever for food, we explain the rat's behavior by pointing to its consequences. Thus, the current frequency of bar pressing is explained by the contingency between bar pressing and food in the past. The rat's behavior has been selected by its history of reinforcement.

Both immediate and remote causal explanations are acceptable in science. Behavior analysts have emphasized remote causation and selection by consequences, but they are also interested in direct analysis of physiological and neurochemical processes (immediate causation). Ultimately, both types of explanation will provide a more complete account of learning and behavior.

The Evolution of Learning

When organisms were faced with unpredictable and changing environments, natural selection favored those individuals whose behavior could be conditioned. Organisms who condition are more flexible, in the sense that they can learn the new requirements of the environment. Such behavioral flexibility must reflect an underlying structural change of the organism. Genes code for the anatomical and physiological characteristics of the individual. Such physical changes allow for different degrees of behavioral flexibility. Thus,

differences in the structure of organisms based on genetic variation give rise to differences in the regulation of behavior. Processes of learning, like operant and respondent conditioning, lead to greater (or lesser) reproductive success. Presumably, those organisms that changed their behavior as a result of experience during their lives survived and had offspring—those that were less flexible did not. Simply stated, this means that *the capacity for learning is inherited.*

The evolution of learning processes had an important consequence. Behavior that was closely tied to survival and reproduction could be influenced by experience. Specific physiological processes typically regulate behavior related to survival and reproduction. However, for behaviorally flexible organisms, this control by physiology may be modified by experiences during the lifetime of the individual. The extent of such modification depends on both the amount and the scope of behavioral flexibility (Baum, 1983). For example, sexual behavior is closely tied to reproductive success and is regulated by distinct physiological processes. For many species, sexual behavior is rigidly controlled. In humans, however, sexual behavior is also influenced by socially mediated experiences. These experiences dictate when sexual intercourse will occur, how it is performed, and who can be a sexual partner. Powerful religious or social control can make people abstain from sex. This example illustrates that even the biologically relevant behavior of humans is partly determined by life experience.

The Biological Context of Behavior

Although behavior analysts recognize the importance of biology and evolution, they focus on the interplay of behavior and environment. To maintain this focus, the evolutionary history and biological status of an organism are examined as part of the **context of behavior** (see Morris, 1988, 1992). This contextualist view is seen in B. F. Skinner's analysis of imprinting in a duckling:

> Operant conditioning and natural selection are combined in the so-called imprinting of a newly hatched duckling. In its natural environment the young duckling moves towards its mother and follows her as she moves about. The behavior has obvious survival value. When no duck is present, the duckling behaves in much the same way with respect to other objects. Recently it has been shown that a young duckling will come to approach and follow any moving object, particularly if it is the same size as a duck—for example, a shoebox. Evidently survival is sufficiently well served even if the behavior is not under the control of the specific visual features of a duck. Merely approaching and following is enough.
>
> Even so, that is not a correct statement of what happens. What the duckling inherits is the *capacity to be reinforced by maintaining or reducing the distance between itself and a moving object* [italics added]. In the natural environment, and in the laboratory in which imprinting is studied, approaching and following have these consequences, but the contingencies can be changed. A mechanical system can be constructed in which movement *toward* an object causes the object to move rapidly away, while movement away from the object causes it to come closer. Under these conditions, the duckling will move *away from* the object rather than approach or follow it. A duckling will learn to peck a spot on the wall if pecking brings the object closer. Only by knowing what and how the duckling learns during its lifetime can we be sure of what it is equipped to do at birth (Skinner, 1974, pp. 40–41).

The duckling's biological history, in terms of capacity for reinforcement by proximity to a duck-sized object, is the context for the regulation of its behavior. Of course, the anatomy and physiology of the duck allow for this capacity. However, the way the environment is arranged determines the behavior of the individual organism. Laboratory experiments in behavior analysis identify the general principles that govern the behavior of organisms, the

specific events that regulate the behavior of different species, and the arrangement of these events during the lifetime of an individual.

The Selection of Operant Behavior

Early behaviorists like John Watson used the terminology of stimulus–response (S–R) psychology. From this perspective, stimuli force responses much like meat in a dog's mouth elicit (or forces) salivation. In fact, Watson based his stimulus–response theory of behavior on Pavlov's conditioning experiments. Stimulus–response theories are mechanistic in the sense that an organism is compelled to respond when a stimulus is presented. This is similar to a physical account of the motion of billiard balls. The impact of the cue ball (stimulus) determines the motion and trajectory (response) of the target ball. Although stimulus–response conceptions are useful for analyzing reflexive behavior and other rigid response patterns, the push–pull model is not as useful when applied to voluntary actions or operants. To be fair, Watson talked about "habits" in a way that sounds like operant behavior, but he lacked the experimental evidence and vocabulary to distinguish between respondent and operant conditioning.

It was B. F. Skinner (1935, 1937) who made the distinction between two types of conditioned reflex, corresponding to the difference between operant and respondent behavior. In 1938, Skinner introduced the term operant in his classic book, *The Behavior of Organisms*. Eventually, Skinner rejected the mechanistic (S–R) model of Watson and based operant conditioning on Darwin's principle of selection. The basic idea is that an individual emits behavior that produces effects, consequences, or outcomes. Based on these consequences, those performances that are appropriate increase, whereas inappropriate forms decline or become extinct. Julie Vargas is the daughter of B. F. Skinner and a professor of behavior analysis. She has commented on her father's model of causation:

> Skinner's paradigm is a *selectionist* paradigm not unlike Darwin's selectionist theory of the evolution of species. Where Darwin found an explanation for the evolution of species, Skinner looked for variables functionally related to changes in behavior over the lifetime of an individual. Both explanations assumed variation; Darwin in inherited characteristics, Skinner in individual acts. Skinner, in other words, does not concern himself with why behavior varies, only with how patterns of behavior are drawn out from the variations that already exist. In looking at the functional relationships between acts and their effects on the world, Skinner broke with the S-R, input-output transformation model. (Vargas, 1990, p. 9)

Skinner recognized that operants are selected by their consequences. He also noted that operant behavior naturally varies in form and frequency. Even something as simple as opening the door to your house is not done the same way each time. Pressure on the doorknob, strength of pull, the hand that is used, and so on change from one occasion to the next. If the door sticks and becomes difficult to open, a forceful response will eventually occur. This response may succeed in opening the door and become the most likely performance for the situation. Other forms of response will occur at different frequencies depending on how often they succeed in opening the door. Thus, *operants are selected by their consequences*.

Similarly, it is well known that babies produce a variety of sounds called "babbling." These natural variations in babbling are important for language learning. When sounds occur, parents may react to them. When the infant produces a familiar sound, parents often repeat it more precisely. Unfamiliar sounds are usually ignored. Eventually, the baby begins to talk like other people in the culture. Selection of verbal behavior by its social consequences is an important process underlying human communication (Skinner, 1957).

Culture and Behavior Analysis

Although much of the research in the experimental analysis of behavior is based on laboratory animals, contemporary behavior analysts are increasingly concerned with human behavior. The behavior of people occurs in a social environment. Society and culture refer to aspects of the social environment that regulate human conduct. One of the primary tasks of behavior analysis is to show how individual behavior is acquired, maintained, and changed through interaction with others. An additional task is to account for the practices of the group, community, or society that affect an individual's behavior (Lamal, 1997).

Culture is usually defined in terms of the ideas and values of a society. However, behavior analysts define **culture** as all the conditions, events, and stimuli arranged by other people that regulate human action (Glenn, 1988; Skinner, 1953). The principles and laws of behavior analysis provide an account of how culture regulates an individual's behavior. A person in an English-speaking culture learns to speak in accord with the verbal practices of the community. People in the community provide reinforcement for a certain way of speaking. In this manner, a person comes to talk like other members of the public and, in doing so, contributes to the perpetuation of the culture. The customs or practices of a culture are therefore maintained through the social conditioning of individual behavior.

Another objective is to account for the evolution of cultural practices. Behavior analysts suggest that the principle of selection (by consequences) also occurs at the cultural level. Cultural practices therefore increase (or decrease) based on consequences produced in the past. A cultural practice of making containers to hold water is an advantage to the group, because it allows for the transportation and storage of water. This practice may include making and using shells, hollow leaves, or fired-clay containers. The cultural form that is selected (e.g., clay jars) is the one that proves most efficient. In other words, the community values those containers that last the longest, hold the most, and so on. For this reason, people manufacture clay pots, and the manufacture of less efficient containers declines.

Behavior analysts are interested in cultural evolution, because cultural changes alter the social conditioning of individual behavior. Analysis of cultural evolution suggests how the social environment is arranged and rearranged to support specific forms of human behavior. On a more practical level, behavior analysts suggest that the solution to many social problems requires a technology of cultural design. B. F. Skinner (1948) addressed this possibility in his utopian book, *Walden Two*. Although this idealistic novel was written some 4 decades ago, contemporary behavior analysts are conducting small-scale social experiments based on Skinner's ideas (Komar, 1983). For example, behavioral technology has been used to manage environmental pollution, encourage energy conservation, and regulate overpopulation (Glenwick & Jason, 1980).

FOCUS ON B. F. SKINNER

B. F. Skinner (1904–1990) was the intellectual force behind behavior analysis. He was born Burrhus Frederic Skinner on March 20, 1904, in Susquehanna, Pennsylvania. When he was a boy, Skinner spent much of his time exploring the countryside with his younger brother. He had a passion for English literature and mechanical inventions. His hobbies included writing stories and designing perpetual-motion machines. He wanted to be a novelist and went to Hamilton College in Clinton, New York, where he graduated with a degree in English. After graduating from college in 1926, Skinner reported that he was not a great writer because

FIG. 1.3. *B. F. Skinner. Reprinted with permission from the B. F. Skinner Foundation.*

he had nothing to say. He began reading about behaviorism, a new intellectual movement, and as a result went to Harvard in 1928 to learn more about a science of behavior. Skinner earned his master's degree in 1930 and his Ph.D. the following year.

Skinner (Fig. 1.3) began writing about the behavior of organisms in the 1930s when the discipline was in its infancy, and he continued to publish papers until his death in 1990. During his long career, Skinner wrote about and researched topics ranging from utopian societies to the philosophy of science, teaching machines, pigeons that controlled the direction of missiles, air cribs for infants, and techniques for improving education. Some people considered him a genius, whereas others were upset by his theories.

Skinner was always a controversial figure. He proposed a natural-science approach to human behavior. According to Skinner, the behavior of organisms, including humans, was determined. Although common sense suggests that we do things because of our feelings, thoughts, and intentions, Skinner stated that behavior resulted from both genes and environment. This position bothered many people who believed that humans have some degree of self-determination. Even though he was constantly confronted with arguments against his position, Skinner maintained that the scientific facts required the rejection of feelings, thoughts, and intentions as causes of behavior. He said that these internal events were not explanations of behavior; rather, these events were additional activities of people that needed to be explained.

> The practice of looking inside the organism for an explanation of behavior has tended to obscure the variables which are immediately available for a scientific analysis. These variables lie outside the organism in its immediate environment and in its environmental history. They have a physical status to which the usual techniques of science are adapted, and they make it possible to explain behavior as other subjects are explained in science. These independent variables [causes] are of many sorts and their relations to behavior are often subtle and complex, but we cannot hope to give an adequate account of behavior without analyzing them. (Skinner, 1953, p. 31)

One of Skinner's most important achievements was his theory of operant behavior. The implications of behavior theory were outlined in his book, *Science and Human Behavior*. In this book, Skinner discussed basic operant principles and their application to human behavior. Topics include self-control, thinking, the self, social behavior, government, religion, and culture. Skinner advocated the principle of positive reinforcement and argued against the use of punishment. He noted how governments and other social agencies often resort to punishment for behavior control. Although punishment works in the short run, he noted that it has many negative side effects. Positive reinforcement, Skinner believed, is a more effective means of behavior change—people act well and are happy when behavior is maintained by positive reinforcement.

People have misunderstood many of the things that Skinner has said and done (Catania & Harnard, 1988; Wheeler, 1973). One popular misconception is that he raised his children

in an experimental chamber—the so-called baby in a box. People claimed that Skinner used his daughter as an experimental subject to test his theories. A popular myth is that this experience drove his child crazy. His daughter, Julie, was confronted with this myth and recalls the following:

> I took a class called "Theories of Learning" taught by a nice elderly gentleman. He started with Hull and Spence, and then reached Skinner. At that time I had read little of Skinner and I could not judge the accuracy of what was being said about Skinner's theories. But when a student asked whether Skinner had any children, the professor thought Skinner had children. "Did he condition his children?" asked another student. "I heard that one of the children was crazy." "What happened to his children?" The questions came thick and fast.
>
> What was I to do? I had a friend in the class, and she looked over at me, clearly expecting action. I did not want to demolish the professor's confidence by telling who I was, but I couldn't just sit there. Finally, I raised my hand and stood up. "Dr. Skinner has two daughters and I believe they turned out relatively normal," I said, and sat down. (Vargas, 1990, pp. 8–9)

In truth, the box that Skinner designed for his children had nothing to do with an experiment. The air crib was an enclosed cot that allowed air temperature to be adjusted. In addition, the mattress cover could be easily changed when soiled. The air crib was designed so that the child was warm, dry, and free to move about. Most importantly, the infant spent no more time in the air crib than other children do in ordinary beds (Skinner, 1945).

Although Skinner did not experiment with his children, he was always interested in the application of conditioning principles to human problems. His many books and papers on applied behavioral technology led to the field of applied behavior analysis. Applied behavior analysis is concerned with the extension of behavior principles to socially important problems. In the first issue of the *Journal of Applied Behavior Analysis*, Baer, Wolf, and Risley (1968) outlined a program of research based on Skinner's views:

> The statement [of behavior principles] establishes the possibility of their application to problem behavior. A society willing to consider a technology of its own behavior apparently is likely to support that application when it deals with socially important behaviors, such as retardation, crime, mental illness, or education. Better applications, it is hoped, will lead to a better state of society, to whatever extent the behavior of its members can contribute to the goodness of a society. The differences between applied and basic research are not differences between that which "discovers" and that which merely "applies" what is already known. Both endeavors ask what controls the behavior under study. . . . [Basic] research is likely to look at any behavior, and at any variable which may conceivably relate to it. Applied research is constrained to look at variables which can be effective in improving the behavior under study. (p. 91)

One area of application that Skinner wrote about extensively was teaching and learning. Although Skinner recognized the importance of behavior principles for teaching people with learning disabilities, he claimed that the same technology could be used to improve our general educational system. In his book, *The Technology of Teaching*, Skinner (1968) offered a personalized system of positive reinforcement for the academic performance of students. In this system, teaching involves arranging materials, designing the classroom, programming lessons, and so on to reinforce and maintain the performance of students. Learning is defined objectively in terms of answering questions, solving problems, using grammatically correct forms of the language, and writing about the subject matter.

An aspect of Skinner's history that is not generally known is his humor and rejection of formal titles. He preferred to be called "Fred" rather than Burrhus, and the only person who called him Burrhus was his close friend and colleague Fred Keller, who felt that he had prior claim on the name Fred (he was a few years older than Skinner). C. B. Ferster, one of Skinner's earliest students, tells about a time early in his acquaintance that Skinner tried

to get Ferster to call him "Fred." The story goes, (as recalled by Carl Cheney the author) that one day Ferster walked into the living room of Skinner's house to see Skinner seated on the sofa with a large sign around his neck saying "FRED."

In the later part of his life, Skinner worked with Margaret Vaughan (1983) on positive approaches to the problems of old age. Their book, *Enjoy Old Age: A Program of Self-Management*, is written for the elderly reader and provides practical advice on how to deal with daily life. For example, the names of people are easy to forget and even more so in old age. Skinner and Vaughan suggest that you can improve your chances of recalling a name by reading a list of people you are likely to meet before going to an important occasion. If all else fails "you can always appeal to your age. You can please the friend whose name you have forgotten by saying that the names you forget are always the names you most want to remember" (p. 52).

Skinner, who held the A. E. Pierce chair, officially retired in 1974 from Harvard University. Following his retirement, Skinner continued an active program of research and writing. Each day he walked 2 miles to William James Hall, where he lectured, supervised graduate students, and conducted experiments. Eight days before his death on August 18, 1990, B. F. Skinner received the first (and only) citation for outstanding lifetime contribution to psychology from the American Psychological Association. Skinner's contributions to psychology and a science of behavior are documented in a recent film, *B. F. Skinner: A Fresh Appraisal* (1999). Murray Sidman, a renowned researcher in the experimental analysis of behavior, narrated the film (available from the bookstore of the Cambridge Center for Behavioral Studies, www.behavior.org).

A Brief History of Behavior Analysis

Contemporary behavior analysis is based on ideas and research that became prominent at the turn of the century. The Russian scientist Ivan Petrovich Pavlov discovered the conditional reflex (a reflex that only occurs under a particular set of conditions such as the pairing of stimuli), and this was a significant step toward a scientific understanding of behavior.

Ivan Petrovich Pavlov (1849–1936)

Pavlov (Fig. 1.4) was born the son of a village priest in 1849. He attended seminary school in order to follow his father into the priesthood. However, after studying physiology he decided on a career in the biological sciences. Although his family protested, Pavlov entered the University of St. Petersburg, where he graduated in 1875 with a degree in physiology. After completing his studies in physiology, Pavlov was accepted as an advanced student of medicine. He distinguished himself and obtained a scholarship to continue his studies of physiology in Germany. In 1890, Pavlov was appointed to two prominent research positions in Russia. He was Professor of Pharmacology at the St. Petersburg Medical Academy and Director of the Physiology Department. For the next 20 years, Pavlov studied the physiology of digestion, and in 1904 he won the Nobel Prize for this work, the year that B. F. Skinner was born.

Ivan Pavlov worked on the salivary reflex and its role in digestion. Pavlov had dogs surgically prepared to expose the salivary glands in the dogs' mouths. The animals were brought into the laboratory and put in restraining harnesses. As shown in Fig. 1.5, food was then placed in the dogs' mouths, and the action of the salivary glands was observed.

FIG. 1.4.   *Ivan Petrovich Pavlov. Reprinted with permission from the Archives of the History of American Psychology, The University of Akron.*

The analysis of the salivary reflex was based on prevailing notions of animal behavior. At this time, many people thought that animals, with the exception of humans, were complex biological machines. The idea was that a specific stimulus evoked a particular response in much the same way that turning a key starts an engine. In other words, animals reacted to the environment in a simple cause–effect manner. Humans, on the other hand, were seen as different from other animals in that their actions were purposive. Humans were said to anticipate future events. Pavlov noticed that his dogs began to salivate at the sight of an experimenter's lab coat *before* food was placed in the animal's mouth. This suggested that the dogs anticipated food. Pavlov recognized that such a result challenged conventional wisdom.

Pavlov made an important observation in terms of the study of behavior. He reasoned that anticipatory reflexes were learned or conditioned. Further, Pavlov concluded that these
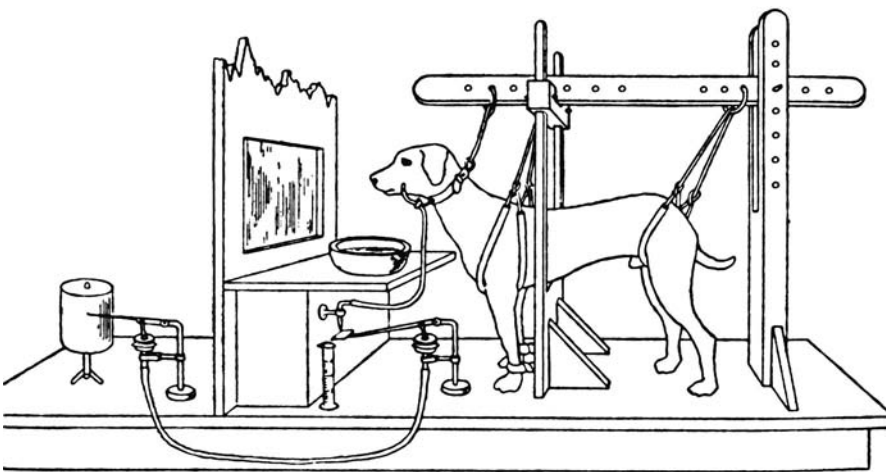
FIG. 1.5.   *A dog in the experimental apparatus used by Pavlov.*

FIG. 1.6. *John Watson. Reprinted with permission from the Archives of the History of American Psychology, The University of Akron.*

conditioned reflexes were an essential part of the behavior of organisms. Although some behaviors were described as innate reflexes, other actions were based on conditioning that occurred during the animal's life. These **conditioned reflexes** (termed conditional reflexes by Pavlov) were present to some degree in all animals but were most prominent in humans.

The question was how to study conditioned reflexes systematically. Pavlov's answer to this question represents a major advance in the experimental analysis of behavior. If dogs reliably salivate at the sight of a lab coat, Pavlov reasoned, then any arbitrary stimulus that preceded food might also be conditioned and evoke salivation. Pavlov replaced the experimenter's lab coat with a stimulus that he could systematically manipulate and reliably control. In some experiments, a metronome (a device used to keep the beat while playing the piano) was presented to a dog just before it was fed. This procedure resulted in the dog eventually salivating to the sound of the metronome. If a particular beat preceded feeding and other rhythms did not, the dog salivated most to the sound associated with food.

Although Pavlov was a physiologist and believed in mental associations, his research was directed at observable responses and stimuli. He discovered many principles of the conditioned reflex. These principles included spontaneous recovery, discrimination, generalization, and extinction. The later part of his career involved an experimental analysis of neurosis in animals. He continued these investigations until his death in 1936.

John Broadus Watson (1878–1958)

Pavlov's research became prominent in North America, and the conditioned reflex was incorporated into a more general theory of behavior by the famous behaviorist John B. Watson. Watson (Fig. 1.6) acknowledged Pavlov's influence:

> I had worked the thing out [conditioning] in terms of *Habit* formation. It was only later, when I began to dig into the vague word *Habit* that I saw the enormous contribution Pavlov had made, and how easily the conditioned response could be looked upon as the unit of what we had been calling *Habit*. I certainly, from that point on, gave the master his due credit. (Watson, personal communication to Hilgard & Marquis, 1961, p. 24)

Watson went on to argue that there was no need to make up unobservable mental associations to account for human and animal behavior. He proposed that psychology should be a science based on observable behavior. Thoughts, feelings, and intentions had no place in a scientific account, and researchers should direct their attention to muscle movements and neural activity. Although this was an extreme position, Watson succeeded in directing the attention of psychologists to behavior–environment relationships.

Watson was a rebellious young man who failed his last year at Furman University because he handed in a final-exam paper "backwards."[1] He graduated in 1899, when he was 21 years old. After spending a year as a public-school teacher, Watson decided to further his education and was admitted to graduate studies at the University of Chicago. There he studied philosophy with John Dewey, the famous educator. He never really appreciated Dewey's ideas and later in his life commented, "I never knew what he was talking about then, and, unfortunately for me, I still don't know" (Watson, 1936, p. 274). While a graduate student at Chicago, he also studied psychology with James Angell and biology and physiology with Henry Donaldson and Jacques Loeb (Pauley, 1987). In 1903, he obtained his doctorate for research with laboratory rats. The experiments concerned learning and correlated changes in the brains of these animals.

Watson (1903) published a book called *Animal Education: An Experimental Study of the Psychical Development of the White Rat, Correlated with the Growth of Its Nervous System* that was based on his doctoral research. The book demonstrated that Watson was a capable scientist who could clearly present his ideas. Ten years later, Watson (1913) published his most influential work in *Psychological Review*, "Psychology as the Behaviorist Views It." This paper outlined Watson's views on behaviorism and argued that objectivity was the only way to build a science of psychology.

> I feel that *behaviorism* is the only consistent logical functionalism. In it one avoids [the problem of mind-body dualism]. These time-honored relics of philosophical speculation need trouble the student of behavior as little as they trouble the student of physics. The consideration of the mind-body problem affects neither the type of problem selected nor the formulation of the solution of that problem. I can state my position here no better than by saying that I should like to bring my students up in ignorance of such hypotheses as one finds among other branches of science. (Watson, 1913, p. 166)

In this paper, Watson also rejected as scientific data what people said about their thoughts and feelings. Further, he pointed to the unreliability of psychological inferences about another person's mind. Finally, Watson noted that the psychology of mind had little practical value for behavior control and public affairs.

Perhaps Watson's most famous experiment was the study of fear conditioning with Little Albert (Watson & Rayner, 1920). Little Albert was a normal, healthy infant who attended a day-care center. Watson and his assistant used classical-conditioning procedures to condition fear of a white rat. At first Little Albert looked at the rat and tried to touch it. The unconditioned stimulus was the sound of a hammer hitting an iron rail. This sound made Little Albert jump, cry, and fall over. After only six presentations of the noise and rat, the furry animal also produced the fear responses. The next phase of the experiment involved a series of tests to see if the child's fear reaction transferred to similar stimuli. Albert was also afraid when presented with a white rabbit, a dog, and a fur coat.

At this point, Watson and Rayner discussed a number of techniques that could be used to eliminate the child's fear. Unfortunately, Little Albert was removed from the day-care center before counter-conditioning could be carried out. In his characteristic manner, Watson later used the disappearance of Little Albert to poke fun at Freud's method of psychoanalysis. He suggested that as Albert got older, he might go to an analyst because of his strange fears. The analyst would probably convince Albert that his problem was the result of an unresolved Oedipal complex. But, Watson remarked, we would know that Albert's fears were actually caused by conditioning—so much for Freudian analysis.

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[1]This description of John Watson is partially based on a paper by James Todd and Edward Morris (1986) on "The Early Research of John B. Watson: Before the Behavioral Revolution."

   Watson had many interests, and he investigated and wrote about ethology, comparative animal behavior, neural function, physiology, and philosophy of science. Based on his controversial views and charisma, Watson was elected president of the American Psychological Association in 1915 when he was only 37 years old. His career came to an abrupt end in 1920 when he began having a public affair with his graduate student and collaborator Rosalie Rayner. There was also a claim that Watson carried out experiments on human sexual behavior, but these rumors have not been substantiated (Todd & Morris, 1992). Because of Watson's open love affair with Rayner, his wife divorced him. This resulted in a scandal and the end of Watson's academic career. After leaving Johns Hopkins University, he became successful in industry by applying conditioning principles to advertising and public relations (Buckley, 1998). Watson implemented the use of subliminal suggestion and the pairing of hidden symbols in advertising—techniques still used today.

Edward Lee Thorndike (1874–1949)

Watson's behaviorism emphasized the conditioned reflex. This analysis focuses on the events that precede action and is usually called a stimulus–response approach. Edward Lee Thorndike, another American psychologist (Fig. 1.7), was more concerned with how success and failure affect the behavior of organisms. His research emphasized the events and consequences that follow behavior. In other words, Thorndike was the first scientist to systematically study operant behavior, although he called the changes that occurred trial-and-error learning (Thorndike, 1898).

   Edward L. Thorndike was born in 1874 in Williamsburg, Massachusetts. He was the son of a Methodist minister and had no knowledge of psychology until he attended Wesleyan University. There he read William James' (1890) book *Principles of Psychology*, which had a major impact on him. After reading the book, Thorndike was accepted as a student at Harvard, where he studied with William James. It is important to note that James' psychology focused on the mind and used the method of introspection (people's reports of feeling and thoughts). Thus, in contrast to John Watson, Thorndike was concerned with states of mind. In terms of contemporary behavior analysis, Thorndike's contribution was his systematic study of the behavior of organisms rather than his mental interpretations of animal and human behavior.

FIG. 1.7. *Edward Thorndike. Reprinted with permission from the Archives of the History of American Psychology, The University of Akron.*

Thorndike was always intrigued with animal behavior. While at Harvard, his landlady became upset because he was raising chickens in his bedroom. By this time, James and Thorndike were good friends, and Thorndike moved his experiments to the basement of James' house when he could not get laboratory space at Harvard. He continued his research and supported himself by tutoring students for 2 years at Harvard. Then Thorndike moved to Columbia University, where he studied with James McKeen Cattell, the famous expert on intelligence testing. Thorndike took two of his "smartest" chickens with him to Columbia but soon switched to investigating the behavior of cats.

At Columbia University, Thorndike began his famous experiments on trial-and-error learning in cats. Animals were placed in what Thorndike called a "puzzle box," and food was placed outside the box. A cat that struggled to get out of the box would accidentally step on a treadle, pull a string, and so on. These responses resulted in opening the puzzle-box door. Thorndike found that most cats took less and less time to solve the problem after they were repeatedly returned to the box (i.e., repeated trials). From these observations, Thorndike made the first formulation of the law of effect:

> The cat that is clawing all over the box in her impulsive struggle will probably claw the string or loop or button so as to open the door. And gradually all the other *non-successful impulses will be stamped out and the particular impulse leading to the successful act will be stamped in by the resulting pleasure* [italics added], until after many trials, the cat will, when put in the box, immediately claw the button or loop in a definite way. (Thorndike, 1911, p. 40)

Today, Thorndike's law of effect is restated as the principle of reinforcement. This principle states that all operants may be followed by consequences that increase or decrease the probability of response in the same situation. Notice that references to "stamping in" and "pleasure" are not necessary and that nothing is lost by this modern restatement of the law of effect.

Thorndike was appointed to the Teachers College, Columbia University, as a professor in 1899, and he spent his entire career there. He studied and wrote about education, language, intelligence testing, comparison of animal species, the nature–nurture problem, transfer of training, sociology of the quality of life, and most importantly, animal and human learning. Thorndike published more than 500 books and journal articles. His son (Robert Ladd Thorndike, 1911–1990) became a well-known educational psychologist in his own right and in 1937 joined the same department of psychology as that of his father. In 1949, Edward Lee Thorndike died.

B. F. Skinner and the Rise of Behavior Analysis

The works of Pavlov, Watson, Thorndike, and many others have influenced contemporary behavior analysis. Although the ideas of many scientists and philosophers have had an impact, Burrhus Fredrick Skinner (1904–1990) is largely responsible for the development of modern behavior analysis. In the Focus on B. F. Skinner section, some details of his life and some of his accomplishments are described, and in the following, his contribution to contemporary behavior analysis is outlined.

Skinner was studying at Harvard during a time of intellectual change. He wanted to extend the work of Pavlov to more complicated instances of the conditioned reflex. Rudolph Magnus was a contemporary of Ivan Pavlov, and he had been working on the conditioning of physical movement. Skinner had read his book *Korperstellung* in the original German and was impressed with it. Skinner said, "I began to think of reflexes as behavior rather than with Pavlov as 'the activity of the cerebral cortex' or, with Sherrington, as 'the integrative action of the nervous system'" (Skinner, 1979, p. 46).

The idea that reflexes could be studied as behavior (rather than as a reflection of the nervous system or the mind) was fully developed in Skinner's (1938) book, *The Behavior of Organisms*, where Skinner distinguishes between Pavlov's reflexive conditioning and the kind of learning reported by Thorndike. Skinner proposed that respondent and operant conditioning regulated behavior. These terms were carefully selected to emphasize the study of behavior for its own sake. Pavlov interpreted reflexive conditioning as the study of the central nervous system, and Skinner's respondent conditioning directed attention to environmental events and responses. Thorndike's trial-and-error learning was based on unobservable states of mind, and Skinner's operant conditioning focused on the functional relations between behavior and its consequences. Both operant and respondent conditioning required the study of observable correlations among objective events and behavior.

Skinner soon talked about a science of behavior rather than one of physiology or mental life. Once stated, the study of behavior for its own sake seems obvious; but consider that most of us say that we do something either because we have made up our mind to do it or, in more scientific terms, because of a neural connection in our brain. Most people accept explanations of behavior that rely on descriptions of brain, mind, intelligence, cognitive function, neural activity, thinking, or personality. Because these factors are taken as the cause(s) of behavior, they become the focus of investigation. Skinner, however, suggested that remembering, thinking, feeling, the action of neurons, and so on are more behaviors of the organism that require explanation. He further proposed that the action of organisms could be investigated by focusing on behavior and the environmental events that precede and follow it.

Skinner's behavioral focus was partially maintained and influenced by his lifelong friend, Fred Simmons Keller. Skinner and Keller attended Harvard graduate school together, and Keller encouraged Skinner to pursue a behavioral view of psychology. By 1946, Skinner had formed a small group of behaviorists at Indiana University. At this same time, Fred Keller and his friend Nat Schoenfeld organized another group at Columbia University (Keller, 1977, chaps. 2 and 6).

Although the number of **behavior analysts** was growing, there were no sessions on behavioral issues at the American Psychological Association annual meetings. Because of this, Skinner, Keller, Schoenfeld, and others organized their own conference at Indiana University. This was the first conference on the experimental analysis of behavior (see Fig. 1.8). These new-style behaviorists rejected the extreme views of John B. Watson and offered an alternative formulation. Unlike Watson, they did not reject genetic influences on behavior; they extended the analysis of behavior to operant conditioning, and they studied behavior for its own sake.

These new behavior analysts found it difficult to get their research published in the major journals of psychology. This was because they used a small number of subjects in their experiments, did not use statistical analysis, and their graphs of response rate were not appreciated. By 1958, the group was large enough to start its own journal, and the first volume of the *Journal of the Experimental Analysis of Behavior* (JEAB) was published. As research accumulated, the practical implications of behavior principles became more and more evident, and applications to mental illness, retardation, rehabilitation, and education increased. In 1968, the *Journal of Applied Behavior Analysis* (JABA) was published for the first time.

By 1964, the number of behavior analysts had grown enough that the American Psychological Association established a special division. Division 25 is called The Experimental Analysis of Behavior and has several thousand members. Subsequently, the Association for Behavior Analysis (ABA) was founded in the late 1970s. This association holds an annual international conference that is attended by behavior analysts from a variety of countries. The association publishes a journal of general issues called *The Behavior Analyst*.
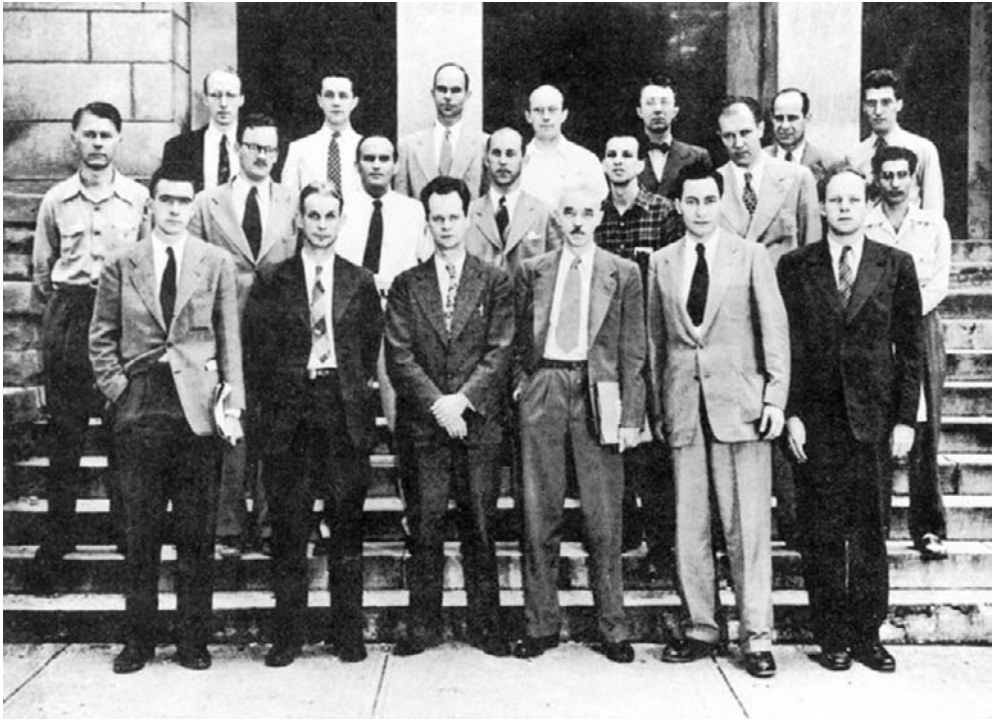
FIG. 1.8. *Photograph taken at the first conference on the experimental analysis of behavior held in 1946 at Indiana University. From left to right in front row: Dinsmoor, Musgrave, Skinner, Keller, Schoenfeld, Lloyd. Middle row: Ellson, Daniel, Klein, Jenkins, Wyckoff, Hefferline, Wolin. Back row: Estes, Frick, Anderson, Verplanck, Beire, Hill, Craig. From* Journal of the Experimental Analysis of Behavior, 5, 456. Copyright 1958, the Society for the Experimental Analysis of Behavior, Inc. Reprinted with permission.*

In addition to ABA, Robert Epstein, one of B. F. Skinner's last students, noted behavioral researcher, and current editor of the well-known magazine, *Psychology Today*, founded the Cambridge Center for Behavioral Studies in 1981. The Cambridge Center is devoted to helping people find effective solutions to behavior problems (e.g., in education, business, and other applied settings). As part of this mission, the Center maintains an information Web site (www.behavior.org) for the public, publishes books and journals, and sponsors seminars and conferences on effective behavior management in applied settings (e.g., the annual conference *Behavioral Safety Now* in the field of industrial safety).

A continuing issue in the field of behavior analysis is the separation between applied behavior analysis and basic research. During the 1950s and 1960s, no distinction existed between applied and basic investigations. This was because applied behavior analysts were trained as basic researchers. That is, the first applications of behavior principles came from the same people who were conducting laboratory experiments. The applications of behavior principles were highly successful, and this led to a greater demand for people trained in applied behavior analysis. Soon applied researchers were no longer working in the laboratory or reading the basic journals.

This separation between basic and applied research was first described by Sam Deitz (1978), who noted the changing emphasis from science to technology among applied

behavior analysts (see also Hayes, Rincover, & Solnick, 1980; Michael, 1980; Pierce & Epling, 1980). Donald Baer (1981) acknowledged the technical drift of applied behavior analysis but suggested that this was a natural progression of the field that may have positive effects.

Today the separation issue is not entirely resolved, although much progress is apparent. Applied researchers are more in contact with basic research through the *Journal of Applied Behavior Analysis*. In addition to application research, this journal publishes applied articles based on modern behavior principles (e.g., Ducharme & Worling, 1994) as well as reviews of basic research areas (e.g., Mace, 1996). We have written this book assuming that an acquaintance with basic research is important, even for those who are primarily concerned with behavioral applications. Students can study this text not only for a basic grounding in behavioral science but also for a solid foundation in human behavior and application.

Science and Behavior: Some Assumptions

All scientists make assumptions about their subject matter. These assumptions are based on prevailing views in the discipline and guide scientific research. In terms of behavior analysis, researchers assume that the behavior of organisms is lawful. This means that it is possible to study the interactions between an organism and its environment in an objective manner. To carry out the analysis, it is necessary to isolate behavior–environment relationships. The scientist must identify events that reliably precede the onset of some action and the specific consequences that follow behavior. If behavior systematically changes with variation of the environmental conditions, then behavior analysts assume that they have explained the action of the organism. There are other assumptions that behavior analysts make about their science.

The Private World

Contemporary behavior analysts include internal events as part of an organism's environment. This point is often misunderstood; internal functioning like an upset stomach, full bladder, low blood sugar, and so on are part of a person's environment. Internal physical events have the same status as external stimuli such as light, noise, odor, and heat. Both external and internal events regulate behavior. Although this is so, behavior analysts usually emphasize the external environment. This is because external events are the only stimuli available for behavior change. The objective procedures of psychological experiments are giving instructions and observing how the person acts. From a behavioral view, the instructions are external stimuli that regulate both verbal and nonverbal behavior. Even when a drug is given to a person and the chemical alters internal biochemistry, the direct injection of the drug is an external event that subsequently regulates behavior. To make this clear, without the drug injection neither the biochemistry nor the behavior of the person would change.

Many psychological studies involve giving information to a person in order to change or activate cognitive processes. In the cognitive view, thoughts are used to explain behavior. The problem is that the existence of thoughts (or feelings) is often inferred from the behavior to be explained, leading to circular reasoning. For example, a child who peers out the window about the time his or her mother usually comes home from work is said to do

this because of an expectation. The expectation of the child is said to explain why the child peers from the window. In fact, there is no explanation, because the cognition (expectation) is inferred from the behavior it is said to explain. Cognitions could explain behavior if the existence of thought processes were based on some evidence other than behavior. In most cases, however, there is no independent evidence that cognitions caused behavior, and the explanation is not scientifically valid. One way out of this problem of logic is not to use thinking and feeling as causes of behavior. That is, thinking and feeling are treated as more behavior to be explained.

Feelings and Behavior

Most people assume that their feelings and thoughts explain why they act as they do. Contemporary behavior analysts agree that people feel and think, but they do not consider these events as causes of behavior. They note that these terms are more correctly used as verbs rather than as nouns. Instead of talking about thoughts, behavior analysts point to the action word "thinking." And instead of analyzing feelings as things we possess, the behavioral scientist focuses on the action of feeling or sensing. In other words, thinking and feeling are activities of the organism that require explanation.

Feelings as By-products

Because feelings occur at the same time that we act, they are often taken as causes of behavior. Although feelings and behavior are necessarily correlated, it is the environment that determines how we act and, at the same time, how we feel. Feelings are real, but they are by-products of the environmental events that regulate behavior. For this reason, a behavioral approach requires that the researcher trace feelings back to the interaction between behavior and environment.

Pretend that you are in an elevator between the 15th and 16th floors when the elevator suddenly stops and the lights go out. You hear a sound that appears to be the snapping of elevator cables. Suddenly, the elevator lurches and then drops 2 ft. You call out, but nobody comes to your rescue. After about an hour, the elevator starts up again, and you get off on the 16th floor. Six months later, a good friend invites you to dinner. You meet downtown, and you discover that your friend has made reservations at a restaurant called The Room at the Top, which is located on the 20th floor of a skyscraper. Standing in front of the elevator, a sudden feeling of panic overwhelms you. You make a socially appropriate excuse like, "I don't feel well," and you leave. What is the reason for your behavior and the accompanying feeling?

There is no question that you feel anxious, but this feeling is not why you decide to go home. Both the anxious feeling and your decision to leave are easily traced to the negative experience in the elevator that occurred 6 months ago. It is this prior conditioning that behavior analysts emphasize. Notice that the behavioral position does not deny your feelings. These are real events. However, it is your previous interaction with the broken elevator that changed both how you feel and how you act.

Reports of Feelings

You may still wonder why behavior analysts study overt behavior instead of feelings—given that both are changed by experience. The answer concerns the accessibility of feelings and overt behavior. Much of the behavior of organisms is directly accessible to the observer or scientist. This public behavior provides a relatively straightforward subject matter for

scientific analysis. In contrast, feelings are largely inaccessible to the scientific community. Of course, the person who feels has access to this private information, but the problem is that reports of feelings are highly unreliable.

This unreliability occurs because we learn to talk about our feelings (and other internal events) as others have trained us to do. During socialization, people teach us how to describe ourselves, but when they do this they have no way of accurately knowing what is going on inside of us. Parents and teachers rely on public cues to train self-descriptions. They do this by commenting on and correcting verbal reports when behavior or events suggest a feeling. A preschooler is taught to say, "I feel happy," when the parents guess that the child is happy. The parents may base their judgment on smiling, excitement, and affectionate responses from the child. Another way this training is done is that the child may be asked, "Are you happy?" in a circumstance where the parents expect the child to feel this way (e.g., on Christmas morning). When the child appears to be sad, or circumstances suggest this should be so, saying "I am happy" is not reinforced by the parents. Eventually, the child says "I am happy" in some situations and not in others.

Perhaps you have already noticed why reports of feelings are not good scientific evidence. Reports are only as good as the training of correspondence between public conditions and private events. In addition to inadequate training, there are other problems with accurate descriptions of feelings. Many of our internal functions are poorly correlated (or uncorrelated) with public conditions, and this means that we cannot be taught to describe such events accurately. Although a doctor may ask for the general location of a pain (e.g., abdomen), he or she is unlikely to ask whether the hurt is in the liver or in the spleen. This report is simply inaccessible to the patient, because there is no way to teach the correspondence between exact location of damage and public conditions. Generally, we are able to report in a limited way on private events, but the unreliability of such reports makes them questionable as scientific observations. Based on this realization, behavior analysts focus on the study of behavior rather than feelings.

Thinking and Behavior

Behavior analysts have also considered thinking and its role in a science of behavior. In contrast to views that claim a special inner world of thought, behavior analysts suggest that human thought is human behavior. Skinner (1974) stated that:

> The history of human thought is what people have said and done. Symbols are the products of written and spoken verbal behavior, and the concepts and relationships of which they are symbols are in the environment. Thinking has the dimensions of behavior, not a fancied inner process which finds expression in behavior. (pp. 117–118)

A number of behavioral processes, like generalization, discrimination, matching to sample, stimulus equivalence, and so on (see later chapters), give rise to behavior that, in a particular situation, may be attributed to higher mental functions. From this perspective, thinking is treated as behavior.

Thinking and Response Tendencies

The term *think* in our culture has a variety of meanings. A person may say, "I am thinking of buying a new car" when the individual is reporting a low probability of action. Presumably, responses like "I will buy a car" or "I will definitely buy a new car" occur when the probability of action is higher. In accounting for these responses, the behavior analyst must specify the conditions that contributed to either raising or lowering the probability of action (e.g.,

reinforcement variables) and show how the person is able to report on such tendencies to respond. Another example of people saying "I think" occurs when there is weak control of behavior by a stimulus. When shown an unfamiliar object, you may say, "I think it's a computer chip," which is contrasted with the responses "I know it's a computer chip" or "It's a computer chip." The critical factor in this episode is inadequate discrimination of the chip, as indicated by adding *think* to the sentence. In common English, when people are not sure about an object, event, or circumstance, they often add the word *think* to a descriptive sentence.

Thinking as Private Behavior

More interesting examples of thinking involve **private behavior**, or behavior only accessible to the person doing it. Thinking as private behavior is observed in a game of chess. We may ask another person, "What is the player thinking about?" A response like "She is probably thinking of moving the castle" refers to thinking that precedes the move itself. Sometimes this prior behavior is observable—the player may place a hand on the castle in anticipation of the move. At other times, behavior is private and cannot be observed by others. An experienced chess player may think about the game and imagine the consequences of moving a particular piece.

Presumably, this private behavior is overt when a person learns to play chess. For example, first the basic rules of the game are explained and a novice player is shown how the pieces move and capture. In moving the pieces from place to place, the player is asked to describe the relationships between the opposing chess pieces. This establishes the behavior of visualizing the layout of the board. As the player receives additional corrective feedback, visualizing layout becomes more skillful. The person begins to see relationships and moves that were not previously apparent. During the first few games, new players are often given instructions like "Don't move your knight there, or you'll lose it." Additionally, the player may be told, "A better move would have been . . . ", and a demonstration of the superior move is usually given. After some experience, the student is asked to explain why a particular move was made, and the explanation is discussed and evaluated. Eventually, the teacher stops prompting the player and encourages the person to play chess in silence. At this point, visualizing the layout of the board (e.g., white controls the center of the board) and describing the possible consequences of moves (e.g., moving the knight to this square will split the two rooks) become covert.

The function of thinking, as private behavior, is to increase the effectiveness of practical action. People can act at the covert level without committing themselves publicly. An advantage is that an action can be revoked if the imagined consequences are not reinforcing. In our example, the chess player considers the possible moves and the consequences that may follow. Based on the covert evaluation, a player makes the move that appears to be best. Thus, the covert performance functions to prompt and guide overt action. Once the move is made, the player faces the objective consequences. If the move results in an advantage that could result in checkmate, then thinking about such a move in similar circumstances is strengthened. On the other hand, a bad move weakens the consideration of such moves in the future. Overall, thinking is operant behavior. Thinking that leads to effective action is likely to occur again, whereas thinking that prompts ineffective performance declines.

In this section, we have discussed thinking as reports on strength of response and as covert behavior. There are many other ways that the term thinking is used. When a person remembers, we sometimes talk about thinking in the sense of searching and recalling. Solving problems often involves private behavior that furthers a solution. In making a

decision, people are said to think about the alternatives before a choice is made. The creative artist is said to think of novel ideas. In each of these instances, it is possible to analyze thinking as private behavior that is regulated by specific features of the environment. The remainder of this book discusses the behavioral processes that underlie all behavior, including thinking.

KEY WORDS

Applied behavior
    analysis
Behavior
Behavior analysis
Behavior analyst
Conditioned reflexes
Context of behavior

Culture
Experimental analysis
    of behavior
Immediate causation
Law of effect
Learning
Operant

Private behavior
Reflex
Remote causation
Respondent
Science of behavior
Trial-and-error
    learning

ON THE WEB

http://www.bfskinner.org/ The B. F. Skinner Foundation was established in 1987 to both educate the public about B. F. Skinner's work and promote an understanding of the role of contingencies in human behavior.

http://www.behavior.org/ The Web site for the Cambridge Center for Behavioral Studies is useful to learn more about behavior analysis, behaviorism, and applied behavior analysis. The Center publishes several journals, is host to the Virtual Behavioral Community, and offers recent publications through an online bookstore.

http://web.utk.edu/~wverplan/ William S. Verplanck, a major contributor to the experimental analysis of behavior and behaviorism, died in September of 2002. This award-winning site provides information on his past activities, publications, and addresses, plus on interesting issues about psychology and the study of behavior.

http://www.wmich.edu/aba/ Go to the web page for the Association for Behavior Analysis to find out about the annual convention, the official journals (*The Behavior Analyst* and *Verbal Behavior*), and membership in the Association.

http://www.behavior-analyst-online.org/ A new site to visit is Behavior Analyst Online, which offers the e-journal called *The Behavior Analyst Today* (BAT), an online behavioral community Web forum, membership in the organization, links to other related sites, and so on.

STUDY QUESTIONS

The best way to use these study questions is to choose or assign speaker–listener pairs. Each student in the dyad reads and studies the material; this is followed by a discussion session (scheduled at the convenience of the two students). At the discussion session (perhaps having a coffee), the students take turns as speaker and listener. The speaker's job is to talk about the textbook chapter based on the study questions; the listener's role is to pay attention to and provide corrective feedback for the speaker's behavior (checking with

the textbook if necessary). An alternative to verbal interaction is that students write brief answers in paragraph form to each of the questions. The page(s) for the answers is (are) indicated in parentheses.

1. Define learning and behavior. (1) Describe the difference between prescientific accounts of behavior and the modern-scientific view of behavior theory. (1–2)
2. What is the experimental analysis of behavior? (2) Give an example of such analysis based on this textbook. (2–3)
3. Explain the term behavior analysis. (3) What are the primary objectives of behavior analysis? (3) How does behavior analysis differ from applied behavior analysis? (3)
4. Summarize what a reflex means. (3) State (or write) a sentence or two that includes the terms respondent behavior, reflex, and survival value. (3)
5. Summarize what respondent conditioning is and point to the adaptive function of this process. (3–4)
6. Discuss operant conditioning and give some common examples of operant behavior. (4) Briefly compare operant and respondent conditioning. (3–5)
7. Be able to write or talk about selection as a causal process. (5) What are immediate and remote causes? (5). Discuss the evolution of learning and the implications of behavioral flexibility. (5–6)
8. Discuss the meaning of the biological context of behavior. (6) Give an example using Skinner's analysis of imprinting in young ducklings. (6–7)
9. Talk about Watson's stimulus–response view. (7) What distinction did Skinner make? (7). Explain what is meant by the selection of operant behavior. (7) Compare the stimulus–response and selectionist models of behavior. (7)
10. Discuss the extension of behavior analysis to human behavior and culture. (8) Talk about the meaning of culture from a behavioral perspective and outline what selection means at the cultural level. (8)
11. **FOCUS ON**: Be able to discuss the achievements and contributions of B. F. Skinner to the science of behavior. (8–9) Give an example from this textbook of a popular misconception of Skinner's research and ideas. (9)
12. **FOCUS ON**: Skinner had a sense of humor and dislike of formal titles—discuss. (10–11) Describe Skinner's contributions to education and problems of old age. (11). What award did Skinner win from the American Psychological Association, and what new film depicts his life and research? (11)
13. Describe Pavlov's history, research on the salivary reflex, conditioned reflexes, and contribution to modern behavior analysis. (11–13) Outline Watson's behaviorism and its influence on psychology, his experiment with Little Albert, and his career. (13–15) Discuss Thorndike's history, trial-and-error learning, and law of effect. (15–16)
14. Describe Skinner's contributions to a science of behavior. (16) Outline the rise of behavior analysis and the experimental analysis of behavior. (17) Name the journals and associations that support behavior analysis. (17) What happened to the split between basic and applied research? (18–19)
15. Explain what is meant by the statement, "The behavior of organisms is lawful." (19)
16. Talk about how private events are part of an organism's environment. (19). In the cognitive view, thoughts explain behavior. What is wrong with this view from a behavioral perspective? (19–20)
17. Summarize the behavioral viewpoint on the relationship between feelings and behavior. (20) Be able to discuss how people can talk about their feelings and the accuracy of their reports. (20–21).

18. Discuss thinking as behavior. (21) Point to the different meanings of the verb "to think" and analyze thinking as response tendencies or as private behavior (mostly verbal) using the example of a chess game. (21–23)

BRIEF QUIZ

1. _____ is the alteration (or maintenance) of an organism's behavior due to _____.
   (a) behavior; causes
   (b) learning; lifetime events
   (c) culture; social norms
   (d) evolution; genes
2. The experimental analysis of behavior is
   (a) a natural-science approach to understanding behavior regulation
   (b) concerned with controlling and changing factors that affect behavior
   (c) concerned with the principle of reinforcement
   (d) all of the above
3. A _____ is behavior that is elicited by a biologically relevant stimulus, whereas _____ is behavior controlled by its consequences.
   (a) reflex; respondent
   (b) respondent; voluntary
   (c) reflex; operant
   (d) operant; respondent
4. Selection by consequences occurs at three levels. What are these?
   (a) natural selection, behavior selection, and cultural selection
   (b) artificial selection, culture, and linguistic selection
   (c) natural selection, artificial selection, and cultural selection
   (d) artificial selection, natural selection, and linguistic selection
5. What does a duckling inherit in terms of imprinting?
   (a) the behavior of following its mother
   (b) the behavior of following a "duck-sized object"
   (c) the capacity to be reinforced by reducing the distance between itself and a moving object
   (d) the capacity to follow its mother as she obtains food in an ecological area
6. Skinner stated that behavior (including human behavior) resulted from
   (a) genes
   (b) environment
   (c) self-determination
   (d) both a and b
7. According to Baer, Wolf, and Risley (1968), what is the difference between basic and applied behavior analysis?
   (a) basic research is likely to look at any behavior and any variable
   (b) applied research looks at variables that could improve behavior
   (c) both a and b
   (d) none of the above
8. Which statements are true of Pavlov and his contributions?
   (a) he won the Nobel Prize
   (b) he investigated the salivary reflex
   (c) he discovered the conditioned (or conditional) reflex
   (d) all of the above

9. In terms of the new-style behaviorists (behavior analysts) and their views
    (a) they adopted the behaviorism of John B. Watson
    (b) they studied behavior for its own sake
    (c) they rejected genetic influences
    (d) all of the above
10. How are thinking and feeling treated from a behavioral perspective?
    (a) more behavior to be explained
    (b) the causes of overt behavior
    (c) the relationship between the mental and the physical
    (d) the mind and its regulation of behavior

Answers to brief quiz (*page*): b(1); d(2); c(3–4); a(5); c(6); d(7); c(10); d(11–13); b(17); d(20)

The Experimental Analysis of Behavior

IN THIS CHAPTER

1. Learn about a functional analysis of behavior and basic stimulus functions.
2. Find out how perception can be analyzed within a functional analysis of behavior.
3. Discover the term *establishing operation* and its significance for environment–behavior relations.
4. Learn about Claude Bernard's method of experimental analysis and how it extends to the study of behavior.
5. Inquire about basic experimental designs used in the experimental analysis of behavior.
6. Find out about internal and external validity of experimental research.

The experimental analysis of behavior (EAB) refers to a method of analyzing behavior–environment relationships. This method is called functional analysis. **Functional analysis** involves classifying behavior according to its response functions and analyzing the environment in terms of stimulus functions. The term *function* refers to the characteristic effect *produced* by either a behavioral or an environmental event. Once a reliable classification has been established, the researcher uses experimental methods to show a causal relationship between the environmental event and a specified response. Because of this objective method, behavior analysts need not restrict their findings to one or a few species. The principles of behavior—environment relationships—hold for all animals. Based on this assumption, researchers often use non-human subjects as their "tools" for discovering principles of behavior.

Functional Analysis of Behavior

There are two ways to classify the behavior of organisms: structurally and functionally. In the **structural approach**, behavior is analyzed in terms of its form. For example, many developmental psychologists are interested in the intellectual growth of children. These researchers often investigate what a person does at a given stage of development. Children may be said to show "object permanence" when they look for a familiar object that has just been hidden. In this case, the form of response, or what the child does (e.g., looks for and finds the hidden object), is the important aspect of behavior. The structure of behavior is emphasized, because it is said to reveal the underlying "stage" of intellectual development. Notice that, in this example, the structural approach studies behavior to draw inferences about hypothetical internal cognitive abilities.

In the previous chapter, we noted that behavior analysts study behavior for its own sake and at its own level. To keep attention focused on behavior, structure and function are

interrelated. That is, a particular form of response is traced to its characteristic effects, outcomes, or consequences. For example, a person presses a light switch with the left hand, the thumb and index finger, and a particular force. This form, structure or **topography**, of response occurs because it has been highly efficient, relative to other ways of operating the light switch. Thus, the topography (structure) of a response is determined by the function (outcome) of this behavior. Functionally, grasping the switch in a particular way produces light in an efficient manner.

In the more complex example of a child who finds a hidden object, a *functional analysis* suggests that this behavior also produces some specific consequence—the child gets the hidden toy. Rather than infer the existence of some intellectual stage of development or internal ability (like object permanence), the behavior analyst suggests that a particular **history of reinforcement** is responsible for the child's capability. Presumably, a child that demonstrates object permanence (searching for objects when they are not in sight) has had numerous opportunities to search for and find missing or hidden objects. One advantage of this functional account is that it is testable.

A mother who breastfeeds her newborn often removes some of her clothing just before feeding the baby. After some experience, the baby may tug at the mother's blouse when he or she is hungry. This is one potential instance of the early conditioning of searching for hidden objects. A few months later, the infant may inadvertently cover up a favorite rattle. In this situation, the child who accidentally pulls back the cover is reinforced by getting the toy. As children get older, they are directly taught to find hidden objects. This occurs when children are given presents to open at Christmas and when they hunt for Easter eggs. A functional analysis of object permanence accounts for the behavior by pointing to its usual effects or consequences. That is, object permanence occurs because searching for out-of-sight objects usually results in finding them. Also, children who do not have these or similar experiences (playing peek-a-boo) will perform poorly on a test of object permanence.

Response Functions

Behavior is not always composed of discrete responses. In fact, it is better to consider behavior as a performance that follows a specific stimulus and at some point results in a particular consequence. (One memorable three-term notation system used to denote this arrangement is A–B–C, which stands for antecedent, behavior, and consequence as detailed in chap. 13.) Although we will use the term *response* throughout this book, the term does not always refer to a discrete movement like a muscle twitch or a lever press. A response is an integrated set of movements, or a behavioral performance, that is functionally related to environmental events. In fact, some writers have referred to a behavioral stream into which antecedent and consequence events are inserted.

Functionally, we speak of two basic types of behavior: respondent and operant. These behavioral classes were briefly discussed in chapter 1 and will be throughout the book, but here we will emphasize the functional classification of behavior. The term **respondent** is used to refer to behavior that increases or decreases by the presentation of a stimulus (or event) that *precedes* the response. We say that the *presentation of the stimulus regulates or controls the response*. Respondent behavior is said to be **elicited**, in the sense that it reliably occurs when the stimulus is presented. The notation system used with elicited behavior is S → R. The stimulus S causes (arrow) the response R. The constriction (and dilation) of the eye pupil is respondent behavior. It occurs when a bright light is directed into (away from) the eye. Salivation is another respondent that is elicited by food in the mouth. The stimulus,

S (light or food), elicits the response, R. For the moment you may consider respondents to be the activity of smooth muscles or glands.

There is another large class of behavior that does not depend on an eliciting stimulus. This behavior is said to be **emitted** and may (or may not) occur at some frequency. For example, human infants emit a random pattern of vocal sounds usually referred to as "babbling." These sounds contain the basic elements of all human languages. English-speaking parents attend to babbling that sounds like English, and the baby soon begins to emit more and more English sounds. When emitted behavior is either strengthened or weakened by the events that follow the response, it is called **operant** behavior. Thus, operants are emitted responses that occur more or less often depending on the consequences they produce. To make clear the subtle distinction between emitted behavior and operants, consider the action word *walking* versus the phrase *walking to the store*. Walking is emitted behavior, but it has no specified function. In contrast, walking to the store is an operant that is defined by getting food at the store. Pecking a disk is emitted behavior by a bird, but it is an operant when pecking the disk has resulted in food. Generally, operants are responses that occur in the absence of an obvious eliciting stimulus; these responses are altered in frequency by their effects or consequences.

Operant and respondent behaviors often occur at the same time. A person who steps out of a movie theater in the middle of a bright afternoon may show both types of responses. The change from dark to bright light will elicit pupil contraction. This contraction is a reflexive response that decreases the amount of light entering the eye. At the same time, the person may either shade their eyes with a hand or put on a pair of sunglasses. This latter behavior is operant because it is strengthened by the removal of the sun—the aversive stimulus. In another example, you find that you have failed an important exam. The bad news may elicit a number of conditioned emotional responses like heart palpitations, changes in blood pressure, and perspiration. These physiological responses are probably felt as dread or anxiety. The person standing next to you as you read the results of the exam asks, "How did you do on the test?" You say, "Oh, not too bad," and walk down the hall. Your reply is operant behavior that avoids the embarrassment of discussing your poor performance. Although operant and respondent processes often occur at the same moment, we will usually analyze them separately to clarify the factors that regulate such behavior.

Response Classes

When a person emits a relatively simple operant like putting on a coat, the performance changes from one occasion to the next. The coat may be put on using either the left or the right hand; it may be either grasped at the collar or held up by a sleeve. Sometimes one arm is inserted first, whereas in other circumstances both arms may be used. Careful observation of this everyday action will reveal an almost infinite variety of responses. The important point is that each variation of response has the common effect of staying warm by putting on a coat. To simplify the analysis, it is useful to introduce the concept of a class of responses. A **response class** refers to all the forms of the performance that have a similar function (e.g., putting on a coat to keep warm). In some cases, the responses in a class have close physical resemblance, but this is not always the case. A response class for convincing an opponent may include dramatic gestures, giving sound reasons, and paying attention to points of agreement. To get service from a restaurant server, you may call out as he or she passes, wave your hand in the air, or ask the bus-person to send the server to your table.

Functional Analysis of the Environment

In chapter 1, we noted that behavior analysts use the term environment to refer to events and stimuli that change behavior. These events may be external to the organism or may arise from internal physiology. The sound of a jet aircraft passing closely overhead and that of an upset stomach may both be classified as aversive by their common effects on behavior. That is, both events strengthen any behavior that removes them. In the case of a passing jet, people may cover their ears; a stomachache may be removed by taking antacid medication.

The location of the source of stimulation, internal versus external, is not a critical distinction for a functional analysis. There are, however, methodological problems with stomach pains that are not raised by external events like loud sounds. Internal sources of stimulation must be indirectly observed with the aid of instruments or inferred from observable behavior–environment interactions. Evidence for stomach pain, beyond the verbal report, may include the kinds of foods recently eaten, the health of the person when the food was ingested, and current external signs of discomfort.

Stimulus Functions

All events and stimuli, whether internal or external, may *acquire* the capacity to affect behavior. When the occurrence of an event changes the behavior of an organism, we may say that the event has a **stimulus function**. Both respondent and operant conditioning are ways to create stimulus functions. During respondent conditioning, an arbitrary event like a tone comes to elicit a particular response, such as salivation. Once the tone is effective, it is said to have a **conditioned-stimulus function** for salivation. In the absence of a conditioning history, the tone may have no specified function and does not affect behavior.

Similarly, operant conditioning generally results in establishing or changing the functions of stimuli. Any stimulus (or event) that follows a response and increases its frequency is said to have a **reinforcement function** (see chap. 1). When an organism's behavior is reinforced, those events that reliably precede responses come to have a **discriminative function**. These events are said to *set the occasion* for behavior and are called discriminative stimuli. Discriminative stimuli acquire this function because they predict (have been followed by) reinforcement. In the laboratory, a pigeon's key pecks may be followed by food when the key is illuminated red, but pecking is not reinforced when the key is blue. After some time, the red key color is said to set the occasion for the response. In everyday language, the red key "tells" the bird when pecking will be reinforced. More technically, the red key is a discriminative stimulus, since the probability of reinforcement (and pecking) is higher when the key is red than when it is blue. That is, the bird discriminates between red and blue.

The concept of stimulus function is an important development in the analysis of behavior. Humans and other animals have evolved in such a way that they can sense those aspects of the environment that have been important for survival. Of all the stimuli that can be physically measured and sensed by an organism, at any one moment, only some affect behavior (have a stimulus function). Imagine you are sitting on a park bench with a friend on a nice sunny day. The physical stimuli include heat, wind current; sounds from traffic, birds, insects, rustling leaves; tactile pressure from sitting; the sight of kids playing ball; people walking in the park; the color of flowers, grass, trees, and so on. Although all of these (and many more) stimuli are present, only some will affect your behavior—in the sense that you will turn your face into the sun, comment on the beauty of the flowers, and look in the

direction of a passing fire truck. The remaining stimuli, at this moment in time, either have no function or serve as the context for those events that do.

ADVANCED ISSUE: PERCEIVING AS BEHAVIOR

Even if you do your best to put down everything you see, will it really be everything? What about the singing of birds? And the freshness of the morning? And your own feeling of somehow being cleansed by it all? After all, as you paint, you perceive these things – they are inseparable from what you see. But how can you capture them in the painting so they are not lost for anyone who looks at it? Obviously they must be suggested by your composition and the color you use – since you have no other means of conveying them. (Solzhenitsyn, 1973, p. 395)

The concept of stimulus function raises some interesting issues. Most of us believe that we accurately perceive the world around us and are able to report on this with some reliability. In everyday language and in psychology, perception is an inferred, underlying cognitive process that determines behavior. In contrast, behavior analysis suggests that perceiving is behavior that must be accounted for by environment–behavior relationships. The typical account of perception is seen in the following descriptions taken from a variety of introductory psychology textbooks.

The view of perception that has been more or less dominant in psychology over the last 100 years holds that our experiences teach us how to draw broad inferences about the world from very limited sensory information and that most perceptions are transformed constructions, or synthesizations, from combinations of more elementary sensations. It also maintains that these perceptual inferences are usually so accurate, highly practiced, and nearly automatic that you are almost totally unaware of making them (Darley, Glucksberg, & Kinchla, 1991, p. 109).

Perception, in its narrow usage, refers to the next stage in which an internal representation of an object is formed, and an experienced percept of the external stimulus is developed. The representation provides a working description of the perceiver's external environment. Information from lower-order detectors is organized and modified by higher-order brain processes to convert environmental stimulus features and elements into patterns and forms that are recognizable. (Zimbardo, 1988, p. 185)

Perception refers to the process of selecting, organizing, and interpreting sensory data into a usable mental representation of the world. (Huffman, Vernoy, Williams, & Vernoy, 1991, p. 101)

Perception is the process by which we organize and make meaningful the mass of sensations we receive. Our past experience and our current state of mind influence the intricate series of steps between sensation and perception. (Martin, 1991, p. 126).

Generally, these passages reflect a view of human experience that has been popular for centuries. The basic idea is that receptors like eyes, ears, and tongue are constantly receiving and processing sensory input that is a disorganized array of raw data. The person is said to transform the sensations by mentally organizing the input into a meaningful representation of the situation.

From a behavioral perspective, the difficulty with this view of perception is that the mental organization and representation of sensory input is not directly observable. That is, there is no objective way of getting information about such hypothetical events except by observing the behavior of the organism. Such **hypothetical constructs** are not always

undesirable in science, but when used to account for behavior, these terms usually lack explanatory power because they are grounded in the very behavior that they are used to explain. This problem of explanatory power is seen in the perception account of the Stroop effect (Stroop, 1935).

In the Stroop task, a person is given two lists of color names that are made up with different printed colors. On one list the words and colors correspond. For example, the word *red* is printed in the color red and the word *blue* appears in blue print. The second list contains color words that are printed with colors that are different from the meaning of the word. In this case the word *red* might be printed in yellow ink and the word *blue* could appear in green print.

In a typical experiment, people are first given the list in which colors and words correspond and are told to "look at the words on the list and name the colors as fast as you can." In the second part of the experiment, they are given the noncorresponding list and asked to "look at the list and name each color while ignoring what each word says." The second task is much more difficult and takes more time. Why do you suppose it takes longer to name the colors on the list where the color of print and the color name do not match?

From a mentalistic or cognitive representation point of view, the explanation is as follows: ". . . the highly practiced and almost automatic perception of word meaning facilitates reading. However, this same perception automatically makes it difficult to ignore meaning and pay attention only to certain other aspects of the stimulus. Thus, the Stroop effect is a failure of selective perception" (Darley, Glucksberg, & Kinchla, 1991, p. 112).

From the behavior analysis perspective, the foregoing account restates the fact that your performance is better when the words are not competing with other features of the stimulus. The meanings and attention to the words are inferences of the researcher with no independent evidence for their occurrence. For this reason, the explanation is not satisfying to the behavior analyst. The question becomes: How do environment–behavior relationships regulate performance on this task?

After people learn to read, they may be asked to say a word out loud. For example, children are often drilled with flash cards to identify words vocally, and they are given corrective feedback for performance. In behavioral terms, the sight of the word, or pattern of letters, sets the occasion for saying the word, and the corrective feedback functions as reinforcement. Thus, a child may be given a card with RED written on it, and the correct response is saying "red." In a similar fashion, people learn to identify and label colors. Because of this conditioning, both the colors and the written words come to control two different response classes. When written words that refer to color are presented in a color different from the word, the two properties of the stimulus compete for the respective responses. Based on the simultaneous control by these two aspects of the blended stimulus, the time to complete the task increases. In other words, the situation is confusing, and because of this, the task takes longer to complete. Consider what you might do if you were driving and came to an intersection with a red-hexagon sign that had the word PROCEED painted on it. In contrast to the selection–perception explanation, behavior analysts point to response competition and reinforcement history as reasons for your hesitation.

There are other interesting implications of a functional analysis of perceiving. For example, you walk into a room and look around, believing that you are taking in reality. But what do you see? Seeing itself is something an organism is prepared to do based on its genetic endowment, but seeing a particular object, on a given occasion, may be analyzed

as either respondent or operant behavior. That is, observing an object or event is behavior that is either elicited by the event, has a high probability due to past consequences, or becomes likely due to motivating conditions (e.g., hunger, thirst, etc.). Imagine that you have gone camping with several friends. After supper you decide to entertain your friends by telling a horror story about an axe murder that took place in the same area a few years ago. One of your companions is finishing supper, and the fried egg on her plate begins to look like a giant dead eye that is about to explode with yellow "glop." As the night gets darker, another camper hears ominous sounds and begins to see figures moving in the brush. In everyday words, your friends are imagining these events. Behaviorally, the frightening story may be analyzed as a motivating condition that momentarily increases the probability of seeing things that appear to be threatening.

  B. F. Skinner (1953) has described other conditions that affect seeing as a conditioned response. He stated that:

> Conditioned seeing explains why one tends to see the world according to one's previous history. Certain properties of the world are responded to so commonly that "laws of perception" have been drawn up to describe the behavior thus conditioned. For example, we generally see completed circles, squares, and other figures. An incomplete figure presented under deficient or ambiguous circumstances may evoke seeing a completed figure as a conditioned response. For example, a ring with a small segment missing when very briefly exposed may be seen as a completed ring. Seeing a completed ring would presumably not be inevitable in an individual whose daily life was concerned with handling incomplete rings. (pp. 267–268)

Skinner (1953) later points out that operant conditioning can also affect what is seen.

> Suppose we strongly reinforce a person when he finds a four-leaf clover. The increased strength of "seeing a four-leaf clover" will be evident in many ways. The person will be more inclined to look at four-leaf clovers than before. He will look in places where he has found four-leaf clovers. Stimuli which resemble four-leaf clovers will evoke an immediate response. Under slightly ambiguous circumstances he will mistakenly reach for a three-leaf clover. If our reinforcement is effective enough, he may even see four-leaf clovers in ambiguous patterns in textiles, wallpaper, and so on. He may also "see four-leaf clovers" when there is no similar visual stimulation—for example, when his eyes are closed or when he is in a dark room. If he has acquired an adequate vocabulary for self-description, he may report this by saying that four-leaf clovers "flash into his mind" or that he "is thinking about" four-leaf clovers. (p. 271)

You must realize that no one knows what a person "sees." What we know is what the perceiver says he or she sees. The person tells us he or she sees (or does not see) something, and this statement is itself an operant; as an operant the verbal statement of seeing "X" is regulated by its past history of consequences (including the social consequences provided by other people).

  Epling and Cameron (1994) reported an interesting instance of operant seeing that appeared in Euell Gibbons's book *Stalking the Wild Asparagus*. Gibbons was enthusiastic about eating wild asparagus, and on a fishing trip he spotted some fine young asparagus shoots. Spying these shoots was reinforcement for looking for, seeing, and discovering other clumps of asparagus.

> . . . I was walking along the bank of an irrigation ditch, headed for a reservoir where I hoped to catch some fish. Happening to look down, I spied a clump of asparagus growing on the ditch bank, with half a dozen fat, little spears that were just the right size to be at their best. . . . Even when cutting this cluster, I saw another with several more perfect little sprouts. Alerted, I kept my eyes open and soon found another cluster and then another. . . . About this time I noticed that an old, dry, last-year's stalk stood above every clump of new asparagus tips. . . . I

sat down on the ditch bank and for five minutes I did nothing but just *look* at one old dry asparagus stalk. It looked very much like the dead weeds and plants that surrounded it, and yet there were differences. The old asparagus plant stood about three feet high and had a central stem or "trunk" about a half inch in diameter which easily distinguished it from weeds with forking stems. . . . After getting the size, color and form thoroughly in my mind, I stood up and looked back along the ditch bank. Instantly, I saw a dozen old dead asparagus stalks that I had missed. I went back to where I had found the first clump and worked my way down the ditch again, and this time I really reaped a harvest. . . . That five minutes I spent [many years] ago, concentrating on one dead asparagus plant, has lead me to many pounds of this most delicious of early vegetables. The eyetraining it gave me has lasted until now. Whenever I drive, in late winter or early spring, my eye automatically picks up the dead asparagus stalks by the roadside, and I make an almost unconscious mental note of the places where the green spears will be plentiful when warm weather arrives (pp. 28–32)

This phenomenon is also called "perceptual set" by psychologists or "search image" by ethologists. In fact, many psychologists do not consider seeing as operant or respondent behavior. These researchers prefer to study perception as a cognitive process that underlies behavior. Although the issue is not resolved here, Skinner makes it clear that analyzing seeing as behavior is one way to understand such processes. That is, perceiving may be treated like *signal detection* rather than like mental states and processes (Green & Swets, 1966). The behavior analysis of seeing (or, more generally, perceiving) also applies to other sensory dimensions such as hearing, feeling, and smelling. Notice that such an analysis accounts for perceiving without reference to mental events.

Stimulus Classes

In a preceding section, we noted that responses that produce similar effects may be many and varied. To encompass response variation in form, behavior analysts use the term *response class*. Stimuli that regulate operant and respondent behavior also vary from one time to the next. When stimuli vary across physical dimensions but have a common effect on behavior, they are said to be part of the same **stimulus class**. Bijou and Baer (1978) have used the concept of stimulus class in an analysis of child development and have made the point that:

A mother's face has a fair consistency to it, we may think, in that we know our mother's face from anyone else's face. But careful observations show that it is sometimes shiny, sometimes dusty, sometimes wet; occasionally creased into its facial lines, but sometimes smooth; the eyes range between fully open and fully closed, and assume a wide range of angles of regard; sometimes hairs fall in front of the face, sometimes not. Then let us remember that whenever we speak of a stimulus, we will almost surely mean a class of stimuli. (p. 25)

It is important to note that a stimulus class is defined entirely by the common effect on behavior. For this reason, a stimulus class cannot be defined by the apparent similarity of the stimuli. Consider the words *boring* and *uninteresting*. In common English, we say they have the same meaning. In behavior analysis, these words have a similar effect on the person who reads or hears them; for this reason, they belong to the same stimulus class even though they have completely different physical dimensions. Other stimuli may appear physically similar but belong to different stimulus classes. For example, mushrooms and toadstools look somewhat similar, but for an experienced woods person these stimuli have different functions—you pick and eat mushrooms but avoid toadstools.

Classes of Reinforcing Stimuli

The concept of stimulus class may also be used to categorize the consequences of behavior. When behavior operates on the environment to produce effects, the effects that increase the frequency of response are a class of reinforcing stimuli. Some consequences strengthen behavior when they are presented, like money for a job well done, and others strengthen it when they are removed, like scratching an itch. In this case, we can divide the general class of reinforcing stimuli into two subsets. Those events that increase behavior when presented are called **positive reinforcers**, and those that increase behavior when removed are **negative reinforcers**. For example, a smile and a pat on the back may increase the probability that a child will complete his or her homework; for this reason, the smile and pat are positive reinforcers. The same child may stop dawdling and start working on a school project when a parent scolds the child for wasting time, and the nagging stops when the child gets going. In this case, reinforcement for working is based on the removal of scolding, and the reprimand is a negative reinforcer.

Establishing Operations

The relations between stimulus and response classes depend on the broader **context of behavior**. That is, environment–behavior relationships are always conditional—depending on other circumstances. One of the most common ways to change environment–behavior relationships is to have the person (or other organism) experience a period of deprivation or satiation. For example, a pigeon will peck a key for food only if it is deprived of food for some period of time. More specifically, the peck-for-food contingency depends on the level of food deprivation.

Jack Michael (1982a) made an important distinction between the discriminative and motivational functions of stimuli. In that paper, he introduced the term **establishing operation** to refer to any environmental change that had two major effects: (a) the change increased the momentary effectiveness of reinforcement supporting operant behavior, and (b) the change increased momentarily the responses that had in the past produced such reinforcement (see also Michael, 1993, 2000). For example, the most common establishing operation is deprivation for primary reinforcement. The procedure involves withholding reinforcement for some period of time or, in the case of food, until the organism reaches 80% of free-feeding body weight (see chap. 5). The establishing operation of deprivation has two effects. First, food becomes an effective reinforcer for any operant that produces it. That is, the deprivation procedure establishes the reinforcement function of food. Second, behavior that has previously resulted in getting food becomes more likely—in the wild, a bird may start to forage in places where it has previously found food. Formally, an establishing operation is defined as "any change in the environment which alters the effectiveness of some object or event as reinforcement and simultaneously alters the momentary frequency of the behavior that has been followed by that reinforcement" (Michael, 1982a, pp. 150–151).

Establishing operations regularly occur in everyday life. For example, television commercials are said to influence a person's attitude toward a product. One way to understand the effects of TV commercials is to analyze them as establishing operations. In this case, an effective commercial alters the reinforcement value of the product and increases the likelihood of purchasing the item or using it if available. For example, dairy farmers advertise the goodness of ice-cold milk. Those who are influenced by the commercial are likely to go to the fridge and have a glass of milk. Of course, this immediate effect of the commercial depletes the amount of milk you have on hand, and eventually you buy more milk.

Tactics of Behavioral Research

To discover elementary relationships between functional stimuli, responses, and conse-
quences, behavior analysts have relied on experimental methods developed in biology,
medicine, and behavior analysis (Bachrach, 1962; Bernard, 1927; Bushell & Burgess, 1969;
Johnston & Pennypacker, 1993; Kazdin, 1982; 1998; Sidman, 1960). In 1865, the French
physician Claude Bernard outlined the central objectives for experimental analysis. He
stated that:

> We can reach knowledge of definite elementary conditions of phenomena only by one road,
> viz., by experimental analysis. Analysis dissociates all the complex phenomena successively
> into more and more simple phenomena, until they are reduced, if possible, to just two elemen-
> tary conditions. Experimental science, in fact, considers in a phenomenon only the definite
> conditions necessary to produce it. (Bernard, 1927, p. 72).

In his book, *An Introduction to the Study of Experimental Medicine*, Bernard (1927) provided
a classic example of experimental analysis.

> One day, rabbits from the market were brought into my laboratory. They were put on the table
> where they urinated, and I happened to observe that their urine was clear and acid. This fact
> struck me, because rabbits, which are herbivora, generally have turbid and alkaline urine; while
> on the other hand carnivora, as we know, have clear and acid urine. This observation of acidity
> in the rabbits' urine gave me an idea that these animals must be in the nutritional condition of
> carnivora. I assumed that they had probably not eaten for a long time, and that they had been
> transformed by fasting, into veritable carnivorous animals, living on their own blood. Nothing
> was easier than to verify this preconceived idea or hypothesis by experiment. I gave the rabbits
> grass to eat; and a few hours later, their urine became turbid and alkaline. I then subjected them
> to fasting and after twenty-four hours, or thirty-six hours at most, their urine again became clear
> and strongly acid; then after eating grass their urine became alkaline again, etc. I repeated this
> very simple experiment a great many times, and always with the same result. I then repeated
> it on a horse, an herbivorous animal which also has turbid and alkaline urine. I found that
> fasting, as in rabbits, produced prompt acidity of the urine, with such an increase in urea that
> it spontaneously crystallizes at times in the cooled urine. As a result of my experiments, I thus
> reached the general proposition which then was still unknown, to wit, that all fasting animals
> feed on meat, so that herbivora then have urine like that of carnivora.
>   But to prove that my fasting rabbits were really carnivorous, a counter proof was required.
> A carnivorous rabbit had to be experimentally produced by feeding it with meat, so as to see
> if its urine would then be clear, as it was during fasting. So I had rabbits fed on cold boiled
> beef (which they eat very nicely when they are given nothing else). My expectation was again
> verified, and as long as the animal diet was continued, the rabbits kept their clear and acid
> urine. (pp. 152–153)

Bushell and Burgess (1969) provided an outline of the basic tactics of experimental
analysis used by Bernard in the rabbit experiment. The following account is loosely based
on their outline. Notice that Bernard made an observation that, as a physiologist, seemed
unusual and puzzling—namely, that the rabbits from the market had urine that was char-
acteristic of carnivores. Only a trained physiologist familiar with carnivores and herbivores
would notice the anomaly of the urine. Most of us would run and get a cloth to wipe it up.
The point is that a researcher must have a thorough familiarity with the subject matter to
find a significant problem.

Once Bernard identified the *problem*, he stated it in terms of a conjecture. The problem
statement related type of diet to the chemistry of the urine. That is, fasting results in the
animal living off its own body stores, and this produces acidity of the urine. On the other

Independent Variable

- What is changed in an experiment
- X variable
- Commonly called a *cause*
- In Bernard's experiment, type of diet
- In behavioral experiments, environmental change

Dependent Variable

- What is measured in an experiment
- Y variable
- Commonly called an *effect*
- In Bernard's experiment, chemistry of urine
- In behavioral experiments, behavior of the organism

FIG. 2.1. *A table of scientific terms used to discuss cause-and-effect relationships.*

hand, when herbivores eat their usual diet of grass, their urine is alkaline. Thus, there is a clear relationship between type of diet and the nature of the animal's urine.

Experimentally, Bernard's statement suggests that we change, manipulate, or control the type of diet and measure the chemistry of the urine. The condition that is changed by the experimenter (i.e., type of diet) is called the **independent variable** (variable X) because it is free to vary at the discretion of the researcher. Bernard changed the animal's diet and measured the effect on the urine. The measured effect in an experiment is called the **dependent variable** (variable Y), because a change in it depends on a change in the independent variable. Whether the urine was acid or alkaline (dependent variable) depended on the nature of the diet (independent variable). Figure 2.1 explains the terms used in this section.

The purpose of any experiment is to establish a cause-and-effect relationship between the independent (X) and dependent (Y) variables. To establish such a relationship, the researcher must show that changes in the independent variable are functionally related to changes in the dependent variable. This is called showing covariation of the X and Y variables. In addition, the experimenter must show that the changes in the independent variable preceded changes in the dependent variable. Both of these conditions are seen in Bernard's experiment.

In Fig. 2.2, you can see that changes between fasting and grass diet reliably alter the chemistry of the rabbits' urine. For this reason, changes in type of diet, the X variable, may
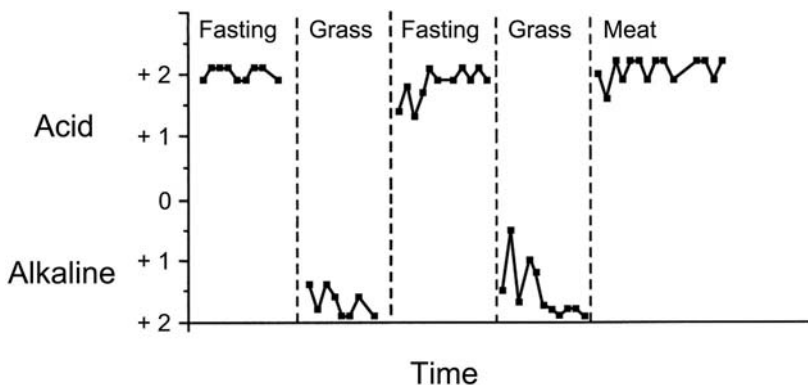

FIG. 2.2. *The results of Bernard's experiment. Notice that the change in diet (independent variable) reliably changes the chemistry of the urine (dependent variable). Each time the diet is changed, the urine changes from acid to alkaline or vice versa (based on results reported by Bushell & Burgess, 1969, p. 133).*

be said to covary with degree of acidity of urine, the Y variable (see Fig. 2.1 to clarify terms). Recall that Bernard changed the type of diet and then measured its effects on the urine. This procedure of manipulating the independent variable ensures that a change in X (type of diet) precedes the change in Y (chemistry of urine). At this point, Bernard has shown two of the three important conditions for causation: (a) covariation of X and Y and (b) the independent variable preceding a change in the dependent variable.

The central question in all experiments is whether the changes in the dependent variable are uniquely *caused by* changes in the independent variable. The problem is that many other factors may produce changes in the dependent variable, and the researcher must rule out this possibility. In the Bernard experiment, the initial change from fasting to grass diet may have been accompanied by an illness caused by contaminated grass. Suppose that the illness changed the chemistry of the animals' urine. In this case, changes from fasting to grass, or from grass to fasting, will change the chemistry of the urine, but the changes are caused by the unknown illness rather than by the type of diet. That is, the unknown illness *confounds* the effects of type of diet on the acidity of the urine. At this point, stop reading and look again at both Bernard's description of his experiment and Fig. 2.2. Try to determine how Bernard eliminated this rival hypothesis.

One procedure for eliminating rival explanations is the systematic introduction and elimination of the grass diet. Notice that Bernard withholds and gives the grass diet and then repeats this sequence. Each time he introduces and removes the grass, a rapid change occurs from alkaline to acid (and vice versa). This rapid and systematic change makes it unlikely that illness accounts for the results. How can an animal recover from and contract an illness so quickly? Another procedure would be to use different batches of grass, because it is unlikely that they would all be contaminated. However, the most convincing feature of Bernard's experiment, in terms of eliminating rival explanations, is his final procedure of introducing a meat diet. The meat diet is totally consistent with Bernard's claim that the animals were living off their body stores and counteracts the rival explanation that the animals were ill. More generally, the reversal of conditions and the addition of the meat diet eliminate most other explanations.

The Reversal Design and Behavior Analysis

Bernard's experimental design is commonly used to study behavior–environment relationships. The design is called an **A–B–A–B reversal** and is a powerful tool used to show causal relationships among stimuli, responses, and consequences. The reversal design is ideally suited to show that an organism's behavior is regulated by specific features of the environment.

The A-phase, or **baseline**, measures behavior before the researcher introduces an environmental change. During baseline, the experimenter takes repeated measures of the behavior under study, and this establishes a criterion against which any changes (caused by the independent variable) may be assessed. Following the baseline phase, an environmental condition is changed (B-phase) and behavior is repeatedly measured. If the independent variable, or environmental condition, has an effect, then the behavioral measure (dependent variable) will change (increase or decrease).

At the same time, as we have indicated, the researcher must rule out rival explanations for the change in behavior, such as simple coincidence. To do this, the baseline phase is reintroduced (A) and behavior is repeatedly measured. When the treatment is removed, behavior should return to pretreatment or baseline levels. Finally, the independent variable is changed again and the behavior is carefully measured (B). According to the logic of the design, behavior should return to a level observed in the initial B-phase of the experiment.

This second application of the independent variable helps to ensure that the behavioral effect is caused by the manipulated condition.

An example of the reversal design, as used in behavior analysis, is seen in an experiment conducted by Goetz and Baer (1973). The researchers were interested in the creative play of children and the role of reinforcement for such behavior. Several 4-year-old girls in a preschool were said to lack "creative skill" at block building. One measure of creative behavior is the number of different forms that a child builds with blocks during a play session (form diversity). The researchers wondered if positive attention from the teacher could function as reinforcement for building new block constructions (the experimental problem).

During the baseline phase, the teacher watched the child closely but said nothing about the child's use of the blocks. After baseline measures of form diversity were taken, the teacher then socially reinforced novel block constructions. The teacher remarked with "interest, enthusiasm, and delight every time the child placed and/or rearranged blocks so as to create a form which had not appeared previously" (Goetz & Baer, 1973, p. 212). Form diversity was assessed for several sessions with this procedure in effect.

To be certain that the reinforcement procedure was responsible for the increase in diversity, Goetz and Baer altered the contingency between teacher attention and block building. During this phase, the child was reinforced for repeating a form that had previously been built. Thus, similarity of form was reinforced in this phase. Finally, reinforcement of diverse forms was reinstated. The results of this experiment are portrayed for one of the three children (Sally) in Fig. 2.3. The experimental design is a modified A–B–A–B reversal. The baseline phase (A) provides a measure of block-building diversity before any intervention by the teacher. Next, a reinforcement contingency was arranged for novel forms of construction (B). During the third phase (C) of the experiment, the contingency of reinforcement was changed to support repetitive forms. Finally, reinforcement for novel constructions was reinstated (B). The independent variable in this experiment is the contingency of reinforcement—contingent reinforcement of novelty versus contingent reinforcement of repetition. The dependent variable is the number of different forms that the child produced
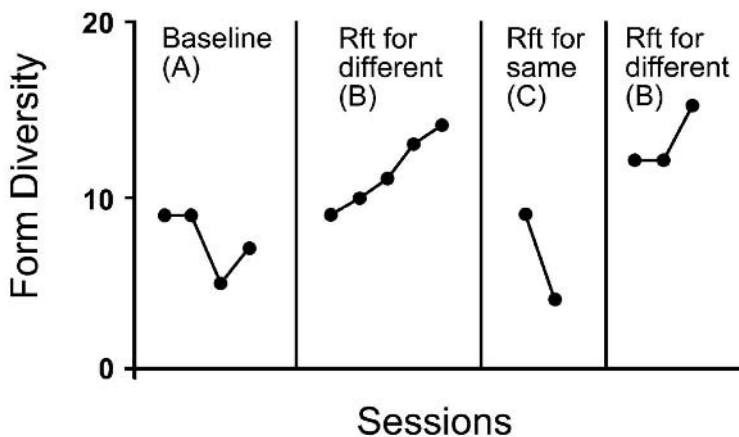
FIG. 2.3. *A reversal design in which the researchers altered the contingency between teacher attention and block building. First, a baseline measure of behavior (A) was taken for several days. During the second phase of the experiment (B), the child was reinforced (Rft) for varying a form (diversity) that had been previously built. Next, the child was reinforced for building similar block forms (C), and finally the B-phase was reinstated. Adapted from "Social Control of Form Diversity and the Emergence of New Forms in Children's Blockbuilding," by E. M. Goetz and D. M. Baer, 1973,* Journal of Applied Behavior Analysis, 6, *pp. 209–217.*

during each phase of the experiment. As you can see, the dependent variable reliably changes in the expected direction with changes in the contingency of reinforcement (i.e., teacher attention for diversity or repetition).

The A–B–A–B reversal design is the most fundamental research design used in the experimental analysis of behavior. There are, however, difficulties that may make this design inappropriate for a given research question. One major problem is that behavior, once changed, may not return to baseline levels. Consider what might happen if you used a reinforcement technique to teach an illiterate adult to read. You could measure reading level, introduce your teaching technique, and after some time withdraw reinforcement for reading. It is very unlikely that the student will again become illiterate. In behavioral terms, the student's reading is maintained by other sources of reinforcement such as getting information that enables the student to behave effectively (e.g., reading a menu, traffic signs, etc.).

Another difficulty is that it is sometimes unethical to reverse the effects of a behavioral procedure. Suppose that a behavioral program to eliminate the use of crack cocaine works, but the doctors who run the program are not absolutely certain that the decline in drug use is caused by reinforcement procedures. It would be highly unethical to remove and reinsert the reinforcement therapy in order to be certain about causation. This is because removing the reinforcement procedure could lead to an increase in drug use. Nonetheless, when this and other difficulties are not encountered, the A–B–A–B reversal design is a preferable mode of analysis.

Throughout this book, we address research that uses the reversal design, modified-reversal designs (e.g., adding other control conditions), and other forms of experimental analysis. We have concentrated on the reversal design, because it demonstrates the basic logic of behavioral experimentation. The task of all behavioral experiments is to establish with high certainty the cause-and-effect relationships that govern the behavior of organisms. Based on these causal relationships, behavior analysts search for general principles that organize experimental findings (e.g., principle of reinforcement).

FOCUS ON ISSUES: INTERNAL AND EXTERNAL VALIDITY IN EXPERIMENTS

A common reaction to laboratory experimental findings goes something like, "What in the world does that research have to do with anything important?" (Galileo may have been asked a similar question in the 17th century by church officials, when he was rolling balls down inclined planes and discovering the basic principles of physics.) Consider an experiment in which rats are placed in a small, sound-proof chamber and are given a 45-mg food pellet after pressing a lever 50 times. The rat rapidly makes 50 responses, gets a bit of food, pauses for a few seconds, and then presses the lever another 50 times. A legitimate question might be, "Why bother doing this sort of research since all it tells us is what rats, in a highly controlled circumstance, do?" Some individuals would say that such an experiment says little about the responses of rats; never mind what people behave like. As you will see in this book, however, experiments like this build on one another and occasionally pay off in a direct sense.

More importantly for the present discussion, this research meets the minimum requirement for all experiments: The cause-and-effect relationships that govern the behavior of the animal are identified with a reasonable amount of certainty. This is because many variables

that may have accidentally produced the effect (extraneous variables) are ruled out by the control procedures of the experiment. When many *extraneous variables* are ruled out by an experimental design, Campbell and Stanley (1966) say that the research has high **internal validity**. That is, changes in the dependent variable may be reasonably attributed to changes in the independent variable (cause → effect).

The popular press occasionally reports scientific research that appears to have great practical value but, in fact, is difficult to interpret. Several years ago, a news report on television suggested that when parents and therapists imitated the disturbed behavior of autistic children, miraculous improvements in these children occurred. For example, a child would rock back and forth and the mother would imitate this rocking behavior. Although the observation did not make theoretical sense, we hoped it was a valid finding, because such a simple treatment offered hope to many parents and children. We contacted the researchers to discover more about their experimental methods.

The research was practically useful, easy to utilize, and appeared reasonable to many parents of autistic children; it had high **external validity**. External validity refers to the extent that an experimental finding generalizes to other behavior (not only rocking), settings, reinforcers, and populations (Campbell & Stanley, 1966). Unfortunately, the "experiment" on parental imitation of rocking was low on internal validity and could not be evaluated. There may have been many reasons for an apparent improvement in the children. The gains that the children made may have been a matter of interpretation by the researchers, or variables other than imitation could have produced the positive effect. Uncontrolled variables like extra attention from caretakers, selection of children for treatment, the particular therapist who worked with the child, and so on may have been responsible for the research outcome.

Internal Validity

To illustrate the distinctions between internal and external validity, consider a study by Ayllon (1963). The subject was a female patient in a mental hospital who hoarded a large number of towels and collected them in her room. In desperation, the ward staff raided her room twice a week to regain the missing towels. The staff did a baseline count of the number of towels in her room and determined that she hoarded between 19 and 29 towels, even though the nurses continued to remove them from her room.

The next phase involved two procedures. First, the nursing staff stopped raiding her room and taking the towels. Second, throughout the day the staff brought her towels when she was in her room. This was done without comment, and the number of towels given increased from 7 to 60 per day by the third week of the experiment. Figure 2.4 shows that the number of towels in her room increased to 625, at which time she began to remove them and the staff stopped giving towels to her. Ayllon discusses the results of the experiment as follows:

> The procedure used to reduce the amount of towel hoarding bears resemblance to satiation of a reinforcer. A reinforcer loses its effect when an excessive amount of that reinforcer is made available. Accordingly, the response maintained by that reinforcer is weakened. In this application, the towels constituted the reinforcing stimuli. When the number of towels in her room reached 625, continuing to give her towels seemed to make their collection aversive. The patient then proceeded to rid herself of the towels until she had virtually none.
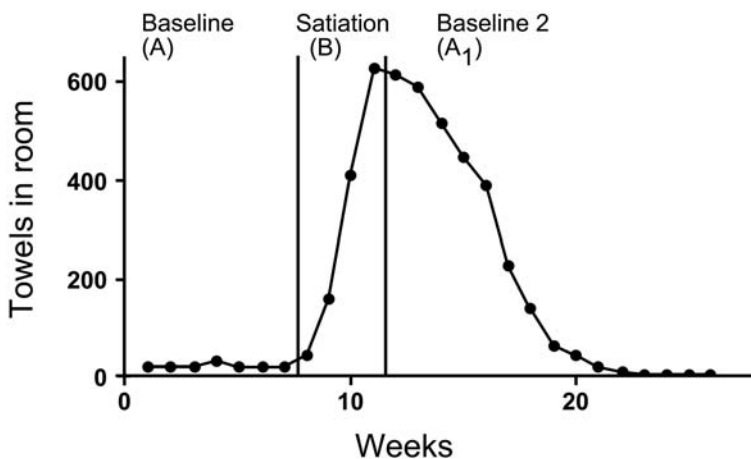
FIG. 2.4. *Modification of towel hoarding by a psychotic patient. A baseline count of the number of towels in the patient's room was taken, and as you can see she hoarded between 19 and 29 towels per day. The treatment phase of the experiment involved two procedures. First, the nursing staff stopped raiding her room and taking the towels. Second, throughout the day the staff brought her towels when she was in her room. The number of towels in her room increased to 625 before she started throwing them out.* Note. *Based on data from "Intensive Treatment of Psychotic Behavior by Stimulus Satiation and Food Reinforcement," by T. Ayllon, 1963,* Behavior Research and Therapy, 1, *pp. 53–61.*

During the first weeks of satiation, the patient was observed patting her cheeks with a few towels, apparently enjoying them. Later, the patient was observed spending much of her time folding and stacking the approximately 600 towels in her room. A variety of remarks were made by the patient regarding receipt of towels. All verbal statements made by the patient were recorded by the nurse. The following represent typical remarks made during this experiment. First week: As the nurse entered the patient's room carrying a towel the patient would smile and say, "Oh, you found it for me, thank you." Second week: When the number of towels given to patient increased rapidly, she told the nurses, "Don't give me no more towels. I've got enough." Third week: "Take them towels away. . . . I can't sit here all night and fold towels." Fourth and fifth weeks: "Get these dirty towels out of here." Sixth week: After she had started taking the towels out of her room, she remarked to the nurse, "I can't drag any more of these towels, I just can't do it." (Ayllon, 1963, pp. 53–61)

The experiment was designed to stop towel hoarding by providing excessive amounts of the valued item. The researchers used the principle of satiation and applied it to the management of psychotic behavior. The experimental design was an A–B–A$_1$, where A was the initial baseline where towels were removed by staff and a count was taken; B was the treatment phase where towels were given; A$_1$ was a return to baseline but without the removal of towels. In terms of internal validity, the question is whether the decline in towel hoarding (dependent variable) was caused by the provision of towels (independent variable).

To the extent that there are alternative explanations for the outcome of this study, it is weak on internal validity. Any factor, other than the independent variable, that could reasonably account for the findings represents a *threat to internal validity*. Such threats weaken confidence in cause-and-effect conclusions. Campbell and Stanley (1966) outline a number of different threats to internal validity, some of which are applicable to operant-research designs and to Ayllon's study of towel hoarding.

History

One kind of threat to internal validity is called history. History refers to conditions that change at the same time as the manipulation of the independent variable. For example, the provision of towels may have cluttered the patient's room, and she discarded them to make more space. Although this appears to be a reasonable explanation for her behavior, it does not explain why she threw all the towels away. If she had kept the same 20 towels in her room, as during baseline, she would have as much space as before.

Not all history effects are so easily countered. The hospital laundry could have run out of fabric softener, or changed to a detergent with a peculiar smell, and this may have changed the texture or odor of the towels—making them aversive rather than reinforcing. This is a reasonable alternative hypothesis, since it fully accounts for both the patient's taking the towels out of her room and the subsequent decline to near zero hoarding. Recall that the A_1 condition, where the nurses stop giving her towels, was implemented on the basis of the patient's behavior (she started to throw towels out of her room), and this would occur if a change in the laundry happened at this time. Therefore, some kind of history effect could account for the outcome of the experiment.

Maturation

Another source of invalidity is called maturation, which refers to biological or psychological processes that change over time. Again, if these maturational changes occurred at the same time as the manipulation of the independent variable, they could explain the findings. Suppose that this woman had a sudden spontaneous remission of her psychosis. Presumably, this would account for why she no longer wanted to hoard towels. Although her 9 years of hospitalization argue against this possibility, the researcher should have gathered evidence about her psychiatric condition before and after the experiment.

Instrument Decay

A third threat to internal validity is called instrument decay. In behavioral research, instrument decay refers to observers becoming better or worse at measuring the dependent variable. Such an effect can occur in reversal designs where repeated observations are made. For example, observers may be very interested and attentive when they first record the psychotic verbalizations of a mental patient. After many days of this task, the same observers may become bored and consequently miss many psychotic remarks. If the researcher was reinforcing normal speech, the apparent reduction in psychotic talk may be assigned to the reinforcement procedure rather than to the decay in measurement. In Ayllon's experiment, the before and after measures were taken by the nursing staff. Number of towels is a very concrete measure, requiring little interpretation by the staff. Also, the number of towels is steady and low in baseline, rises rapidly during satiation, and falls in the second baseline. For these reasons, instrument decay is very unlikely—only if the nursing staff was fabricating the data could such an effect occur.

Generally, in terms of internal validity, history is the most serious problem in Ayllon's study of towel hoarding. This problem could have been remedied by adding a second subject who hoarded other objects. If the satiation procedure was staggered so that the second subject received satiation at a different time than the towel-hoarding woman, then history effects would be extremely unlikely. Of course, this assumes that the procedure works or replicates for both subjects. The change in the object hoarded would rule out our laundry hypothesis, as would the staggered start of the experiment.

External Validity

Generality of Results

External validity refers to the extent that laboratory findings generalize over time, place, dependent measures, and similar experimental manipulations. That is, do the cause-and-effect relationships found in an experiment occur at different times and places, with different organisms and diverse responses, when the original conditions are in effect?

When a dependent variable changes just because it is being measured, the effect is called **reactive measurement**. Reactive measurement limits the generality of a treatment (or intervention) to situations where the dependent variable is being measured or counted. For example, a person in a weight-control program (treatment) may lose weight just because he or she is weighed daily by a researcher. Daily weighing may focus attention on being overweight, and the program is only effective under these conditions. In Ayllon's experiment, the patient could have observed the nurses counting the ever-increasing number of towels, and the satiation procedure would be limited to this kind of situation. Reactive measurement is unlikely, however, since the nurses were counting during baseline, treatment, and the return to baseline. Also, the decline in towel hoarding following the satiation procedure is gradual rather than sudden, suggesting measurement of the number of towels did not limit the effects of satiation in this study.

At a broader level, a result has high external validity when we are able to identify the conditions that produce it. For example, the principle of reinforcement governs the behavior of organisms under specified conditions. Some of these conditions involve a genetic capacity for operant conditioning and an establishing operation that makes the response–reinforcer relationship effective. In a pigeon, the peck-for-food relationship depends on the genetic endowment of the bird and deprivation of food in the immediate past. For humans, who have an extensive capacity for operant conditioning, going to a soda machine to get a cold drink is an effective contingency on a hot afternoon. In terms of external validity and operant conditioning, the question is, to what extent do the laws and principles of operant behavior generalize over species, settings, responses, and reinforcers?

The research by Ayllon (1963) on towel hoarding may be viewed as a generalizing experiment. The principle of satiation states that any response–reinforcer relationship is weakened by repeated presentation of the reinforcer. In everyday language, the more you get something, the less valuable it becomes. How important is a free steak dinner if you just had a large meal? Ayllon used this principle of satiation to weaken the relationship between taking and accumulating towels. In this case, he assumed that stealing and hoarding towels was reinforced by the accumulation of towels in the patient's room. If this was so, then the repeated presentation of towels must reduce hoarding behavior. Since this occurred (assuming internal validity), the experiment generalizes the principle of satiation to psychiatric patients, mental hospitals, nonconsumable reinforcers, and socially significant behavior. At the time of this experiment, most mental health professionals doubted the generality of operant principles to this kind of problem. Ayllon (1963) commented that:

> The ward nurses, who had undergone a three year training in psychiatric nursing, found it difficult to reconcile the procedure in this experiment with their psychiatric orientation. Most nurses subscribed to the popular psychiatric view which regards hoarding behavior as a reflection of a deep "need" for love and security. Presumably, no "real" behavioral change was possible without meeting the patient's "needs" first. Even after the patient discontinued hoarding towels in her room, some nurses predicted that the change would not last and that worse behavior would

replace it. Using a time-sampling technique, the patient was under continuous observation for over a year after the termination of the satiation program. Not once during this period did the patient return to hoarding towels. Furthermore, no other behavioral problem replaced hoarding. (pp. 57–58)

Correspondence with Extra Laboratory Settings

Another index of external validity is the correspondence between laboratory findings and what organisms do under similar conditions in everyday life. For example, laboratory experiments have shown that, under certain conditions, television violence increases the aggressive behavior of children (Bandura, 1973, 1983). The basic principles involve social modeling and imitation. A child who sees violence on televised sports, movies, and cartoons may imitate such behavior if the violence is condoned by either parents or other significant adults. Correspondence between laboratory findings and everyday life is suggested when naturalistic studies (e.g., surveys, observation, and coding, etc.) show that the more children are exposed to violent television, the more aggressive they are at home, in school, and throughout their young lives (Eron, Huesmann, Dubow, Romanoff, & Yarmel, 1987). Although it is tempting to carry out only naturalistic research, such studies are relatively weak on both the internal validity and the discovery of basic principles.

In summary, there is a tradeoff between internal and external validity. As internal validity increases, external validity decreases—and vice versa. When an experimenter holds all things constant and manipulates the independent variable, he or she is very certain about cause-and-effect relationships. Unfortunately, the fact that all things are held constant limits the generality of the relationship under investigation. As seen in the next section, generality may be increased by repeating the experiment under new conditions. Ultimately, the answer to the question of generality comes from the well-known tactic of experimental replication.

Single-Subject Research

Behavior analysis is concerned with discovering basic principles that govern the behavior of single organisms. Each individual's behavior is studied to assess the impact of a given environmental condition. Notice that Goetz and Baer (1973) applied their reinforcement procedures with only one subject and showed that her behavior reliably changed when the contingency of reinforcement was altered (she built new block constructions). The researchers applied the same procedures to two other children and found similar effects. Thus, the experimenters argued that reinforcement of diversity in block building generalized across different children. They claimed, "It seems clear that diversity of response within this delimited sphere of activity, is readily modified by simple, everyday reinforcement contingencies" (Goetz & Baer, 1973, p. 216). In other words, the researchers are suggesting that, all things being equal, any child given reinforcement for creative play will show an increase in such activity. This broader statement linking reinforcement to creative play is called an empirical generalization. Most behavior analysts assume such generality in their conclusions.

Replication of Results

Generalizing from single-subject experiments is a well-founded scientific strategy (see the preceding Focus on Issues). A single individual is exposed to all values of the independent

variable, and the experiment may be conducted with several subjects. Each subject replicates the experiment; if there are four subjects, the investigation is repeated four separate times. Thus, every additional individual in a single-subject experiment constitutes a **direct replication** of the research. Direct replication involves manipulating the independent variable in the same way for all subjects in the experiment. Another way to increase the generality of a finding is by **systematic replication** of the experiment. Systematic replication uses procedures that are different but are logically related to the original research question (see Sidman, 1960, for a detailed discussion of direct and systematic replication). For example, in Bernard's research with the rabbits, changing the diet from fasting to grass altered the chemistry of the urine and may be considered an experiment in its own right. Feeding the animals meat may be viewed as a second experiment—systematically replicating the initial research using a grass diet. Given Bernard's hypothesis that all fasting animals become carnivores, it logically follows that meat should change the chemistry of the urine from alkaline to acid.

In a behavioral experiment, such as the creativity experiment by Goetz and Baer (1973), the researchers could have established generality by using a different task and a different kind of reinforcement (e.g., tactile contact like hugging). Here the central idea is that the **contingency of reinforcement** is the critical factor that produced the increase in creative block design. That is, the observed change in behavior does not depend on either the type of activity (block building) or the nature of the reinforcer (positive attention). In fact, many behavioral experiments have shown that contingencies of reinforcement generalize across species, type of reinforcement, diverse settings, and different operants.

Generality and Single-Subject Research

A common misunderstanding about single-subject (or small "n") experiments is that generalizations are not possible, because a few individuals do not represent the larger population. Some social scientists believe that experiments must include a large group of individuals in order to make general statements. This position is valid if the social scientist is interested in descriptions of what the average individual does. For example, single-subject research is inappropriate for questions like, "What sort of advertising campaign is most effective for getting people in Los Angeles to recycle garbage?" In this case, the independent variable might be type of advertising; and the dependent variable, the number of citizens in Los Angeles who recycle their waste. The central question is concerned with how many people recycle, and a group experiment is the appropriate way to approach the problem.

Behavior analysts are less interested in aggregate or group effects. Instead the analysis focuses on the behavior of the individual. These researchers are concerned with predicting, controlling, and interpreting the behavior of single organisms. The generality of the effect in a behavioral experiment is established by *replication*. A similar strategy is sometimes used in chemistry. The process of electrolysis can be observed in an unrepresentative sample of water from Logan, Utah. A researcher who follows the procedures for electrolysis will observe the same result in all samples of water, whether from Logan or from the Ganges. Importantly, the researcher may claim—on the basis of a single experiment—that electrolysis occurs in all water, at all times, and in all places. Of course, only replication of the experiment will increase confidence in this empirical generalization.

Assessment of Behavior Change

Single-subject experiments require a preintervention baseline period of measurement. This baseline serves as a comparison or reference for any subsequent change in behavior produced

by the independent variable. This baseline is essential in order to know if your independent variable has any effect. To construct an appropriate baseline, it is necessary to define the response class objectively and clearly. In the animal laboratory, the response class of pressing a lever is most often defined by the closure of an electrical switch. There is no dispute about the state of the switch; it is either on or off. An animal may press the lever in many different ways. The left or right paw may be used as well as the hind foot, nose, mouth, and so on. The point is that no matter how the response is made, all actions that result in a switch closure define the operant class. Once the response class is defined, the number of times the response occurs can be counted and a baseline constructed.

Outside of the laboratory, response classes are usually more difficult to define. Consider that you are asked to help manage the behavior of a troublesome child in a classroom setting. The teacher complains that the child is disruptive and interferes with his or her teaching. On the surface, measuring the disruptive behavior of the child seems easy. Further reflection, however, suggests that it is not easy to define the operant class. What exactly does the teacher mean when he or she says, "the child is disruptive"? After talking to the teacher and observing the child in the classroom, several "disruptive" responses may be identified: The child is often out of his or her seat without permission and at times when a lesson is being taught. Another behavior that occurs is talking loudly to other children during study periods. Both of these responses are more clearly defined than the label "disruptive," but objective measurement may still be difficult. Notice that each response is partially defined by prior events (permission) and the current situation (study periods). In addition, terms like *loud* and *out of seat* remain somewhat subjective. How loud is loud, and is sitting on the edge of the desk out of seat? The answer is to keep refining the response definition until it is highly objective. When two observers can agree most of the time on whether a response has occurred, then a baseline can be established.

In addition to defining the response class, assessment of behavior change requires some measure of response variability. During the baseline, repeated measures are taken and the number of responses are plotted. Figure 2.5 is a graph of an idealized experiment to modify the out-of-seat behavior of the child in the foregoing classroom example. Pretend that the teacher is requested to pay attention and give tokens to the child only when he or she is sitting quietly in his or her seat. At the end of the school day, the tokens may be exchanged for small prizes. Does this procedure alter the child's behavior? The graphs in Figs. 2.5A and 2.5B show two possible baselines and the results of the intervention.

Compare your assessment of the treatment effect in Figs. 2.5A and 2.5B. You probably judge that the reinforcement procedure was effective in graph A but possibly not in graph B. What do you suppose led to your conclusion? Notice that the range of values in the baseline of graph A is quite small when compared to those in the baseline of graph B. The number of times the child is out of his or her seat does not change much from day to day in graph A, but there is substantial variation in the baseline of graph B. The effect of the modification can only be evaluated against a departure from the baseline. Because the baseline of graph B is so variable, it is difficult to judge whether the reinforcement procedure had an effect. If you have had a course in statistics, it may occur to you that the difficulty in graph B could be solved by a statistical test. Although this is possible, behavior analysts would try different tactics.

One approach is to reduce the variability of the baseline. This might involve a more precise definition of the out-of-seat response. This would reduce variation introduced by imprecise measurement of the response class. Another reasonable strategy would be to increase the power of the intervention. In this case, the attempt is to produce a larger shift in behavior, relative to the baseline. For example, the small prizes earned at the end of the school day may be changed to more valuable items. Notice that these strategies lead to refinement in measures and procedures used in the experiment. This increases
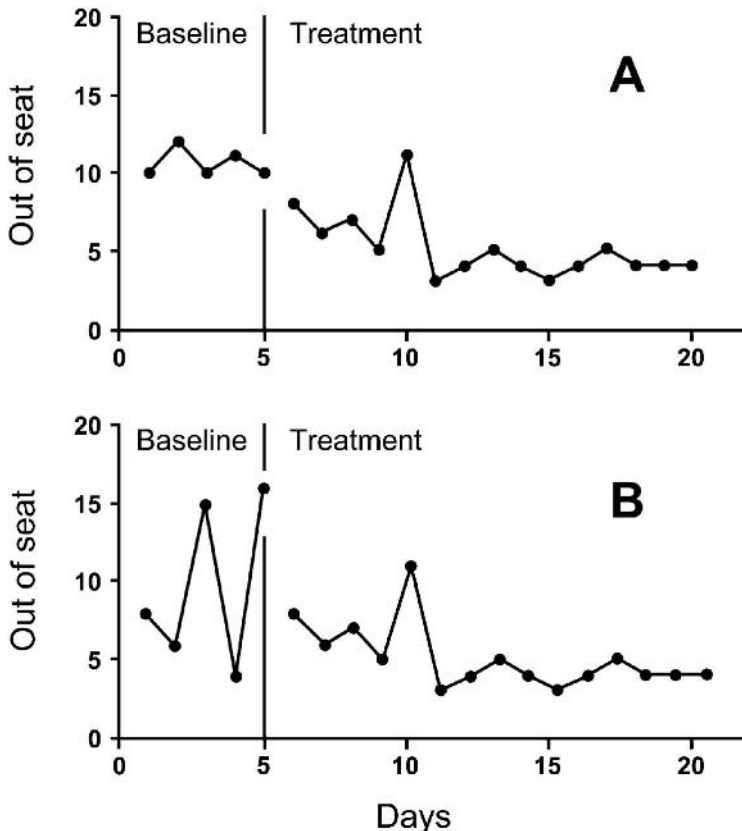
FIG. 2.5.   *Compare your assessment of the treatment effect in graphs A and B. Notice that the range of values in the baseline of graph A is quite small when compared to those in the baseline of graph B. The effect of an experimental manipulation can only be evaluated against a departure from baseline. Because the baseline of graph B is so variable, it is difficult to judge whether the reinforcement procedure had an effect.*

the experimenter's control over the subject matter, and this is a primary objective of the experimental analysis of behavior.

Assessment of behavior change may be more difficult if there is a trend in the baseline measures. A **trend** is a systematic decline or rise in the baseline values. A drift in baseline measures can be problematic when the treatment is expected to produce a change in the same direction as the trend. Figure 2.6 is a graph of the loud-talking behavior by the child in our hypothetical experiment. Notice that the number of loud-talking episodes during baseline starts at a moderately high level and drifts downward over days. Perhaps the child's parents are getting more and more complaints from the school, and as the complaints mount they put more pressure on the child to "shut up." Regardless of why the trend is occurring, the modification procedure is expected to decrease loud talking. As you can see in Fig. 2.6, the trend continues throughout the experiment, and the decline in talking cannot be attributed to the treatment.

A downward (or upward) drift in baseline may be acceptable if the treatment is expected to produce an opposite trend. For example, a shy child may show a declining trend in talking to other students. In this case, an intervention could involve reinforcing the initiation of conversation by the child. Because the treatment is expected to increase talking, the
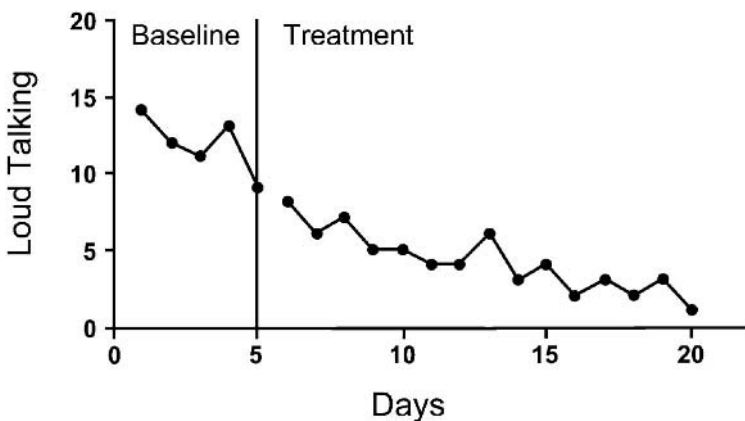
FIG. 2.6. *A drift in baseline measures can make interpreting results difficult when the treatment is expected to produce a change in the same direction as the baseline drift.*

downward trend in baseline is acceptable. Generally, single-subject research requires a large shift in level or direction of behavior relative to the baseline. This shift must be clearly observed when the independent variable is introduced and withdrawn.

KEY WORDS

A–B–A–B reversal design
Baseline
Conditioned-stimulus
    function
Context of behavior
Contingency of
    reinforcement
Dependent variable
Direct replication
Discriminative function
Discriminative stimuli
Elicited
Emitted
Environment

Establishing operation
External validity
Functional analysis
Generality
History (with regard to
    validity in experiments)
History of reinforcement
Hypothetical constructs
Independent variable
Instrument decay (validity)
Internal validity
Maturation
Negative reinforcers
Operant

Positive reinforcers
Reactive measurement
Reinforcement function
Respondent
Response classes
Response function
Single-subject research
Stimulus class
Stimulus function
Structural approach
    (to classifying behavior)
Systematic replication
Topography
Trend (as in baseline)

ON THE WEB

http://www.envmed.rochester.edu/wwwrap/behavior/jeab/jeabhome.htm The homepage for the *Journal of the Experimental Analysis of Behavior* (JEAB)—a journal that illustrates the experimental method discussed in chapter 2. Early issues of the journal are helpful in terms of basic design (A–B–A–B reversal).

http://www.envmed.rochester.edu/wwwrap/behavior/jaba/jabahome.htm The web page for the *Journal of Applied Behavior Analysis* (JABA)—a journal that is devoted to the

application of behavior principles. The articles often illustrate the basic designs used in behavior analysis, especially earlier issues of the journal.

http://www-personal.umich.edu/~hinderer/scrdrefs.htm A site maintained by Kathy Hinderer that supplies categorized references to single-case research designs and provides references to articles that appear in JEAB or JABA related to experimental design.

http://www.dharma-haven.org/science/myth-of-scientific-method.htm A site maintained by Terry Halwes, who argues that scientists deviate in important ways from the logical hypothesis-testing view taught in most scientific methods books. He states that "the procedure that gets taught as 'The Scientific Method' is entirely misleading. Studying what scientists actually do is far more interesting."

STUDY QUESTIONS

1. Define the term functional analysis. (27) Discuss the difference between structural and functional accounts of behavior and provide a human example based on the textbook. (27–28)

2. Discuss the classification of behavior in terms of response functions, pointing to respondent and operant functions. (28–29) How does the concept of response class aid in a functional analysis of behavior? (29)

3. What is the difference between the external and the internal environment for a functional analysis? (30) Discuss the classification of the environment based on stimulus functions. (30) Give an example from the textbook on discrimination and how stimulus functions may change. (30) Discuss the difference between physical and functional dimensions of stimuli. (30–31)

4. **ADVANCED ISSUE:** Be able to talk about perception as behavior. Discuss the traditional view of perception and contrast it with a behavior-analysis perspective. (31–32) Outline the Stroop effect, the cognitive explanation, and how behavior analysis accounts for it. (32) Talk about seeing as respondent and/or operant behavior. (32–33) Describe conditioned seeing as described by Skinner and how a person may respond to incomplete rings as if they were closed circles. (33) What are the behavioral effects of operant seeing, as when reinforcement is arranged for seeing four-leaf clovers? (33) Analyze Gibbons' account of spying wild asparagus shoots as conditioned seeing. (33–34)

5. Discuss the importance of stimulus class for a functional analysis. (34) Analyze a mother's face in terms of a stimulus class. (34) In English, words like *boring* and *uninteresting* are said to have the same meaning. Provide a stimulus class interpretation of "meaning." (34) Apply the concept of stimulus class to the analysis of reinforcing stimuli. (35)

6. Define establishing operations in terms of Michael's (1982a) two major effects. (35) Use the term establishing operations to show that behavior–environment relationships depend on context. (35) Discuss television commercials, attitude, and establishing operations. (35)

7. What is experimental analysis according to Claude Bernard? (36) Outline Bernard's observation about rabbits' urine. (36) What hypothesis did he formulate? (36) How did he test his hypothesis? (36) Be able to talk about Claude Bernard's method of experimental analysis using the discussion in the textbook. (36–37) How does Fig. 2.2 show that fasting rabbits are transformed into "veritable carnivorous animals"? (37–38)

8. Define an independent and dependent variable. (37) What are three conditions that must be satisfied to show a cause–effect relationship between X and Y variables? (38) How did Bernard eliminate rival explanations for the acidity of the rabbits' urine? (38)

9. Discuss an A–B–A–B reversal design and some problems with reversal experiments. (38–39) Discuss the Goetz and Baer (1973) experiment as a modified example of the reversal design. (39) What is the theoretical importance of the Goetz and Baer research in terms of an experimental analysis of creativity? (39) Point to the difficulties of the A–B–A–B reversal design. (40)

10. **FOCUS ON:** What is a typical response to experimental research with animals? (40) Define the internal validity of an experiment. (41) Define the external validity of an experiment. (41) Discuss the internal validity of Ayllon's (1963) experiment, referring to three possible sources of invalidity. (41–43) Discuss problems of reactive measurement, Ayllon's (1963) experiment, and external validity. (44) How is Ayllon's (1963) study viewed as a generalizing experiment? (44) Discuss the correspondence between laboratory findings and the behavior of organisms in everyday life. (45) Explain the tradeoff between internal and external validity. (45)

11. What is meant by single-subject research? (45) Discuss direct and systematic replications of single-subject experiments. (45–46) What establishes the generality of single-subject research? (46)

12. How does single-subject research allow for assessment of behavior change? (46–47) Talk about defining the response class, measuring variability, baselines, and assessing behavior change. (47)

13. How does variation in baseline measures affect the assessment of behavior change? Refer to Fig. 2.5 in your answer (47–48) Outline ways to detect behavior change when baselines are highly variable or "noisy." (47–48)

14. Discuss baseline trend as a problem for the assessment of behavior change. Refer to Fig. 2.6 in your answer. (48–49)

BRIEF QUIZ

1. In terms of finding an object that is missing or hidden
   (a) a structural account points to stages of development and object permanence
   (b) a behavioral account points to a particular history of reinforcement
   (c) the form or structure of behavior is used by behavior analysts to infer mental stages
   (d) both a and b

2. The term _____ refers to behavior that is elicited, and the term _____ refers to behavior that is emitted.
   (a) operant; respondent
   (b) respondent; operant
   (c) reflexive; flexible
   (d) flexible; reflexive

3. Any stimulus (or event) that follows a response and increases its frequency is said to have
   (a) a reinforcement function
   (b) a discriminative function

(c) a conditioned-stimulus function
(d) a consequence function

4. **ADVANCED ISSUE:** In terms of the Stroop effect, behavior analysts point to _____ and _____ as reasons for hesitation.
   (a) response competition; learning
   (b) learning; reinforcement
   (c) response competition; history of reinforcement
   (d) history of reinforcement; memory

5. In functional analysis, positive and negative reinforcers are examples of
   (a) response classes
   (b) stimulus classes
   (c) conditioned stimuli
   (d) unconditioned stimuli

6. In terms of behavior–environment relations, establishing operations
   (a) are used to construct the foundations of behavior
   (b) increase the momentary effectiveness of reinforcement
   (c) increase momentarily responses that produce reinforcement
   (d) both b and c

7. The variable manipulated by the experimenter is the _____, and the measured effect is the _____.
   (a) dependent; independent
   (b) extraneous; dependent
   (c) independent; dependent
   (d) independent; extraneous

8. In terms of the reversal design and behavioral experiments
   (a) the A-phase is called the baseline
   (b) the B-phase is the experimental manipulation
   (c) the design is used in single-subject experiments
   (d) all of the above

9. When many extraneous variables are ruled out by an experimental design, the experiment is high on
   (a) generality
   (b) external validity
   (c) internal validity
   (d) correspondence with reality

10. The presence of trend in baseline measures
    (a) refers to a systematic rise or decline of the baseline values
    (b) is problematic when the treatment is expected to produce a change in the direction of the trend
    (c) can be helpful when inferring that an independent variable has produce and effect
    (d) both a and b

Answers to brief quiz (*page*): d(27–28); b(28–29); a(30); c(32); b(35); d(35); c(37); d(38); c(41); d(48)

Reflexive Behavior and Respondent Conditioning

IN THIS CHAPTER

1. Learn about fixed action patterns and reaction chains.
2. Find out about the primary laws of the reflex and the phenomenon of habituation.
3. Study Pavlov's experiments on respondent conditioning of salivation.
4. Learn about the complexities of second-order and compound conditioning.
5. Discover the basis of drug tolerance and the effects of context on drug overdose.

A biological imperative, faced by all creatures, is to survive long enough to reproduce. Because of this, behavior related to survival and reproduction is often built into the organism. That is, organisms come into the world with a range of behavior that aids survival and reproduction. Creatures that fly to avoid predators are likely born with the ability to fly. Thus, flying does not need to be learned; it results from the organism's species history. The complex array of motor movement and coordination involved in flying could be learned, but it is much more dependable when this behavior is based on genetic endowment.

For most animals, survival at birth depends on being able to breathe, digest food, and move about. When a worm is dangled over a young robin's head, this stimulus evokes opening the mouth and chirping. The behavior of the chick is the result of biological mechanisms and is released by the sight of the dangling worm. The relationship between the dangling worm (stimulus) and the open mouth (response) is a reflex. Presumably, in the evolutionary history of robins, chicks that presented a gaping mouth and chirped were fed, and those that did not may have been ignored. In humans, reflexive crying by an infant ensures more effective care from the child's parents. Parents engage in a variety of caretaking behaviors in attempts to stop crying. Usually, parental responses such as changing a wet diaper, feeding, or burping the infant will stop the fussing.

Phylogenetic Behavior

Behavior relations that are based on the genetic endowment of an organism are called **phylogenetic** and are present on the basis of species history. Behavior that aids survival or procreation is often (but not always) unlearned. This is because past generations of organisms that engaged in such behavior survived and reproduced. These animals passed (to the next generation) the characteristics that allowed similar behavior. Thus, species history provides the organism with a basic repertoire of responses that are evoked by environmental conditions. Darwin said these characteristics were naturally selected, since they occurred through no action or intervention by man.

Sequences of Behavior

Fixed action patterns or **FAPs** are sequences of behavior (a series of of connected move-ments) that are phylogenetic in origin. All members of a particular species (often all males or all females) engage in the FAP when the appropriate releasing stimuli are presented. Fixed action patterns have been observed and documented in a wide range of animals and over a large number of behaviors related to survival and reproduction. To illustrate, Tinbergen (1951) noted that the male stickleback fish responds with a stereotyped sequence of aggressive displays and movements when other male sticklebacks intrude on its territory during mating season. The female spider *Cupiennius salei* constructs a cocoon and deposits her eggs in it by engaging in a fixed sequence of responses (Eibl-Eibesfeldt, 1975). A greylag goose presented with an egg outside its nest will automatically roll the egg into the nest by reaching over the egg (with its bill) and pulling it carefully toward the nest. If the egg is removed, the bird continues with the fixed sequence of egg-retrieval actions. That is, the bird continues behaving as though the egg is present even though it has been removed. The following passage describes the fixed action pattern that the squirrel *Sciurus vulgaris L.* engages in while putting nuts away for the winter:

> The squirrel . . . buries nuts in the ground each fall, employing a quite stereotyped sequence of movement. It picks a nut, climbs down to the ground, and searches for a place at the bottom of a tree trunk or a large boulder. At the base of such a conspicuous landmark it will scratch a hole by means of alternating movements of the forelimbs and place the nut in it. Then the nut is rammed into place with rapid thrusts of the snout, covered with dirt with sweeping motions and tamped down with the forepaws. (Eibl-Eibesfeldt, 1975, p. 23)

Ethologists refer to such predictable and stereotypic behaviors as fixed action patterns to imply that these behaviors are built-in and imutable. They are looking for heritable genetic-based factors with which to account for behavior. On the other hand, the behavior science model prefers to consider all behaviors as both flexible and adaptable, at least to some degree. So, given the adaptive ability of most animals, we refer to this behavior as *flexible action patterns*. Although the major topographic features of these types of reflex combinations may appear very similar across individuals and situations, there are numerous idiosyncratic differences that show flexibility. For example, all robins (*Turdas Americanis*) build nests that appear very similar in construction. But, it is clear they do not all build in the same location, or use the same materials. There is great individual variation in all phases of nest construction, suggesting modification by the environment (ontogeny).

   Reaction chains are similar to FAPs with one major difference: Each response in a **reaction chain** requires an appropriate stimulus to set it off. Recall that once a fixed action pattern begins, the animal will continue the sequence even when the stimuli that set off the behavior are removed. In the previous squirrel example, if the nut is taken away from the squirrel, the animal will continue to dig a hole and bury a nonexistent nut. In contrast, a reaction chain requires the presence of a specific stimulus to evoke each link in a patterned sequence of behavior. An organism's performance produces stimuli that set off the next set of responses in the sequence; these behaviors produce the next set of stimuli and so on. Presenting stimuli that prompt responses ordinarily occurring in the middle part of the sequence will start the chain at that point rather than at the beginning. Also, unlike fixed action patterns, if the stimuli that evoke behavior are removed, the sequence is disrupted (Fig. 3.1). Reaction chains are much like consecutive sets of reflexes where the stimuli that elicits the next response in the sequence is produced by the previous reflex. The nursing reaction chain of newborn babies is diagrammed in Fig. 3.1. This sequence of reflexive responses may be initiated by tactile stimulation of the infant's cheek. This stimulation
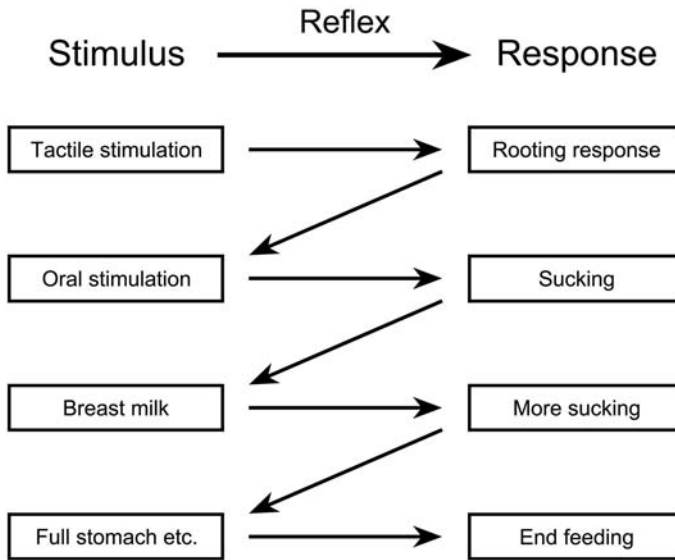
FIG. 3.1.   *The nursing reaction chain of newborn babies is diagrammed. This sequence of reflexive responses is initiated by tactile stimulation of the infant's cheek. Stimulation of the cheek elicits the unconditioned rooting response that involves turning the head toward the nipple, opening the mouth, etc.*

elicits the unconditioned rooting response, which involves turning the head toward the stimulation, opening the mouth, etc. Rooting results in mouth contact with the nipple; this oral stimulation in turn elicits sucking. Sucking produces breast milk in the infant's mouth, leading to further sucking. Eventually, internal stimuli arising from a full stomach, changes in blood chemistry, and so on end the sequence, and the baby stops feeding. (Note: when we discuss operant behavior and operant conditioning in a later chapter, we also speak of response chains; but in this case the sequences are learned and are described as interlocking three-term contingencies.)

Reflexive Behavior

The principles that describe the reflex (and its conditioning) are similar for many different kinds of reflexes. For example, the laws that govern pupil contraction when a light is shined in the eye or principles describing the relationship between a sudden loud noise and a startle response also hold for the salivation produced when you eat a meal. Early work by Sherrington (1906) focused on the reflex and the behavioral laws that he discovered, almost a century ago, still apply to a remarkable variety of stimulus–response relationships. When food is placed in a dog's mouth, the salivary glands produce saliva. This relationship between food in the mouth and salivation is a reflex that is based on the genetic endowment of the organism and is not learned. Many reflexes serve defensive, protective, or survival functions. Frequently such reflexes are not learned because they have to function before adequate experience is provided.

All organisms are born with a built-in set of reflexes, but many are particular to a species. Thus, humans are born with an array of responses that are elicited by specific stimuli. As illustrated earlier, tactile stimulation of the human infant's cheek evokes the rooting

response—turning toward the stimulation with mouth open which then receives the nipple. Also, as we have noted, in young robins, the so-called "begging" reflex (open mouth and chirping) serves a similar function—getting fed. Because these relationships are relatively invariant and biologically based, we refer to the eliciting event as the **unconditioned stimulus (US)**. The related behavior following the stimulus is called the **unconditioned response (UR)**. The term *unconditioned* is used because the reflex does not depend on an organism's experience or conditioning during its lifetime (i.e., learning).

When an unconditioned stimulus elicits an unconditioned response (US → UR), the relationship is called a **reflex.** Reflexive behavior is automatic in the sense that a physically healthy organism will always produce the unconditioned response when presented with an unconditioned stimulus. You do not choose whether to salivate when you have food in your mouth; the US, which is; "food in the mouth" draws out or **elicits** the UR of salivation. This is the way the animal (you) is built. However, there are times and conditions described in the following where the US does not elicit the UR. When repeated presentations of the US lead to a reduction of the UR, we call that process *habituation*.

Laws of the Reflex

Aristotle about 350 b.c. developed principles of association that were re-discovered by psychologists, and in the 1900s by Pavlov a physiologist (Hothersall, 1990, p. 22). Sherrington (1906) studied many different types of reflexes and formulated the laws of reflex action. Because reflexive behavior occurs across most or all animal species from protozoa (Wawrzyncyck, 1937) to humans (Watson & Rayner, 1920) and because associative or respondent conditioning builds on reflexive behavior, it is important to describe the laws of the reflex. The laws are general in that they hold for all eliciting or unconditioned stimuli (e.g., food in the mouth, a touch of a hot surface, a sharp blow just below the knee, a light shining in the eye) and the corresponding unconditioned responses (salivation, quick finger withdrawal, an outward kick of the leg, pupil contraction).

The unconditioned stimuli that elicit unconditioned responses may vary in intensity. For example, light that is shining in the eye may be bright enough to hurt or so faint that it is difficult to detect. A tap below the knee, causing a kick, may vary from a modest to a heavy blow, etc. The intensity of the eliciting US has direct effects on the elicited reflex. These effects are described by the three **primary laws of the reflex.**

1. **The law of the threshold** is based on the observation that at very weak intensities a stimulus will not elicit a response, but as the intensity of the eliciting stimulus increases there is a point at which the response is evoked. That is, *there is a point below which no response is elicited and above which a response always occurs*. The uncertainty region, where roughly 50% of the stimuli that are presented produce a response, is called the threshold.

2. **The law of intensity–magnitude** describes the relationship between the intensity of the eliciting stimulus and the size or magnitude of the evoked response. *As the intensity of the US increases so does the magnitude of the elicited UR*. A light tap on the patella tendon (just below the kneecap) will evoke a slight jerk of the lower leg; a stronger tap will produce a more vigorous kick of the leg (the patella reflex). Of course, there are upper limits to the magnitude of the tap. If a hammer is used to smash into the knee, the result is a broken kneecap and no movement for a long time.

3. **The law of the latency** concerns the time between the onset of the eliciting stimulus and the appearance of the reflexive response. Latency is a measure of the amount

of time that passes between these two events. *As the intensity of the US increases, the latency to the appearance of the evoked UR decreases.* Thus, a strong puff of air will elicit a quick blink of the eye. A weaker puff will also elicit an eye blink, but the onset of the response will be delayed.

These three laws of the reflex are basic properties of all reflexes. They are called primary laws, because taken together they define the relationship between the intensity of the eliciting stimulus (US) and the unconditioned response (UR). Reflexes, however, have other characteristics, and one of these, habituation, has been shown in animals as simple as protozoa and as complex as humans.

Habituation

One of the better documented secondary properties of the reflex is called **habituation.** Habituation is observed to occur when an unconditioned stimulus repeatedly elicits an unconditioned response and the response gradually declines in magnitude. When the UR is repeatedly evoked, it may eventually fail to occur at all. For example, Wawrzyncyck (1937) repeatedly dropped a 4-g weight onto a slide that the protozoa *Spirostomum ambiguum* was mounted on. The weight drop initially elicited a contraction, startle response, that steadily declined to near zero with repeated stimulation.

An interesting report of human habituation, in a dangerous setting, appeared in the July 1997 issue of *National Geographic*. The small island of Montserrat has been home to settlers since 1632. Unfortunately, the relatively silent volcano on the island reawakened in July 1995. Suddenly the quiet life that characterized living on Montserrat was rudely interrupted. Before the major eruption of the volcano, a large group of inhabitants refused to evacuate the island, and these people suffered through several small volcanic explosions.

> . . . Gerard Dyer and his wife, Judith, [have] been staying with friends in St. John's, about as far north of the volcano as you can get. . . . People could get passes to visit the unsafe zone, which is how Gerard came to be working on the flanks of Soufriere Hills that bright morning.
>
>   "If you have animals and crops, you can't just leave them" said Gerard as we walked back to his truck. "You have to come look after them and hope nothing happen." As he spoke, the volcano made a crackling sound like distant thunder—blocks of solid lava rolling down the side of the dome. Gerard didn't even look up.
>
>   Montserratians have become so used to the volcano's huffing and puffing that the initial terror has gone. As one woman said, "At first when there was an ashfall, everybody run. Now when the ash falls, everybody look." (Williams, 1997, p. 66)

In this example, Gerard has been repeatedly exposed to the sound (US) of minor volcanic explosions. At first, this sound elicited a startle/panic response, accompanied by running, but these URs habituated to near zero with repeated eruptions of the volcano. A similar process is observed when people live under an airport flight path; initially the sound of a jet taking off or landing is bothersome, but after some time the sound is barely noticed.

There are a number of general properties that characterize habituation (Thompson & Spencer, 1966). Some of the more important principles of habituation are: (a) The decrease in the habituated response is large at first, but this decrement gets progressively smaller as habituation is continued. (b) If the unconditioned stimulus is withheld for some time, the habituated response recovers. (c) When habituation is repeatedly produced, each series of stimulus presentations generates progressively more rapid habituation. In other words, habituation occurs more quickly on a second series of unconditioned stimulus presentations than on the first, then even faster on a third set and so on.

Habituation is a behavioral process that has come about because of phylogenetic history. Those animals that habituated were more likely to survive and produce offspring. A herbivore that runs away each time the grass rustles gets less to eat than one that stands its ground. A rustling grass sound may indicate the presence of a predator, or simply the wind blowing. Repeated activation of respondent mechanisms, when unnecessary, stresses the animal as well, which is not good in terms of health and physiology.

At the physiological level, habituation is possible because of the way the reflex arc is constructed. To explain, a sensory neuron with a sensory transducer enters the spinal cord and synapses onto a motor neuron. When activated by a touch, for example, the sensory neuron generates an action potential in an effector neuron across a synapse that in turn causes muscle or gland activity. Synapses have many inputs, some of which are excitatory and some that are inhibitory. The presence of the synapse between sensory and motor neurons allows for the presence of inhibitory input and habituation of the UR.

Ontogenetic Behavior

In addition to phylogenetic history, the behavior of an organism is affected by environmental experience. Each organism has a unique **ontogenetic** history or lifetime of conditioning. Change in behavior as a result of such experience is called *learning* and consists of behavior–environment interactions with events in the physical and social world. Learning builds on species or *phylogenetic* history to determine when, where, and what kind of behavior will occur at a given moment.

For example, salivation is involved with the digestion of food. People do not learn to salivate at the taste of food; this is a phylogenetic characteristic of the species. After some experience, however, you may salivate at the sight of the golden arches of McDonald's, especially if you are hungry and like hamburgers. Salivating at the sight of McDonald's arches occurs because of respondent conditioning. It is, however, important to note that respondent conditioning (and other learning processes) evolved because it provided some sort of reproductive advantage. Those organisms whose behavior came under the control of arbitrary (but important) environmental events presumably survived and reproduced. Through evolution and selection, respondent conditioning became a means of behavioral adaptation. In other words, organisms with a capacity for respondent learning were more likely to survive and reproduce.

Respondent Conditioning

Respondent conditioning involves the transfer of the control of behavior from one stimulus to another (or S–S pairing). In chapter 1, we saw that the sound of a bell could come to elicit salivation when the bell was associated with food. This kind of conditioning occurs in many species, including humans, and is common in everyday life. Imagine you are out for an early morning walk and pass a bakery where you smell fresh doughnuts. When this happens, your mouth begins to water and your stomach starts to growl. These conditioned responses occur, because in the past the smell has been associated (paired) with food in the mouth (doughnuts).

Figure 3.2 shows the classical conditioning of salivation described by Pavlov (1960). The upper panel indicates that an arbitrary stimulus such as a light (CS) is presented just before
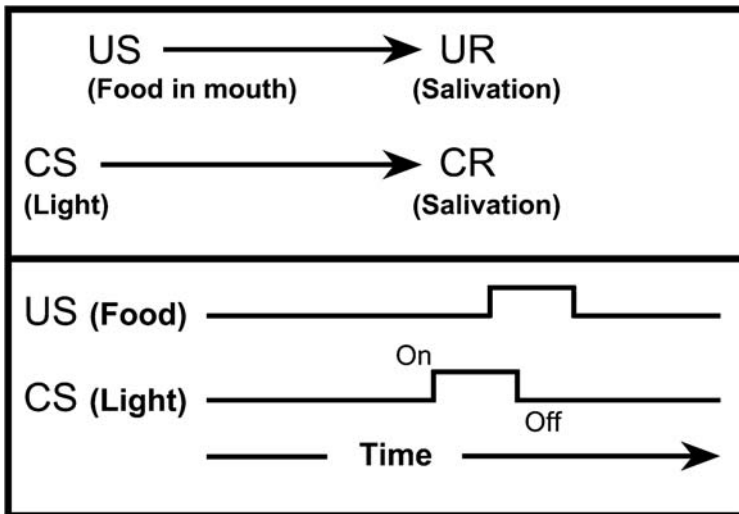
FIG. 3.2. *Simple respondent conditioning. An arbitrary stimulus such as a light (CS) is presented just before food is placed in a dog's mouth (US). After several pairings of light and food, the light is presented alone. If the light now elicits salivation, it is called a conditioned stimulus (CS), and salivation to the light is a conditioned response (CR).*

food (US) is placed in a dog's mouth. After several pairings of the light with the food, the tone is presented alone. If the light now elicits salivation (test phase), it is called a **conditioned stimulus** (CS), and salivation to the light is called the **conditioned response** (CR).

Notice that a new feature of the environment (a light) has come to regulate the behavior (salivation) of the organism. Thus, classical (Pavlovian or respondent) conditioning involves the transfer of behavior control to new and often arbitrary aspects of the environment. To experience this sort of conditioning, try the following: Read the word *lemon* and consider the last time you ate a slice of lemon. Many people salivate at this CS because the word has been contiguously paired with the sour taste of the fruit. This shift in controlling stimulus from food to word is possible because of the anatomy, described previously, involving the critical synapse onto the final common neural pathway. In this case, input to the visual system ends up activating the neuron that innervates the salivary gland.

Because the CR is a response elicited by the CS, it is often called a **respondent.** The terms *conditioned response* and *respondent* are interchangeable throughout this text. The process of presenting stimuli together in time (pairing or associating stimuli) so that a CS comes to regulate the occurrence of the conditioned response is called **respondent conditioning.** Technically, respondent conditioning involves establishing a conditional probability between the CS and US (the occurrence of the US is conditional on the presence of the CS).

Note that the association is between the CS and US (i.e., the word *lemon* and the real fruit in the mouth), because they have been physically presented together at some time in the past—not because of some cognitive (internal mental) association of events. This is an important point: The word "association" is sometimes taken to mean an internal mental process that either a person or other animal performs. We hear people say, "the dog salivates when the bell is sounded because it has associated the sound with the food." In contrast, a behavior analyst points to the physical association of stimuli (CS and US) that occurred in the past. In other words, the association is between events—it does not refer to mental

associations. The word *lemon* (CS) elicits salivation (CR), because the word has occurred at a time and place when the chemistry of a lemon (US) produced salivation (UR).

Respondent Acquisition

When a conditioned stimulus (CS) is repeatedly paired with an unconditioned stimulus (US), the CS gains in control over the conditioned response (CR). The increase in the CR to the presentation of the CS is called **respondent acquistion.** In one experiment, Anrep (1920) demonstrated the conditioning of the salivary reflex to a tone stimulus. The acquisition procedure involved turning on the tone for a brief period and then placing food in a dog's mouth. Anrep measured the conditioned response as the number of drops of saliva during 30-s intervals wherein the tone occurred without food. Figure 3.3A (acquisition) shows that the amount of salivation to the tone increases rapidly during the first 25 trials and then levels off, or reaches its maximum called the asymptote. In other words, with repeated pairings of the CS and US, the magnitude of the conditioned response increases. Once the conditioned reflex reaches asymptote, however, further CS–US pairings have no additional effects.

It is important to note that the asymptote for the conditioned response depends on the intensity of the unconditioned stimulus. As the intensity of the US increases, the magnitude of the UR also increases up to a point. The magnitude of the UR limits the maximum strength of the CR. For example, the more food that a dog is given, the greater the amount of salivation. If a dog is given 2 oz of meat, there will be more salivation than if it is presented with 1 oz. A tone that is associated with 2 oz of food will elicit salivation as a
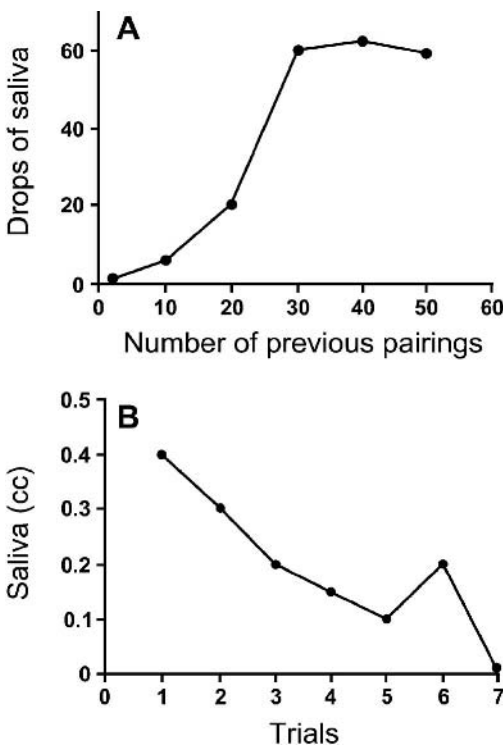
FIG. 3.3.   *The acquisition and extinction of salivation. The acquisition curve (A) is taken from an experiment by Anrep (1920), who paired a tone (CS) with food placed in a dog's mouth (US). The extinction curve (B) is from Pavlov (1960, p. 53), who presented the CS (sight of food) in the absence of the US (food in the mouth). Results are portrayed as a single experiment.*

CR at a higher level (at asymptote) than a tone associated with 1 oz of food. It is clear that these relationships are limited by an organism's physiology. If a dog is given 1 lb of steak, it will probably salivate at maximum strength, and a change to 2 lb will have no further effect. Similar limits are observed for reflexes such as variation in pupil size in response to light, magnitude of the knee jerk in response to a tap, and the degree of startle in response to noise.

Conditioned and Unconditioned Responses

Notice that the conditioned response of salivation appears to be identical to the unconditioned response. That is, when conditioning to the tone has occurred, turning it on will elicit salivation. This response to the tone seems the same as the salivation produced by food in the dog's mouth. In fact, early theories of learning held that the tone substituted for the food stimulus. This implies that the CS–CR relationship is the same as the US–UR relation. If the CS–CR and the US–UR relationships are the same, then both should follow similar laws and principles. The US–UR relation, as you will recall, is governed by the *laws of the reflex.*

If the CS–CR and US–UR relationships are the same, then the law of intensity magnitude should hold for conditioned stimuli and responses. That is, a rise in the intensity of the CS should increase the magnitude of the CR. In addition, the CS–CR relation should follow the law of latency. An increase in the intensity of the CS should decrease the latency between the CS onset and the conditioned response. Research has shown that these, and other laws of the reflex, typically do not hold for the CS–CR relation (Millenson, 1967). Generally, a change in the intensity of the conditioned stimulus decreases the strength of the conditioned response. In Anrep's (1920) experiment, the tone occurred at a particular intensity, and after conditioning it evoked a given magnitude and latency of salivation. If Anrep had increased the sound, there would have been less salivation and it would have taken longer to occur. Thus, the CS–CR relation is specific to the original conditioning and does not follow the laws of the reflex. One reason is that the CS–CR relationship involves processes such as respondent discrimination (see following).

Respondent Extinction

Pavlov (1960) reported a very simple experimental procedure that he called **respondent extinction.** The procedure involves repeatedly presenting the CS in the absence of the US. Figure 3.3B (extinction) shows the decline in salivation when Pavlov's assistant, Dr. Babkin, repeatedly presented the CS but no longer fed the dog. As you can see, the amount of salivation declines and reaches a minimal value by the seventh trial. This minimum level of the CR is often similar to the value obtained during the first trial of acquisition and probably reflects the **respondent level** of this behavior. Respondent level, or baseline, refers to the strength of the target response (e.g., salivation) before any known conditioning has occurred.

A distinction should be made between extinction as a procedure and extinction as a behavioral process. The procedure involves presenting the CS but not the US after conditioning has occurred. As a behavioral process, extinction refers to the decline in the strength of the conditioned response when an extinction procedure is in effect. In both instances, the term *extinction* is used correctly. Extinction is the procedure of breaking the CS–US association, resulting in the decline of the CR.

The decline in the strength of the CR is often rapid. This statement is true for the conditioning of salivation, but other types of conditioned responses may vary in resistance
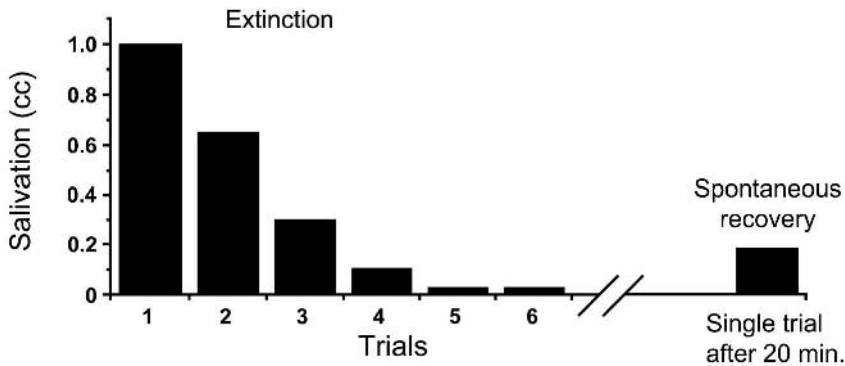
FIG. 3.4. *Extinction and spontaneous recovery of salivation evoked by the sight of meat powder (Pavlov, 1960) (data replotted from Bower & Hilgard, 1981, p. 51).*

to extinction. Even with salivation, Pavlov noted that as the time between test trials increased, the CR declined more slowly. A test trial is any instance in which the CS is given in the absence of the unconditioned stimulus. Of course, repeated test trials are the same as extinction. The slower extinction of salivation with longer intervals between test trials may reflect what is called spontaneous recovery.

Spontaneous Recovery

Spontaneous recovery is the observation of an increase in the conditioned response after respondent extinction has occurred. Recall that after repeated presentations of the CS without the US, the conditioned response declines to respondent level. Following extinction, after some time passes, the CS will again evoke the CR, and the more time that passes between the first and second extinction sessions the more the increase in the conditioned response (Brooks & Bouton, 1993).

The typical effect is seen in Fig. 3.4, which shows the course of extinction and spontaneous recovery from another experiment by Pavlov (1960). In this experiment, the CS was the sight of meat powder, and the US was food in the dog's mouth. As you would expect, the sight of meat powder eventually elicited a conditioned response of salivation. When extinction began, the dog responded with 1 cc of salivation at the sight of the CS. By the fifth extinction trial, the animal showed almost no salivation to the sight of food powder, but after 20 min of rest with no stimulus presentations, the CS again evoked a conditioned response. Note, however, that the amount of salivation on the spontaneous-recovery trial is much less than the amount evoked on the first extinction trial.

Pavlov (1960) argued that spontaneous recovery shows little weakening of the CS–CR relationship during extinction. He went on to suggest that "internal inhibition" came to block the connection between stimuli and responses. Pavlov viewed conditioning phenomena as an index of brain processes, and in this regard saw behavior as a reflection of central nervous system functioning. In this sense, spontaneous recovery reflected underlying physiological processes, and one of these was an active but temporary "dampening" of associative connections between the CS and the conditioned response. Pavlov called this apparent physiological blocking of the CS–CR relationship "internal inhibition."

In contrast to Pavlov's physiological account, a behavioral analysis of spontaneous recovery suggests that the CS–CR relation is weakened by extinction, but the context and/or

features of the situation maintain some level of the conditioned response. During respondent conditioning, many stimuli not specified by the researcher as the CS, but present in the experimental situation, come to regulate behavior. For example, background odors, general illumination of the room, the presence of particular researchers, the passage of time, and all the events that signal the start of a conditioning series come to exert some control over the conditioned response. Each time a recovery test is made, some part of the situation that has not yet been extinguished evokes the CR. This gradual decline in contextual stimulus control through repeated extinction also accounts for progressively less recovery of the conditioned response.

Respondent Generalization and Discrimination

Generalization

Pavlov conducted a large number of conditioning experiments and discovered many principles that remain useful today. One of his important findings concerned the principle of respondent generalization. **Respondent generalization** occurs when an organism shows a conditioned response to values of the CS that were not trained during acquisition. For example, respondent acquisition will occur when a specific stimulus, such as a 60-dB tone at a known frequency (e.g., 375 Hz), is associated with a US (e.g., food). After several pairings, the CS elicits a conditioned response, in this case salivation. If a 60-dB tone of 375 Hz is now presented without the US (a test trial), the animal will salivate at maximum level. To show generalization, the researcher varies some property of the conditioned stimulus. For example, a 60-dB tone of 75, 150, 225, 300, 375, 450, 525, 600, and 675 Hz is presented on test trials, and the magnitude of the conditioned response is measured. Figure 3.5 shows the possible results of such an experiment. As you can see, the amount of salivation declines as the test stimulus departs from the value used in training. This graph, which plots stimulus value against magnitude of response, is called a **generalization gradient.**
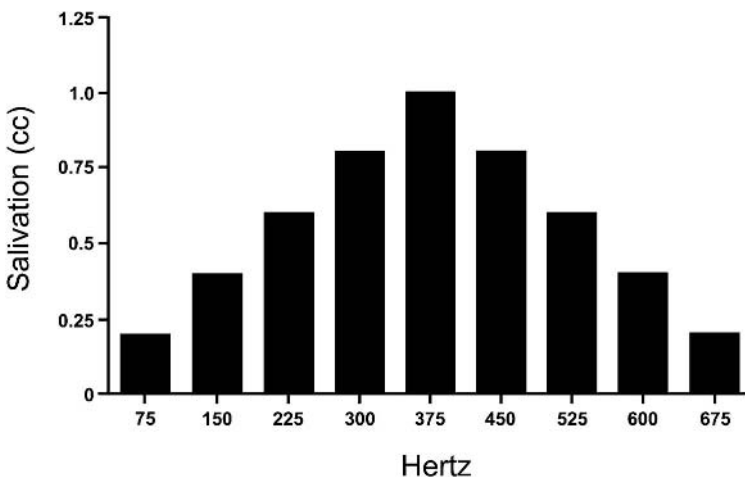
FIG. 3.5. *A hypothetical generalization gradient for the salivary response. In this idealized experiment, training would occur at 375 Hz, and then CSs ranging from 75 to 675 Hz would be presented.*

Interestingly, a similar generalization gradient may not occur if the intensity rather than the tonal quality of the CS is varied. That is, if decibels rather than cycles per second (Hertz) are varied in the generalization test, a different result might occur. A few studies have shown that as the intensity of the CS increases, so does the magnitude of the conditioned response (Heinemann & Chase, 1970; Razran, 1949). Heinemann and Chase (1970) found that proportionally more conditioned responses were evoked as the visual intensity of the CS increased. Based on this finding, Heinemann and Chase suggest that there may be consistent increases in the strength of the CR as the intensity of the CS increases, although not all research has supported this finding (Ernst, Engberg, & Thomas, 1971). A conservative conclusion is that as the CS greatly departs from the value that was originally established, the conditioned response becomes weaker (see also Thomas & Setzer, 1972).

Generalization is an adaptive process that allows the organism to respond similarly even when conditions do not remain exactly the same from trial to trial. Consider a situation in which a predator's approach (US) is associated with the sound of snapping twigs, rustling grass, and so on (CS). An organism that runs away (CR) only in the presence of these exact stimulus conditions would probably not last long. This is because the events that occurred during conditioning are never precisely repeated—each approach of a predator produces variations in sounds, sights, and smells. Even in the laboratory where many features of the environment are controlled, there is some variation in stimuli from one trial to the next. When a bell is paired with food, the dog may change its orientation to the bell and thereby alter the sound; room humidity and other factors may also produce slight variations in tonal quality. Because of generalization, a CS–CR relationship can be strengthened even though the stimulus conditions are never exactly the same from trial to trial. Thus, generalization was likely an adaptive process, allowing organisms to respond to the vagaries of life.

Discrimination

Another conditioning principle that Pavlov discovered is called differentiation or discrimination. **Respondent discrimination** occurs when an organism shows a conditioned response to one stimulus but not to other similar events. This is a process at the other end of the continuum from generalization. A discrimination-training procedure involves presenting both positive and negative conditioning trials. For example, a positive trial occurs when a CS^+ such as a 60-dB tone is associated with an unconditioned stimulus like food. On negative trials, a 40-dB tone is presented (CS^-) but never paired with food. Because of stimulus generalization, the dog may salivate to both the 60-dB (CS^+) and 40-dB (CS^-) tones on the early trials. However, if the procedure is continued, the animal will no longer salivate to the CS^- (40-dB tone) but will show a response to the CS^+ (60-dB tone). Once such a differential response occurs, we may say that the dog discriminates between the tones.

Respondent discrimination is another adaptive process. It would be a chaotic world if an animal spent its day running away from most sounds, sights, and smells, generalizing to everything. Such an animal would not survive and reproduce because there would be no time for other essential activities, such as eating, drinking, and procreating. Discrimination allows an organism to budget its time and responses in accord with the requirements of the environment. In the predator example, noises that are reliably associated with an animal that considers you a main course should become CS^+ for flight or fight. Similar noises made by the wind or harmless animals are CS^- for such behavior. Notice, however, that there is a fine line between discrimination and generalization in terms of survival.

Temporal Relations and Conditioning

Delayed Conditioning

There are several ways of arranging the temporal relationship between the presentation of a CS and the unconditioned stimulus (US). So far we have described a procedure in which the CS is presented a few seconds before the US occurs. This procedure is called **delayed conditioning** (the presentation of the US is slightly delayed relative to the CS) and is shown in Fig. 3.6A.

Delayed conditioning is the most effective way to condition simple autonomic reflexes like salivation. In the diagram, the CS is turned on, and 3 s later the US is presented. The interval between the onset of the CS and the onset of the US (called the CS–US interval) determines the effectiveness of conditioning. For autonomic responses like salivation, blood pressure, skin temperature, hormone levels, sweat secretion, and so on, a CS–US interval between 5 and 30 s appears to be most effective. A brief CS–US interval of about 0.5 s seems to be optimal for the conditioning of quick skeletal responses such as a knee jerk, eye blinks, and retraction of a limb from a hot surface. In human eyeblink conditioning, a delay of 0.4 s between CS and US produces the fastest conditioning in young adults, but a longer delay of about 1 s is more effective with older people (Solomon, Blanchard, Levine, Velazquez, & Groccia-Ellison, 1991)
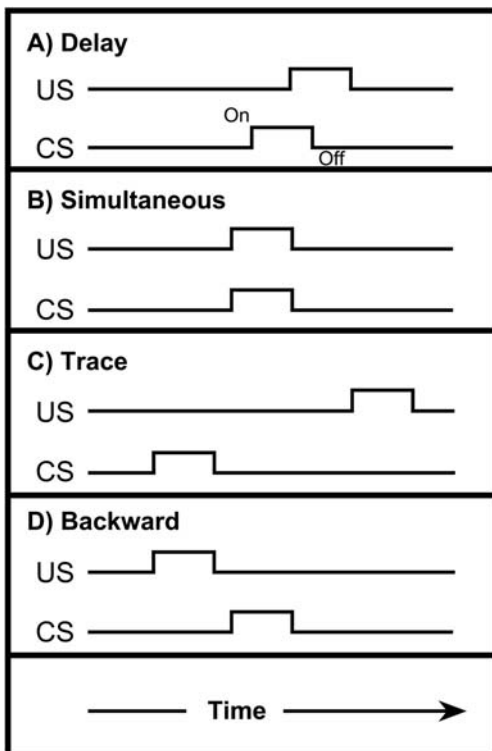
FIG. 3.6. *Several temporal arrangements between CS and US commonly used for simple respondent conditioning. Time is shown in the bottom panel of the figure and moves from left to right. The other panels depict the temporal arrangement between US and CS for four basic respondent conditioning arrangements. For example, delayed conditioning is shown in panel A, where the CS is turned on, and a few seconds later the US is presented.*

Simultaneous Conditioning

Another temporal arrangement is called **simultaneous conditioning**, where the CS and US are presented at the same time. This procedure is shown in Fig. 3.6B, where the CS and US are presented at the same moment. For example, at the same time that the bell rings (CS), food is placed in the dog's mouth (US). Compared to delayed conditioning, simultaneous conditioning produces a weaker conditioned response (Smith & Gormezano, 1965; White & Schlosberg, 1952). One way to understand this weaker effect is to note that the CS does not signal the impending occurrence of the US in simultaneous conditioning. Based on this observation, many researchers have emphasized the predictiveness of the CS as a central feature of classical conditioning (see Rescorla, 1966). That is, the CS works because it provides information that "tells" the organism a US will follow. In simultaneous conditioning, however, there can be no predictive information given by the CS, and yet some conditioning occurs. This suggests that predictiveness may facilitate conditioning but is not necessary for it (Papini & Bitterman, 1990).

Trace Conditioning

The procedure for trace conditioning is shown in Fig. 3.6C. The CS is presented for a brief period, on and off, and after some time the US occurs. For example, a light is flashed for 2 s, and 20 s later food is placed in a dog's mouth. The term **trace conditioning** comes from the idea of a "memory trace" and refers to the fact that the organism must remember the presentation of the CS. Generally, as the time between the CS and the US increases, the conditioned response becomes weaker (Ellison, 1964; Lucas, Deich, & Wasserman, 1981). For eyeblink conditioning (a puff of air in the eye US → an eyeblink UR), the response to the CS does not occur when the CS and US are separated by as little as 2 s (Schneiderman, 1966). When compared to delay conditioning with the same interval between the onset of the CS followed by the US, trace conditioning is not as effective, producing a weaker conditioned response. Recent research has extended trace conditioning to taste aversion learning (see chap. 7) and to biochemical changes that help to bridge stimulus associations over the trace interval (Misanin, Goodhart, Anderson, & Hinderliter, 2002).

Backward Conditioning

As shown in Fig. 3.6D, **backward conditioning** stipulates that the US comes on and goes off before the CS comes on. The general consensus has been that backward conditioning is unreliable, and many researchers question whether it occurs at all (but see Barnet & Miller, 1976; and Heth, 1976, for supportive views). It is true that backward conditioning usually does not produce a conditioned response. That is, if you place food in a dog's mouth and then ring a bell, the bell will not elicit the response of salivation when presented later. Most conditioning experiments have used arbitrary stimuli, such as lights, tones, shapes, and so on, as the conditioned stimulus. However, Keith-Lucas and Guttman (1975) found backward conditioning when they used a biologically significant CS.

These researchers reasoned that following an unsuccessful attack by a predator, the sights, sounds, and smells of the attacker would be associated with pain from the attack. Consider a situation in which a grazing animal is unaware of the approach of a leopard. The attack (US) comes swiftly and without warning (no CS). The animal survives the onslaught, turns in the direction of the leopard, and manages to run away. In this case, the pain inflicted

by the attack is a US for flight that precedes the sight of the predator (CS). For such a situation, backward conditioning would have adaptive value since the animal would learn to avoid leopards.

Keith-Lucas and Guttman (1975) designed an experiment to test this adaptive-value hypothesis. Rats were placed in an experimental chamber and fed a sugar pellet in a particular location. While eating the pellet, the rats were given a one-trial presentation of electric shock (US). After the shock, the chamber was made completely dark for 1, 5, 10, or 40 s. When the light in the chamber came back on, a toy hedgehog (CS) was presented to the rat. To make this experiment clear, eating sugar pellets was viewed as the laboratory equivalent of grazing, the shock represented an attack, and the appearance of the toy hedgehog substituted for the predator. Two control groups were run under identical conditions, except that one group saw the hedgehog but did not get shocked, and the other group got the shock but did not see a hedgehog.

On the next day, each animal was returned to the situation, and a number of responses were measured. Compared with the control groups, backward conditioning was found after a delay of 1, 5, and 10 s but not after 40 s. Relative to control animals, experimental subjects showed greater avoidance (fear) of the hedgehog, spent less time in the presence of the hedgehog, and ate less food. Presumably, the shock (US) elicited a fear–flight reaction (UR), and backward conditioning transferred this reaction to the toy hedgehog (CS). The fear induced by the hedgehog (CR) interfered with eating and produced avoidance of the toy animal. This experiment shows that with a biologically relevant CS, backward conditioning is possible. Despite this outcome, most researchers suggest that the backward arrangement of US then CS does not result in reliable conditioning (but see Cole & Miller, 1999; Siegel & Domjan, 1971; Tait & Saladin, 1986; for backward inhibitory conditioning; also see Arcediano & Miller, 2002, for timing and backward conditioning).

Second-Order Respondent Conditioning

So far we have considered only first-order conditioning. To briefly review, in first-order conditioning, an apparently neutral stimulus is paired with an unconditioned stimulus. After several such pairings, the control of the response to the US is transferred to the neutral stimulus, which is now called a conditioned stimulus (CS). Second-order conditioning extends this transfer of control to events that have not been directly associated with the unconditioned stimulus. These events gain control over the response because of their pairing with an established conditioned stimulus. Thus, **second-order conditioning** involves pairing a second CS_2 with an already functional CS_1, rather than pairing a CS and US (Rizley & Rescorla, 1972). Such higher order conditioning is important because it extends the range of behavioral effects produced by respondent conditioning, especially with regard to learning word meanings (Staats, 1975) and evaluative conditioning in humans (see De Houwer, Thomas, & Baeyens, 2001, for a review).

Some phobic reactions (i.e., a seemingly intense and irrational fear) people have may be caused by higher order conditioning. Consider a young lady who refuses to sit with friends in the backyard on a nice summer day. The sight of flowers greatly upsets her, and she says that "with so many flowers there are probably bees." A possible interpretation is that the person has been stung (US) by a bee (CS_1), and she has noticed that bees hover around flowers (CS_2). The fear of flowers occurs because of the pairing of bees (CS_1) with flowers (CS_2). Thus, phobic reactions and other emotional responses may sometimes involve higher order

respondent conditioning (see Martin & Pear, 1999, on systematic desensitization and the fear hierarchy).

Complex Conditioning and Compound Stimuli

We have so far examined CS and US relationships in isolation, ignoring for the most part the context or background in which these events occur. To investigate the effects of context on respondent behavior, researchers have arranged situations involving compound stimuli. In these cases, and to keep things somewhat simple, two conditioned stimuli (e.g., tone and light) are presented together before (delayed) or during (simultaneous) a US. This arrangement can be shown to acquire the capacity to elicit a single conditioned response. For example, the odor of food at a bakery or restaurant probably becomes a CS for salivation having been paired with doughnuts or burgers and fries (US). But other related stimuli like the name, the order clerk, the location of the store, and the outdoor signs are also paired with eating. These additional features of the fast-food experience become conditioned stimuli that function as the context (compound CS) that evokes salivation. Differences in conditioning procedures related to compound stimuli result in the behavioral processes of sensory preconditioning, blocking, and overshadowing.

Overshadowing

Pavlov (1927) first described overshadowing. A compound stimulus consisting of two or more simple stimuli are presented at the same time. For example, a faint light and a loud tone (compound CS) may be turned on at the same time and paired with an unconditioned stimulus such as food. Pavlov found that the most salient property of the compound stimulus came to regulate exclusively the conditioned response. In this case the loud tone and not the faint light will become a CS and elicit salivation. The tone is said to overshadow conditioning to the light. This happens, even though the weak light could function as a CS if it were originally presented by itself and was paired with a US.

Blocking

Kamin (1969) reported a related effect that also involved compound stimuli. This effect is called **blocking** and describes a situation in which one CS paired with a US blocks a subsequent CS–US association. In blocking, a CS is paired with a US until the conditioned response reaches maximum strength. Following this conditioning, a second stimulus is presented at the same time as the original CS, and both are paired with the unconditioned stimulus. On test trials, the original CS evokes the CR, but the second stimulus does not. For example, a tone (CS) may be associated with food (US) until the tone reliably evokes salivation. Next, the tone and a light are presented together (compound CS), and both are associated with food (US). On test trials, the tone will elicit salivation, but the light will not.

Kamin (1969) used a procedure called conditioned suppression (see Estes & Skinner, 1941). In conditioned suppression, a previously neutral stimulus (e.g., tone, light, etc.) is paired with an aversive US such as an electric shock. After several pairings, the originally neutral stimulus becomes a conditioned aversive stimulus (CS^{ave}). The CS^{ave} is said to elicit a conditioned emotional response (CER) that is commonly called anxiety or fear. Once the CS^{ave} has been conditioned, its effects may be observed by changes in an organism's operant behavior. For example, a rat may be trained to press a lever for food. After a stable

rate of response is established, the CS^{ave} is introduced. When this occurs, the animal's lever pressing is disrupted, presumably because of the CER elicited by the CS^{ave}. Basically we could say the CS^{ave} frightens the animal and it stops pressing the bar. Conditioned suppression is a widely used procedure in respondent conditioning, and as you will see later, it is important in the study of human emotions.

Using a conditioned-suppression procedure, Kamin (1969) discovered the phenomenon of blocking. Two groups of rats were used: a blocking group and a control group. In the blocking group, rats were presented with a tone (CS^{ave}) that was associated with electric shocks for 16 trials. Following this, the rats received 8 trials during which the compound stimulus tone and light were followed by shock. The control group did not receive the 16 light-shock conditioning trials but did have the 8 trials of tone and light paired with shock. Both groups were tested for conditioned suppression of lever pressing in the presence of the light. That is, the light was presented alone, and suppression of bar pressing for food indicated the occurrence of the conditioned emotional response (CER). Kamin found that the light suppressed bar pressing in the control group but did not affect lever pressing in the blocking group. In other words, prior conditioning with the tone blocked or prevented conditioning to the light. Functionally, the light was a CS^{ave} in the control group but not in the blocking group.

Blocking and overshadowing may also be interpreted as cases of redundant stimuli. If two or more stimuli have been paried with the same US, then only one CS element of the compound is required for eliciting the CR. We intentionally generate compound stimuli (actually we can hardly avoid it) so that some aspect or the other of the environment will gain eliciting properties. All stimulus manipulations are conducted in some place, be it in the lab or elsewhere, and components of that environment will be paired with the stimuli of interest. It is the consistent and predictable nature of the specific CS–US pairing that tends to restrict the connection to only some stimuli.

Sensory Preconditioning

Sensory preconditioning is another example of stimulus control by compound events. In this case, two stimuli such as light and tone are repeatedly presented together, preconditioning, that is, without the occurrence of a known US. Later, one of these stimuli is paired with an unconditioned stimulus for several trials, and then the other stimulus is tested for conditioning. Even though the second stimulus was never directly associated with the US, it comes to elicit a conditioned response (Brogden, 1939; Pfautz, Donegan, & Wagner, 1978; Prewitt, 1967). For example, a rat may be repeatedly exposed to 10 s of light with an accompanying tone. Following this preconditioning phase, the tone is paired with an electric shock. Subsequently, using a conditioned-suppression procedure, it is possible to show that the light will also suppress the animal's operant behavior. Notice that the light has never been paired with the shock but comes to have a CS^{ave} function based on previous association with the tone. Preconditioning is a way that stimuli may acquire corresponding or equivalent functions. It might be said that the light "stands for" the tone; and the tone, for the light.

The Rescorla–Wagner Model of Conditioning

The occurrence of overshadowing, blocking, and sensory preconditioning has led many researchers to the conclusion that cognitive processes underlie conditioning. This is because these effects (and others) seem to imply that an animal learns to expect certain events

on the basis of predictive cues. That is, the sight of a predator becomes a predictive cue because the animal expects an attack. The CS is said to provide information about the occurrence of the US, and redundant information, as in blocking, is not processed by the organism.

Although this is an intuitively satisfying account, cognitive processes are not necessary to describe most of the research in respondent conditioning. Bolles (1979) has commented as follows:

> Are we now in a position to conclude that conditioning is really a cognitive process, that it involves the expectancy of an . . . [US], and that the expectancies reflect predictive relationships the animal perceives between cues and consequences? Some psychologists have come to this conclusion. But others have shown restraint. Indeed, it turns out to be possible to account . . . [for many conditioning effects], all without recourse to any cognitive concepts. It can all be done with the clever application of [temporal pairing of stimuli] and other S-R principles. This remarkable development is the work of Wagner, and surprisingly, Rescorla himself. They have produced what is widely known as the Rescorla-Wagner model. (p. 158)

As Bolles (1979) notes, the **Rescorla–Wagner model** (Rescorla & Wagner, 1972; Wagner & Rescorla, 1972) is an S–R pairing theory of respondent conditioning. That is, the Rescorla–Wagner model is a behavioral theory that does not make inferences about underlying cognitive/informational processing.

The basic idea of the Rescorla–Wagner model is that a conditioned stimulus acquires a limited amount of **associative strength** on any trial. We use the term associative strength to *describe* the relation between the CS and the magnitude of the conditioned response (CR). In general, associative strength increases over conditioning trials and reaches some maximum level. It is apparent that a given CS can acquire only so much control over a conditioned response. This is the **maximum associative strength** for the CS. Thus, a tone (CS) that is paired with 1 g of food will have maximum associative strength when the amount of conditioned salivation (CR) is about the same as that of the unconditioned salivation (UR) elicited by the gram of food (US). That is, an unconditioned stimulus elicits a given magnitude of the unconditioned response. This magnitude sets the upper limit for the conditioned response. The CS cannot elicit a greater response than the one produced by the unconditioned stimulus.

A conditioned stimulus gains a certain amount of associative strength on any one trial. The amount of gain or increment depends on several factors. One obvious factor is the maximum associative strength that may accrue to the conditioned stimulus. As noted, this maximum is set by the magnitude of the US–UR relationship. An intense US will set a higher maximum value than a weaker one.

Another factor that affects the increment in associative strength on any trial is the **change in associative strength** or the difference between the present strength of the CS and its maximum possible value. As conditioning trials proceed, the CS gains associative strength, and this means that the difference between present and maximum strength decreases; there is less and less to gain on each trial. For example, assume a 10-trial experiment in which 1 g of meat evokes 2 cc of saliva and the meat is paired with a tone. In terms of change in associative strength, the most gain will occur on the 1st trial, there will be less gain by the 5th, and there will be almost no gain in associative strength by the 10th trial.

The change in associative strength of a conditioned stimulus (CS_1) is also affected by the strength of other conditioned stimuli (CS_2, CS_3, etc.) that elicit the conditioned response in that situation. Because there is a maximum associative strength set by the US, it follows that the associative strength of each CS will add together and reduce the difference between

the present associative strength and the maximum possible value. Thus, if a tone has been frequently paired with meat, it will evoke almost maximum salivation. If a light is now introduced and presented along with the tone, it will show little control over salivation, since most of the possible associative strength has accrued to the tone (blocking).

The Rescorla–Wagner model of respondent conditioning describes a large number of findings and has stimulated a good deal of research. The model makes counterintuitive predictions that have been confirmed in a variety of experimental settings. Since the early 1970s, scores of experiments have been conducted to test some of the implications of the model.

ADVANCED ISSUE: CONDITIONING EFFECTS AND THE RESCORLA–WAGNER EQUATION

The three limiting conditions of (a) maximum associative strength, (b) difference between the current strength and the maximum strength and (c) the number of additional CSs in the situation are represented by Equation 1, suggested by Rescorla and Wagner (1972; see also Wagner & Rescorla, 1972), but simplified for presentation:

$$\Delta V = S\,[V_{MAX} - (V - V_{SUM})]. \tag{3.1}$$

The symbol ΔV stands for the amount of *change in associative strength* (or change in value of the stimulus, V) of any CS that occurs on any one trial. The symbol S is a constant that varies between 0 and 1 and may be interpreted as the **salience** (e.g., dim light versus bright light) of the CS based on the sensory capacities of the organism. The constant S (salience) is estimated after conditioning and determines how quickly the associative strength of the CS rises to maximum. That is, a larger salience coefficient makes the associative strength of the CS rise more quickly to its maximum. The value V_{MAX} represents the maximum associative strength as measured by the magnitude of the unconditioned response (UR). The symbol V represents the associative strength already accrued to the CS_1, and V_{SUM} is any associative strength gained by any other stimuli in the situation ($V_{SUM} = CS_2 + CS_3 + \ldots CS_N$).

Acquisition

Figure 3.7 is a table of values for an idealized experiment on the acquisition of a conditioned response based on Equation 1. Figure 3.8 is the graph of the associative strength V based on the data in the table. In this hypothetical experiment, a tone CS is repeatedly paired with an unconditioned stimulus such as food. In the figure, the S is set at 0.25, and the asymptote (or maximum possible strength) is 10 arbitrary units of the conditioned response (e.g., salivation). The value of V_{SUM} is assumed to be zero, so that all associative strength accrues to the CS. The value of ΔV is given by the equation when we substitute S = 0.25, $V_{MAX} = 10$, and the value of V is zero (V = 0) before conditioning begins. Based on Equation 1, the increase in associative strength from no conditioning to the first trial is

$$\Delta V = 0.25(10 - 0) = 2.50,$$

and the value of V has changed from 0 to 2.50. (Check this with the tabled values of Fig. 3.7.)

Trial	ΔV	V	
1	2.5	2.5	V = associate strength or value
2	1.9	4.4	S = 0.25
3	1.4	5.8	Vmax = 10
4	1.1	6.9	Vsum = 0
5	0.8	7.7	
6	0.6	8.3	
7	0.4	8.7	
8	0.3	9.0	
9	0.25	9.3	
10	0.18	9.4	

FIG. 3.7. *A table of values for a 10-trial acquistion experiment based on solving Rescorla–Wagner equation (Equation 1). The symbols V and ΔV refer to associative strength and change in associative strength for a given trial. The values of V_{MAX}, V_{SUM}, and S are also given in the table. See text for details.*

On each subsequent trial, the associative strength of the CS is 0.25 (salience) of the remaining distance to the asymptote or maximum. Thus for trial 2, we substitute the value 2.50 for V and obtain an increase of 1.88 for ΔV:

$$\Delta V = 0.25(10 - 2.50) = 1.88.$$

The associative strength of the CS, V, after the second trial is $2.50 + 1.88$, or 4.38. This means that roughly one half of the maximum associative strength ($V_{MAX} = 10$) of the CS has been acquired by trial 2.
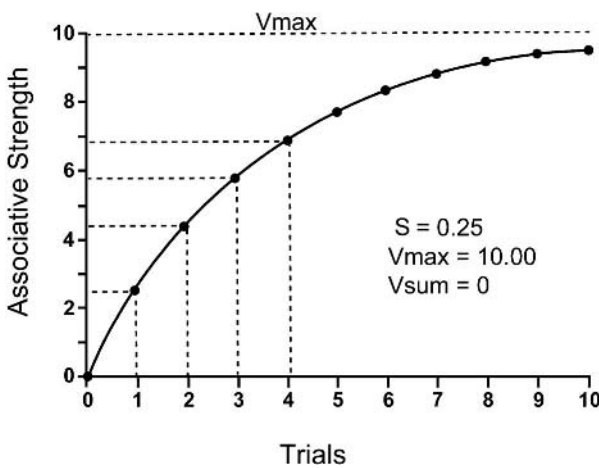
FIG. 3.8. *The acquisition curve predicted by the Rescorla–Wagner equation (Equation 1). Gain in associative strength, from trial to trial, declines as the CR comes closer to the asymptote. The asymptote or upper-flat portion of the curve is set in the equation by the value V_{MAX}. The curve is based on the data in Fig. 3.7.*

The change in associative strength for trial 3 uses V = 4.38 from the second trial and obtains the value

$$\Delta V = 0.25(10 - 4.38) = 1.40,$$

and the new estimate of V is 4.38 + 1.40 or 5.78 (used to obtain ΔV on the 4th trial). Estimates of ΔV and V for all 10 trials of the experiment are obtained in the same way, using Equation 1.

   As you can see in Fig. 3.8, the equation yields a negatively accelerating curve for the associative strength, V, that approaches but never quite reaches maximum associative strength. You can see from the horizontal and perpendicular lines that the largest increase in associative strength is on the first trial, and this change corresponds to the difference in associative strength between trial 0 and trial 1 (2.5-unit increase). The change in associative strength or ΔV gets smaller and smaller over trials. (Check this out in the table of Fig. 3.7.) Notice how the values of ΔV and V depend on the salience, S, of the CS (tone). If the salience of the tone were different, S = 0.50 rather than S = 0.25, a new set of estimates would be given by Equation 1 for ΔV and V.

Blocking Reconsidered

As Bolles (1979) noted, the Rescorla–Wagner equation accounts for many respondent conditioning effects without making assumptions about cognitive processes. One important effect that we have already discussed is blocking. Equation 1 provides a behavioral account of this phenomenon. Consider what will happen when V is almost equivalent to the value V_{MAX}, and a second conditioned stimulus (CS_2) is introduced. For example, a tone (CS_1) is paired with shock until the tone evokes close to maximum response suppression. At this point, a light (CS_2) is presented at the same time as the tone, and conditioning continues. In Equation 1, the light is represented as V_{SUM}, and the tone is represented as V. After the tone acquires close to maximum strength, little is left over for the light (V_{SUM}), and the light has almost no suppressive effect on bar pressing. That is, the previous conditioning to the tone blocks conditioning to the light. Notice that it makes a big difference when the CS_2 is introduced. If CS_1 and CS_2 are paired from the start, then (all things being equal) both stimuli will gain one half of the increase in associative strength (ΔV).

Extinction

Equation 1 can also be used to account for respondent extinction. In this case, the decline in associative strength (ΔV) is determined by S, V_{MAX}, V, and V_{SUM}. As before, assume that a tone is paired with food until the tone (CS) elicits a conditioned response that is close to maximum; there are no other relevant stimuli, so $V_{SUM} = 0$ and cancels out of the equation. Since the procedure is respondent extinction, the curve must decline toward no associative strength, which means that V_{MAX} must be zero. If S = 0.25 and $V_{MAX} = 0.00$ then the decline in associative strength on the first extinction trial is

$$\Delta V = 0.25(0 - 10) = -2.50.$$

Thus, the value of the tone (CS) after the first extinction trial is 10.00 − 2.50, or 7.50 (V = 7.50). Other values of the CS during extinction are determined in a similar fashion (compare with respondent acquisition). Figure 3.9 shows that the predicted extinction
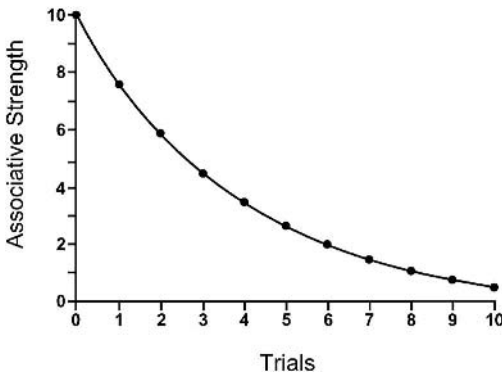
FIG. 3.9. *The extinction curve predicted by the Rescorla–Wagner model. Notice that V_{MAX}, or the asymptote, is zero, because extinction is in effect.*

curve is the *exact opposite of the acquisition curve* of Fig. 3.8. It is important to note that the actual associative strength of the tone before extinction is never exactly equal to the V_{MAX}, but for simplicity we have assumed that it is in Fig. 3.9.

Conditioned Inhibition

The Rescorla–Wagner model can be applied to the phenomenon known as **conditioned inhibition.** When a CS is repeatedly presented without the US (extinction), the conditioned stimulus is said to acquire increasing amounts of inhibition, in the sense that its presentation suppresses the response. Equation 1 may be expressed as Equation 2:

$$\Delta V = S(V_{MAX} - V_{SUM}), \tag{3.2}$$

and in this alternate form V is included with the V_{SUM} term.

Equation 2 predicts that when a CS acquires near maximum associative strength and extinction begins, the introduction of a second stimulus makes the conditioned response decline faster. This is because the second stimulus acquires *negative* associative strength that further suppresses the conditioned response.

Mazur (1990) described a hypothetical experiment that illustrates this effect. Consider that a light (CS) has been paired with food (US) and the light elicits a CR that is 100 arbitrary units of response. In terms of Equation 1, the associative strength, V, for the light is at 100 units. At this point, extinction trials are started, and a tone is presented at the same time as the light. Recall that during extinction $V_{MAX} = 0$, and associative strength, V, drops to the preconditioning level. Based on the Rescorla–Wagner model, the tone should become a conditioned inhibitory stimulus (CS$^-$). This is because Equation 2 makes it clear that if V_{MAX} is less than V_{SUM}, then the associative strengths of all CSs will decline. Such a decline will be equal for the light and tone if the stimuli have the same salience (S). But, because the tone has an initial value of zero (no conditioning), *any decrease in associative strength must result in a negative value for the additional (tone) stimulus.*

If salience is set at $S = 0.20$ for the tone and light, on the first extinction trial the decline in associative strength will be -20, since $\Delta V = 0.2 (0 - 100)$, or a decline of 20 units. On the second trial, the associative strength of the light or V_{LIGHT} is 80 units, or $V_{LIGHT} = 100 - 20$, and the tone has a value of -20, or $V_{TONE} = 0 - 20$. Figure 3.10 is a table that

Trial	ΔV_i	V_{TONE}	V_{LIGHT}	V_{SUM}
1	-20.0	0	100.0	100
2	-12.0	-20.0	80.0	60
3	-7.2	-32.0	68.0	36
4	-4.3	-39.2	60.8	22
5	-2.6	-43.5	56.5	13
6	-1.6	-46.1	53.9	8
7	-0.9	-47.7	52.3	5
8	-0.6	-48.6	51.4	3
9	-0.5	-49.2	50.8	2
10		-49.6	50.4	0

FIG. 3.10. *Table of extinction values predicted by the Rescorla–Wagner model (Equation 2) after a light CS has been conditioned to evoke salivation. During extinction, a tone is presented along with the light.*

shows the results of this experiment over 10 trials. After 10 trials, the sum of associative strengths for the light and tone is approximately zero, and there can be almost no further decline in the conditioned response based on the Rescorla–Wagner model.

Figure 3.11 is based on the data in Fig. 3.10 and shows three separate curves as given by Equation 2. The associative strength of the light declines from an initial value of 100 units of response to an asymptote of approximately 50 units. Recall that the tone
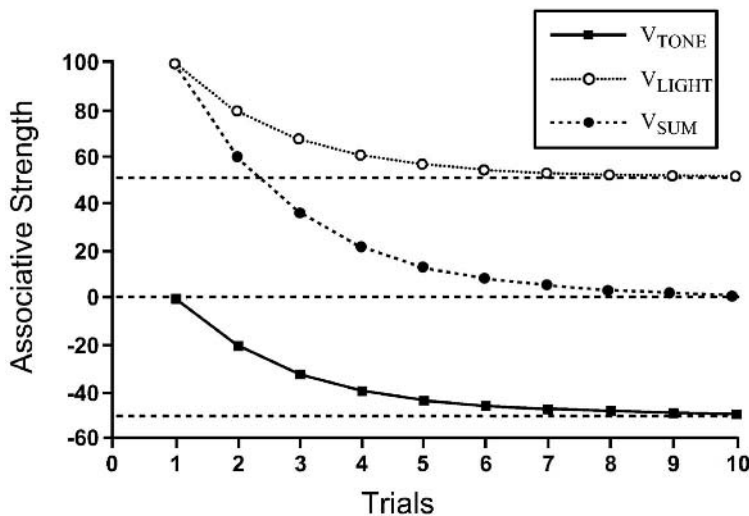
FIG. 3.11. *The extinction curves predicted by the Rescorla–Wagner model after a light CS has been conditioned to evoke salivation. During extinction, a tone is presented along with the light. The curves are plotted from the tabled values given in Fig. 3.10. Notice that the V_{TONE} and V_{LIGHT} curves are summed to give the V_{SUM} curve. The V_{SUM} curve represents the expected strength of the CR as extinction proceeds.*
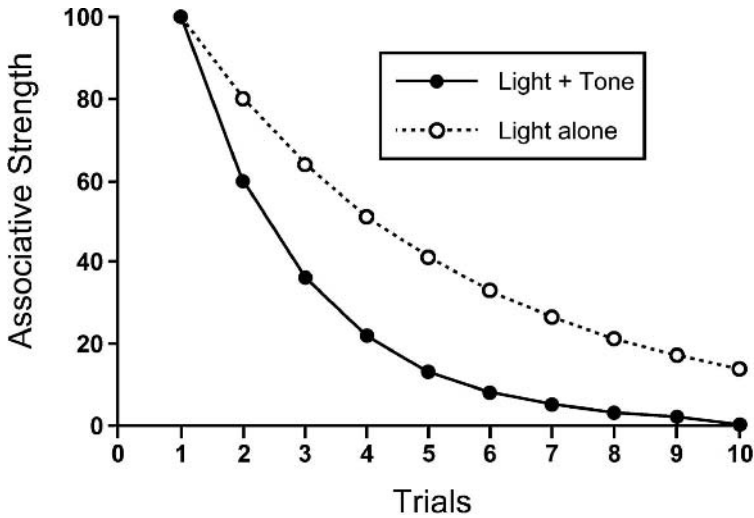
FIG. 3.12. *Extinction curves predicted by the Rescorla–Wagner equation. The open circles are generated by predicting the course of simple extinction. That is, a CS is paired with a US until it evokes a CR at close to asymptote, and then the CS is placed on extinction. The closed circles show the expected curve when the CS is placed on extinction and a second stimulus (tone) is paired with it.*

has never been paired with food, and for this reason its associative strength before the first extinction trial is zero. As extinction proceeds, the tone takes on negative values and decreases to approximately 50 units of response. The third curve (V_{SUM}) is obtained by *summation* of the associative strengths for the light and tone on each trial. This latter curve provides the actual course of extinction based on the separate curves for light and tone. The extinction curve begins with a value of 100 units of response strength and declines to zero (actually near zero) by the 10th trial.

Notice that the Rescorla–Wagner model predicts faster extinction when a CS^+ (light) and CS^- (tone) are presented together than when a CS^+ is presented alone. This situation, depicted in Fig. 3.12, shows the extinction curves for tone and light and for the light presented by itself. As you can see, when *both* light and tone are presented, the extinction curve reaches near zero associative strength by the 10th trial. When the light is presented by itself during extinction, it still has about 13 units of strength remaining after trial 10. Although more rapid extinction is predicted when both tone and light are presented concurrently, we do not know of any experiment that directly tested this possibility.

ON THE APPLIED SIDE: DRUG USE, ABUSE, AND COMPLEXITIES OF RESPONDENT CONDITIONING

Basic research on simple and complex (i.e., contextual effects) respondent conditioning has applied importance. Recently, the U.S. government has declared war on the import and use of illegal drugs. One result of this is that more money is being spent on research

to identify the factors that affect drug use and abuse. Several experiments have shown that conditioned stimuli can produce drug-like effects in both humans and other animals, disrupting behavior and producing physiological changes. In addition, stimuli that have been paired with drugs sometimes produce internal conditioned responses that are opposite to the unconditioned effects of the drug. For example, when animals are injected with insulin (US), the unconditioned response is a reduction in blood sugar (UR). The response to a stimulus (CS) that has been paired with insulin is exactly the opposite; blood sugar levels increase (Siegel, 1972, 1975).

Similar counteractive effects have been found with drugs other than insulin. For example, amphetamine reduces appetite, but a CS that has been paired with it increases food intake (Poulos, Wilkinson, & Cappell, 1981). Pentobarbital is a sedative, but the response to a conditioned stimulus associated with pentobarbital counteracts the drowsiness ordinarily associated with the drug (Hinson, Poulos, & Cappell, 1982).

Effects such as these suggest that respondent conditioning plays a major role in drug tolerance. Here is how it works. With repeated pairings of a drug (US) and a CS (e.g., injection process), the conditioned response gains in strength and increasingly opposes the unconditioned effects of the drug. This means it will take larger and larger amounts for the user to experience the same degree of effect. In everyday life, conditioned stimuli arise from the time of day that a drug is taken, the way it is administered (e.g., using a needle), the location such as a tavern or home, and social events like a party or dance.

Notice that, in the case of tolerance, the reduction in the effects of the drugs (UR) is not due to habituation; rather it is the result of the counteractive effects (CR) to the injection process and setting (CS). When more of a drug (US) is needed to obtain the same drug effects (UR), we talk about drug **tolerance** (Baker & Tiffany, 1985). Thus, the counteractive effects to CSs are major components of drug tolerance.

Heroin Overdose and Context

To consider drug tolerance as a conditioned response helps to explain instances of drug overdose. Heroin addicts are known to survive a drug dose that would kill a person who did not regularly use the drug. In spite of this high level of tolerance, approximately 1% of heroin addicts die from drug overdose each year. These victims typically die from drug-induced respiratory depression. Surprisingly, many of these addicts die from a dose that is similar to the amount of heroin they usually took each day.

Siegel, Hinson, Krank, and McCully (1982) proposed that these deaths resulted from "a failure of tolerance. That is, the opiate addict, who can usually tolerate extraordinarily high doses, is not tolerant on the occasion of the overdose" (p. 436). They suggested that when a drug is administered in the usual context (CS$^+$), the CRs that counteract the drug allow for a large dose. When the situation in which the drug is taken is changed, the CSs are not present, the opposing conditioned response does not occur, and the drug is sufficient to kill the user. Siegel and associates designed an animal experiment to test these ideas.

In one study rats were injected with heroin every other day for 30 days. The amount of heroin was gradually increased to a dose level that would produce tolerance to the drug. On nonheroin days, these rats were injected with dextrose solution (i.e., sugar and water). Both heroin and dextrose injections were given in one of two distinctive contexts—either the ordinary colony room that the rats lived in or a different room with constant white noise. A control group of rats was injected only with the dextrose solution in the two situations. The researchers predicted that experimental animals would develop a tolerance to the drug, and
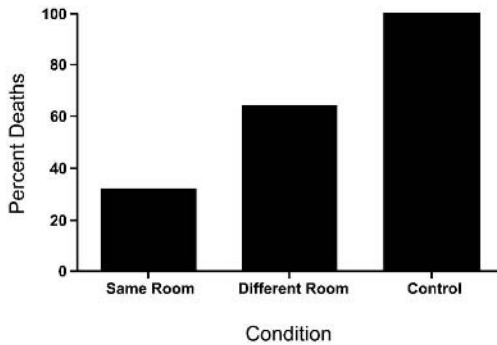
FIG. 3.13. *Results of the experiment by Siegel, Hinson, Krank, and McCully (1982). The same room group of rats received the higher dose in the room where they usually were injected with heroin, and only 32% died. Twice as many animals under the different room condition died from the larger dose, presumably because they were injected in a room where heroin had not been given. Heroin killed almost all of the animals in the control group.* Note: *Adapted from "Heroin 'Overdose' Death: The Contribution of Drug-Associated Environmental Cues," by S. Siegel, R. E. Hinson, M. D. Krank, and J. McCully, 1982, Science, pp. 436–437.*

that this tolerance would occur if aspects of the room in which heroin was given became CSs that evoked opposing responses (CRs) to the drug.

To test this assumption, Siegel and colleagues (1982) doubled the amount of heroin given to experimental animals. The same high dose of heroin was given to the control group, which had no history of tolerance. Half of the experimental animals received this larger dose in the room where the drug was usually administered. The other addicted rats were injected with the higher dose in the room where they usually received a dextrose injection.

Figure 3.13 shows the results of this experiment. As you can see, the large dose of heroin killed almost all of the animals in the control group. For the two groups of animals with a history of heroin use, one group (same room) received the higher dose in the room where they usually were injected with heroin. Only 32% of the rats died under this condition, presumably because the CSs set off the opposing conditioned responses. This inference is supported by the mortality rate of rats in the different room group. These rats were injected with the double dose of heroin in a room that had never been associated with heroin administration. Twice as many animals under this condition died from the larger dose (64%) when compared to the same room group. It seems the effects of context during this kind of respondent conditioning can be a matter of life or death—tolerance to heroin (and perhaps other drugs) is relative to the situation in which the conditioning has occurred (Siegel, 2001).

What happens when the drug-related CS is presented without the drug US, as in the classical extinction procedure? In this case the elicited respondents are often called "cravings," and the process is known as **conditioned withdrawal.** The CS elicits reactions that are ordinarily countered by the US. However, when the US is not delivered and if those CR reactions occur, the subject experiences what is called withdrawal. A heroin addict can have their withdrawal symptoms immediately terminated by a heroin injection. If you are accustomed to having a cigarette after a meal, the craving you experience can be alleviated with a smoke.

Conditioned Immunosuppression

Conditioned immunosuppression is another example of environmental influences altering what is generally considered to be internal and autonomously controlled processes. In this procedure, a CS is paired with a US drug that suppresses immune system function such

as the production of antibodies. (Note that drugs, like cyclophosphamide, are commonly administered to suppress rejection of a transplanted organ.) After several pairings the CS is presented alone and the immune system reaction is measured. Ader and Cohen (1981, 1985, 1993) were the first to systematically investigate and support these phenomena.

Clearly the next question is, can the immune system also be conditioned to increase immune reaction? It appears that it can. In a human study, Buske-Kirschbaum, Kirschbaum, Stierle, Jabaij, and Hellhammer (1994), after pairing a flavor CS and an adrenaline injection US, subsequently raised NK (natural killer) cell production by presentation of the flavor alone.

The issue of conditioned enhancement of the immune system also speaks to the findings of **placebo effects.** How can a neutral substance, a placebo, have any effect on a person's physiological well-being? Many studies have shown that groups receiving a sugar pill do as well as those in the legitimate treatment group (Brody, 2000). How can this be possible when the placebo, by definition, cannot directly cause any change? The obvious conclusion is that there is a CS, say the patient's belief that he or she is receiving treatment, and this verbal stimulus acts as a placebo to elicit the CR mechanisms of improvement. Even sham arthroscopic surgery for arthritis is as functional as actual surgery, and of course with fewer side effects and less cost (Moseley et al., 2002).

One thing these types of studies indicate is that there is a much greater two-way interaction between the environment and the physiological mechanisms than has been suspected. Organisms are adaptive and they learn. It appears that organs (e.g., salivary glands) and organ systems (immune system) also alter their functions as a result of experience. Obviously we need more research to expand and validate these topics.

KEY WORDS

Associative strength
Backward conditioning
Blocking
Change in associative
    strength
Conditioned response
Conditioned stimulus
Conditioned suppression
Conditioned withdrawal
Delayed conditioning
Elicit
Fixed action pattern
Generalization gradient
Habituation
Law of intensity magnitude

Law of the latency
Law of the threshold
Maximum associative
    strength
Ontogenetic
Overshadowing
Phylogenetic
Placebo effect
Primary laws of the reflex
Reaction chain
Reflex
Rescorla–Wagner model
Respondent
Respondent acquisition
Respondent conditioning

Respondent discrimination
Respondent extinction
Respondent generalization
Respondent level
Salience
Second-order conditioning
Sensory preconditioning
Simultaneous conditioning
Spontaneous recovery
Trace conditioning
Tolerance
Unconditioned response
Unconditioned stimulus

ON THE WEB

http://www.uwm.edu/~johnchay/index.htm Go to the web page of John C. Hay and try out a simulated classical conditioning experiment with Pavlov's dog. For example, select

light and food as the CS and US. Try a 10-trial experiment on acquisition of a CS–US relationship. Now try an extinction procedure. Go ahead experiment!

http://www2.psy.uq.edu.au/~landcp/PY269/index.html Try out this web page on associative learning created for an undergraduate psychology class. The site has a good presentation of the Rescorla–Wagner model of conditioning.

http://members.aol.com/avpsyrich/sysden.htm One application of respondent conditioning is called systematic desensitization—an effective treatment for anxiety and phobia. This web page outlines the basic procedures used in applied settings.

STUDY QUESTIONS

1. Give several examples of phylogenetic behavior and include at least one human illustration. (53)
2. Distinguish between a fixed action pattern (FAP) and a reaction chain. (54–55)
3. Outline the three primary laws of the reflex. (56–57)
4. Define habituation, give an example of it, and describe its general characteristics. (57–58)
5. Describe respondent conditioning, using the example of the word *lemon*. (59–60)
6. Be able to define and use the terms *unconditioned stimulus* (US), *unconditioned response* (R), *reflex, conditioned stimulus* (CS), *conditioned response* (CR), and *respondent conditioning*. (55–60) Describe the phylogenetic origins and ontogenetic advantages of respondent conditioning. (58–60)
7. Summarize the acquisition curve for the respondent conditioning of salivation to a light. What determines the asymptote of the curve? (60–61)
8. Show that the US–UR relationship is not the same as the CS–CR relationship, referring to the laws of intensity magnitude and latency. (61)
9. Define respondent extinction as a procedure and as a behavioral process. (61–62)
10. What is spontaneous recovery of respondent behavior? Compare Pavlov's internal inhibition account of spontaneous recovery to the behavioral account based on context. (62–63)
11. Define respondent generalization and discuss how to show generalization in an experiment. (63)
12. Summarize what is known about generalization gradients based on respondent conditioning. (63–64) How is respondent generalization an adaptive feature of the behavior of organisms? (64)
13. Give a definition of respondent discrimination and describe a procedure to produce it. (64) How is respondent discrimination an adaptive feature of the behavior of organisms? (64)
14. Compare and contrast delayed, simultaneous, trace, and backward conditioning in terms of both procedures and behavioral effects. (65–67)
15. Cite evidence that backward conditioning can occur when the CS is biologically relevant. (67) What does this evidence mean for a conditioning view that requires the CS to predict (or provide information about) the US? (you infer)
16. Describe second-order respondent conditioning. Why is second-order conditioning important? (67–68)
17. Define compound stimuli. How does respondent conditioning of compound stimuli extend the principles of respondent behavior to everyday settings, such as McDonald's restaurant. (68)

18. Provide a definition and give an example of overshadowing, blocking, and sensory preconditioning. (68–69)
19. What is conditioned suppression and how is it used to demonstrate the process of blocking? (68–69)
20. Outline the basics of the Rescorla–Wagner model. Be able to use the terms associative strength, maximum associative strength, and change in associative strength in your discussion of the model. (69–71)
21. **ADVANCED ISSUE**: Be able to write the Rescorla–Wagner equation and explain the terms. (71) How does the Rescorla–Wagner equation account for respondent acquisition? (71–73) Provide an account of blocking using the Rescorla–Wagner equation. (73) Apply the Rescorla–Wagner equation to the process of respondent extinction. (73–74) Explain, using a graph, how conditioned inhibition is predicted by the Rescorla–Wagner equation (or model). (74–76)
22. Describe the counteractive effects of the CS in drug administration. (76–77) Summarize the research on drug tolerance and overdose. (77) Draw out the implications of context for the CS–CR relationship. (77–78) What is conditioned immunosuppression, and how does conditioned enhancement of the immune system relate to the placebo effect? (78–79)

BRIEF QUIZ

1. Behavior relations based on the genetic endowment of the organism are called
   (a) operants
   (b) reflexes
   (c) ontogenetic
   (d) phylogenetic
2. Complex sequences of released behaviors are called
   (a) traits
   (b) reaction chains
   (c) fixed action patterns
   (d) second-order conditioned reflexes
3. Reflexive behavior is said to be _____ and _____.
   (a) built-in; flexible
   (b) involuntary; elicited
   (c) respondent; emitted
   (d) voluntary; inflexible
4. Primary laws of the reflex do not include
   (a) law of latency
   (b) law of threshold
   (c) law of habituation
   (d) law of magnitude
5. A diminution in the UR due to repeated presentation of the US is called
   (a) habituation
   (b) extinction
   (c) forgetting
   (d) sensitization
6. Respondent conditioning might also be called
   (a) S–R conditioning
   (b) S–S pairing

(c) CS–CR association
(d) R–S learning
7. To do away with an unwanted CR one should
(a) present the CS without the CR
(b) present the CR without the US
(c) present the US without the CS
(d) present the CS without the US
8. Drug tolerance has been shown to be a result of
(a) generalization
(b) metabolization
(c) elicited CRs
(d) US habituation
9. One of the following is not a traditional way of relating the CS and a US
(a) trace
(b) simultaneous
(c) delayed
(d) overshadowing
10. The Rescorla–Wagner theory suggests that a CS becomes effective
(a) gradually
(b) through backward conditioning
(c) by conditioned inhibition
(d) following tolerance

Answers to brief quiz (*page*): d(53); c(54); b(56); c(56–57); a(57); b(58); d(61); c(77); d(65); a(70)

CHAPTER 4
Reinforcement and Extinction of Operant Behavior

IN THIS CHAPTER

1. Find out about operant behavior and the basic contingencies of reinforcement.
2. Discover whether reinforcement undermines intrinsic motivation.
3. Inquire about the Premack principle and reinforcement as a contingency between behaviors.
4. Learn how to carry out experiments on operant conditioning.
5. Investigate the process of extinction and the conditions that make behavior resistance to extinction.
6. Investigate how reinforcement of variability relates to problem solving and creativity.
7. Learn about extinction and the partial reinforcement effect.

A hungry lion returns to the waterhole, where it has successfully ambushed antelope and other prey. A person who plays a slot machine and wins a large jackpot is more likely to play again than a person who does not win. Students who ask questions and are told "That is an interesting point worth discussing," are prone to ask more questions. When a professor ignores questions or gives fuzzy answers, students eventually stop asking questions. In these cases (and many others), the consequences that follow behavior determine whether it will be repeated in the future.

Recall that operant behavior is said to be emitted (chap. 2). When operant behavior is followed by reinforcing consequences it is selected, in the sense that it increases in frequency. Behavior that is not followed by reinforcing consequences decreases in frequency. This process, called **operant conditioning** is a major way that the behavior of organisms is changed on the basis of ontogeny or life experience (i.e., learning). It is important, however, to recognize that operant conditioning, as a process, has evolved over species history and is based on genetic endowment. That is, operant (and respondent) conditioning as a *general behavior-change process* is based on phylogeny or species history. In other words, those organisms whose behavior changed on the basis of consequences were more likely to survive and reproduce than animals that did not.

Operant Behavior

Operant behavior is commonly described as intentional, free, voluntary, or willful. Examples of operant behavior include conversations with others, driving a car, taking notes, reading a book, and painting a picture. From a scientific perspective, operant behavior is lawful and may be analyzed in terms of its relationship to environmental events. Formally, responses

that produce a change in the environment and increase in frequency due to that change are called operants. The term **operant** comes from the verb *to operate* and refers to behavior that operates on the environment to produce consequences that in turn strengthen the behavior. The consequences of operant behavior are many and varied and occur across all sensory dimensions. When you turn on a light, dial a telephone, drive a car, or open a door, these operants result in visual clarity, conversation, reaching a destination, and entering a room. A **positive reinforcer** is defined as any consequence that increases the probability of the operant that produced it. For example, pretend that your car will not start, but when you jiggle the ignition key it fires right up. Based on past reinforcement, the operant—jiggling the key—is likely to be repeated the next time the car won't start.

Operants are defined by the consequences they produce. Thus, opening the door to reach the other side is the operant, not the physical movement of manipulating the door. Operants are a class of responses that may vary in **topography**. Topography refers to the physical form or characteristics of the response. Consider the number of different ways you could open a door—you may turn the handle, push it with your foot, or (if your arms are full of books) ask someone to open it for you. All of these responses vary in topography and result in reaching the other side of the door. Because these responses result in the same consequence, they are members of the same **operant class**. Thus, the term *operant* refers to a class of related responses that may vary in topography but produce a common environmental consequence (Catania, 1973).

Discriminative Stimuli

Operant behavior is said to be **emitted** in the sense that it often occurs without an observable stimulus preceding it. This is in contrast to reflexive responses, which are **elicited** by a preceding stimulus. Reflexes are tied to the physiology of an organism and, under appropriate conditions, always occur when the eliciting stimulus is presented. For example, Pavlov showed that dogs automatically salivated when food was placed in their mouths. Dogs do not learn the relationship between food and salivation; this reflex is a characteristic of the species. Stimuli may also precede operant behavior. However, these events do not force the occurrence of the response that follows them. An event that precedes an operant and *sets the occasion for behavior* is called a **discriminative stimulus**, or S^D (pronounced esse-dee). Discriminative stimuli change the probability that an operant will be emitted based on a history of differential reinforcement. **Differential reinforcement** involves reinforcing an operant in one situation (S^D) but not in another (S^Δ). The probability of emitting an operant in the presence of an S^D may be very high, but these stimuli do not have a one-to-one relationship with the response that follows them. For example, a telephone ring increases the chances that you will emit the operant, answering the telephone, but it does not force you to do so. Similarly, a nudge under the table may set the occasion for changing the conversation or just shutting up. The events that occasion operant behavior may be private as well as public. Thus, a private event such as a headache may set the occasion for taking an aspirin.

Discriminative stimuli are defined by the operants that are occasioned by these stimuli. The probability of raising your hand in class is much greater when the instructor is present than when he or she is absent. Thus, the presence of an instructor is an S^D for asking questions in class. The teacher functions as an S^D only when his or her presence changes student behavior. The student who is having difficulty with a math problem may ask questions when the teacher enters the room. However, a student who is easily mastering the material is unlikely to do this. For this reason, the teacher functions as an S^D (for asking questions) for the first student but not for the second. This discussion should make it clear that a

stimulus is defined as an S^D, only when it changes the probability of operant behavior. You may typically stop when you pull up to a traffic sign that reads STOP; the sign is a discriminative stimulus. If, however, you are driving a badly injured friend to the hospital, the same sign may not function as an S^D. Thus, discriminative stimuli are not defined by physical measures (e.g., color, size, tone); rather, they are defined as stimuli that precede and alter the probability of operant responses.

The consequences that follow operant behavior establish the control exerted by discriminative stimuli. When an S^D is followed by an operant that produces positive reinforcement, the operant is more likely to occur the next time the stimulus is present. For example, a student may ask a particular teaching assistant questions, because in the past that teaching assistant has provided clear and concise answers. In this example, the assistant is an S^D, and asking questions is the operant that increases in his or her presence. When an operant does not produce reinforcement, the stimulus that precedes the response is called an **S-delta** (S^Δ, esse-delta). In the presence of an S^Δ, the probability of emitting an operant declines. For example, if a second teaching assistant answers questions in a confused and muddled fashion, the student will be less likely to ask that person questions. In this case the second teaching assistant becomes an S^Δ, and the probability of asking questions declines in his or her presence.

Contingencies of Reinforcement

A **contingency of reinforcement** defines the relationship between the events that set the occasion for behavior, the operant class, and the consequences that follow this behavior. In a dark room (S^D), when you flip on a light switch (R), the light usually comes on (S^r). This behavior does not guarantee that the room will light up; the bulb may be burned out or the switch may be broken. It is likely that the light will come on, but it is not certain. In behavioral terms, the probability of reinforcement is high, but it is not absolute. This probability may vary between 0 and 100%. A high probability of reinforcement for turning the switch to the "on" position will establish and maintain a high likelihood of this behavior.

Discriminative stimuli that precede behavior have an important role in the regulation of operant responses (Skinner, 1969). Signs that read OPEN, RESUME SPEED, or RESTAURANT; green traffic lights, a smile from across the room, and so on are examples of simple discriminative stimuli that may set the occasion for specific operants. These events regulate behavior because of a history of reinforcement in their presence. A smile from across a room may set the occasion for approaching and talking to the person who smiled. This is because, in the past, people who smiled reinforced social interaction.

Each of these events—the occasion, the operant, and the consequences of behavior—makes up the contingency of reinforcement. Consider the example of this three-part contingency shown in Fig. 4.1. The telephone ring is a discriminative stimulus that sets the occasion for the operant class of answering the phone. This behavior occurs because, in the past, talking to the other party reinforced the operant. The probability of response is very high in the presence of the ring, but it is not inevitable. Perhaps you are in the process of leaving for an important meeting, or you are in the bathtub.

Discriminative stimuli regulate behavior, but they do not stand alone. The consequences that follow behavior determine the probability of response in the presence of the discriminative stimulus. For example, most people show a high probability of answering the telephone when it rings. However, if the phone is faulty so that it rings but you cannot hear the other party when you answer it, the probability of answering the phone decreases as a function of no reinforcement. In other words, you stop answering a phone that does not work.

SD :[Sets the occasion] R ——Produces——> S^{r+}

Discriminative   Operant Class   Reinforcement
Stimulus

Telephone   Answer phone   Talk to others
Rings

FIG. 4.1.   *The three-term contingency of reinforcement. A discriminative stimulus (S^D) sets the occasion for operant behavior (R), which is followed by a consequence (S^r).*

Four Basic Contingencies

There are four basic contingencies of reinforcement. Events that follow behavior may be either presented or removed (environmental operation). These events can increase or decrease behavior (effect on behavior). The cells of the matrix in Fig. 4.2 define the basic contingencies of reinforcement.

Positive Reinforcement

Positive reinforcement is one of the four basic contingencies of operant behavior. **Positive reinforcement** is portrayed in Fig. 4.2 (cell 1), where a stimulus follows behavior and, as a result, the rate of that behavior increases. For example, a child is praised for sharing a toy

| | Effect on Behavior | |
Stimulus Following Behavior	Increase	Decrease
On/Presented	1 Positive Reinforcement	2 Positive Punishment
Off/Removed	3 Negative Reinforcement	4 Negative Punishment

FIG. 4.2.   *This figure shows the four basic contingencies of reinforcement. The stimulus following a response (consequence) can be either presented (turned on) or removed (turned off). The effect of these procedures is to increase or decrease rate of response. The cells of the matrix, in this figure, define the contingencies of reinforcement. A particular contingency of reinforcement depends on whether the stimulus following behavior is presented or removed and on whether behavior increases or decreases in frequency.*

(operant behavior), and the child begins to share toys more regularly (increase in response strength). Positively reinforcing events usually include consequences such as food, praise, and money. *These events, however, cannot be called positive reinforcers until they have been shown to increase behavior.*

FOCUS ON RESEARCH: REINFORCEMENT, INTRINSIC MOTIVATION, AND CREATIVITY

Over the past 30 years, many social psychologists and educators have been critical of the practice of using rewards in business, education, and behavior modification programs. The concern is that rewards (reward and reinforcement are often used similarly in this literature) are experienced as controlling, thereby leading to a reduction in an individual's self-determination, intrinsic motivation, and creative performance (e.g., see Amabile, 1990; Deci & Ryan, 1985; Deci, Koestner, & Ryan, 1999, 2001; Kohn, 1993; Lepper, Greene, & Nisbett, 1973). Thus, when a child who enjoys drawing is rewarded for drawing, with praise or with tangible rewards like points or money, the child's motivation to draw is said to decrease. From this perspective, the child will come to draw less and enjoy it less once the reward is discontinued. Further, it is alleged that the drawings produced by the child will be less creative than those drawn by children not given the reward. In other words, the contention is that reinforcement reduces people's intrinsic motivation and creativity. This view has been enormously influential and has led to a decline in the use of rewards and incentive systems in many applied settings.

In an article published in 1996 in *American Psychologist*, Dr. Robert Eisenberger, a professor of psychology at the University of Delaware, and Dr. Judy Cameron, a professor of educational psychology at the University of Alberta (Fig. 4.3A and 4.3B), provided an objective and comprehensive analysis of the literature concerned with the effects of reinforcement/reward on people's intrinsic motivation and creativity. Contrary to the belief of many psychologists, their findings indicated no inherent negative property of reward.

(A)   *(B)*

FIG. 4.3.   *(A). Dr. Judy Cameron. (B). Dr. Robert Eisenberger. Reprinted with permission.*

Instead, their research demonstrates that reward has a much more favorable effect on task interest and creativity than is generally supposed.

Rewards and Intrinsic Motivation

Those who oppose the use of rewards support their position by citing experimental studies on reward and intrinsic motivation and claiming that rewards have pervasive negative effects (Deci, Koestner, & Ryan, 1999, 2001; Schwartz, 1990). A cursory examination of these experiments reveals a mixed set of findings. That is, in some studies, extrinsic rewards reduce performance or interest; other studies find positive effects of reward; still others show no effect. In order to make sense of these diverse findings, Judy Cameron, Robert Eisenberger, and the author of this textbook, David Pierce (Cameron, 2001; Cameron, Banko, & Pierce, 2001; Cameron & Eisenberger, 1997; Cameron & Pierce, 1994, 2002; Eisenberger & Cameron, 1996; Pierce & Cameron, 2002), conducted quantitative analyses of this literature to determine whether rewards really do negatively affect people's performance and interest. Using a statistical procedure known as meta-analysis, Cameron et al. (2001) analyzed the results from 145 experiments on rewards and intrinsic motivation.

The findings indicated that rewards could be used effectively to enhance or maintain an individual's intrinsic interest in activities. Specifically, verbal rewards (praise, positive feedback) were found to increase people's performance and interest on tasks. In terms of tangible rewards, the results showed that these consequences increased performance and interest for activities that were initially boring or uninteresting. For activities that people find initially interesting, the results from the meta-analysis point to the importance of reward contingency as a major determinant of intrinsic motivation. Cameron et al. (2001) found that tangible rewards produced a slight decrease intrinsic motivation on tasks with high initial interest when these rewards were offered simply for doing an activity, regardless of level or quality of performance. When tangible rewards were offered for meeting a criterion level of performance or exceeding the performance of others, people's intrinsic interest was either maintained or enhanced (see McGinnis, Firman, Carlyon, 1999, for an ABAB demonstration that tokens and enhance intrinsic interest in math). That is, *rewards tied to level or quality of performance increase intrinsic motivation or leave intrinsic interest unaffected.*

Cameron and her associates (2001) concluded that intrinsic task interest and performance could be enhanced when individuals receive verbal praise, positive feedback, or when tangible rewards are specifically tied to level or quality of performance. The view that rewards undermine people's intrinsic motivation is an overgeneralization. That is, the meta-analytic findings run contrary to the popular argument that rewards have generalized negative effects on people's intrinsic motivation (see Cameron & Pierce, 2002, for a more in-depth coverage of the rewards and intrinsic motivation controversy).

Rewards and Creativity

The generalization that rewards lessen creativity has also been commonly accepted as a fact. The most widely studied form of creativity is divergent thinking, involving varied novel responses to a problem or a question that has multiple possible solutions. Many researchers have reported that offering an individual a reward results in reduced divergent thinking (e.g., Amabile, 1990; Condry, 1977; Deci & Ryan, 1985). Robert Eisenberger has suggested that failures to find increased creativity, resulting from reward, may have occurred because the reward was not actually contingent on creative performance. Because people are rewarded more for conventional performance in their everyday lives, they may fall back

on conventional performance when a reward is offered, with no indication that creativity is preferred. Given this interpretation, Eisenberger and his associates hypothesized that offering reward for creative performance should increase creativity. In one experiment, Eisenberger, Armeli, and Pretz (1998) reported that children who were told explicitly that drawing novel pictures would produce monetary rewards drew more unusual pictures than children who were either offered rewards for undefined drawing or were told to draw novel pictures without any mention of reward.

Eisenberger and his colleagues also investigated the generalized effects of rewards for creativity. Eisenberger (1992) assumed that individuals learn which dimensions of performance (e.g., speed, accuracy, or novelty) are rewarded and generalize rewarded performance in those dimensions to new activities. In his theory of learned industriousness, Eisenberger predicts that rewarding high divergent thinking on one task should increase creativity in an entirely different task. In a test of this contention, Eisenberger and Armeli (1997) asked children to state unusual uses of everyday objects (e.g., paper bag, chair) for which they received no reward, a small monetary reward, or a large monetary reward. When next asked to draw pictures, without the offer of reward, the children who had previously received a large monetary reward (for giving unusual uses of objects) drew the most creative pictures (see also Eisenberger & Rhoades, 2001).

Taken together, Eisenberger and Cameron's research suggests that (a) the explicit offer of reward for creative performance increases creativity; (b) rewards for creative performance produce a generalized increase in novel performance that affects new tasks; (c) in general, rewards increase intrinsic interest and task enjoyment; and (d) the view that rewards undermine people's intrinsic motivation is an overgeneralization; rewards tied to level of performance can increase intrinsic motivation. In summary, when correctly used, rewards have positive effects on creativity and intrinsic motivation.

Negative Reinforcement

When an operant results in the removal of an event, and this procedure increases the rate of response, the contingency is called **negative reinforcement**. This contingency is shown in cell 3 of the matrix in Fig. 4.2. Negative reinforcement is commonly misunderstood as punishment. However, the matrix makes it clear that negative reinforcement involves procedures and effects completely different from those of positive or negative punishment.

Negative reinforcement plays a major role in the regulation of everyday human behavior. For example, you put on sunglasses because in the past this behavior *removed* the glare of the sun. You open your umbrella when it is raining because doing so has prevented you from getting wet. You leave the room when someone is rude or critical, because this behavior has ended other similar conversations. Consider that you live in a place with a very sensitive smoke detector. Each time you are cooking, the smoke detector goes off. You might remove the sound by tripping the breaker or fuse that controls the alarm. In fact, you will probably learn to do this each time before cooking. As a final example, a mother may pick up and rock her crying baby, because, in the past, comforting the child has stopped the crying. In each of these instances, removing an event strengthens an operant.

Positive Punishment

Cell 2 of the matrix in Fig. 4.2 depicts a situation in which an operant produces an event and rate of operant behavior decreases. This contingency is called **positive punishment**. For

example, spanking a child for running onto a busy road is positive punishment if the child now stops (or turns) before reaching the road. In everyday life, people often talk about punishment (and reinforcement) without reference to behavior. For example, a mother scolds her child for playing with matches. The child continues to play with matches, and the parents may comment, "punishment doesn't work with Nathan." In behavior analysis, positive punishment is defined functionally (i.e., by its effects). When behavior is not changed by apparently aversive events, punishment has not occurred. In other words, the parents are arranging an ineffective contingency. The parents could identify another event that reliably decreases behavior; however, this strategy may backfire. For example, as you will see in chapter 6, punishment may produce serious emotional and aggressive behavior. Because of this, punishment should be used only as a last resort for the modification of severe behavior problems.

Negative Punishment

Punishment can also be arranged by removing stimuli contingent on behavior (cell 4 in Fig. 4.2). This contingency is called **negative punishment**. In this case, the removal of an event or stimulus decreases operant behavior. Two children are watching a favorite television program and begin to fight with one another. The parent says, "that's enough fighting," and turns off the television. You tell a sexist joke and people stop talking to you. At school, a student who is passing notes is required to leave the room for a short period of time. In these examples, watching television, talking to others, and participating in classroom activities are assumed to be reinforcing events. When removal of these events contingent on fighting, telling sexist jokes, and passing notes decreases such behavior, negative punishment has occurred.

FOCUS ON ISSUES: REINFORCEMENT AND THE PREMACK PRINCIPLE

As you have seen, there are four basic contingencies of reinforcement. In each case, a stimulus is presented or removed contingent on operant behavior. The contingency is defined as punishment or reinforcement (either positive or negative) by its effects on behavior. One hundred dollars will probably strengthen operants that produce it (e.g., betting 25 cents and pulling the handle on a slot machine). Once a stimulus or event has been shown to increase the rate of operant behavior it may be called a *positive reinforcer*. The consequence of $100 may be defined as reinforcement after its effects are demonstrated. That is, a positive reinforcer or reinforcing stimulus is one that increases the rate of the operant that it follows.

In order to identify a positive reinforcer, you devise a test. The test is to find out whether a particular consequence increases behavior. If it does, the consequence is defined as a positive reinforcer. Such tests are common in science. For example, a litmus test in chemistry tells us whether the solution is either acid or base. One hundred dollars is defined as a positive reinforcer, because it increases the frequency of betting 25 cents and pulling the handle on the slot machine. Notice that the test for a reinforcer is not the same as explaining the behavior. We explain behavior by pointing to the contingencies of reinforcement (S^D: $R \rightarrow S^r$) and basic principles, not by merely identifying a reinforcing stimulus. For example, we can explain a person's betting in a casino by pointing to the schedule of monetary

reinforcement (involving large intermittent payoffs) that has strengthened and maintained this behavior.

Another way to identify a positive reinforcer is based on the **Premack principle**. This principle states that a higher frequency behavior will function as reinforcement for a lower frequency behavior. For example, for a person that spends little time practicing piano but lots of time playing basketball, the Premack principle means that playing basketball (high-frequency behavior) will reinforce practicing the piano. Generally, David Premack (1959) proposed that reinforcement involved a contingency between two sets of behaviors, operant behavior and reinforcing behavior (behavior^{operant} → behavior^{Sr}), rather than between an operant (behavior) and a stimulus (R → S^r). That is, Premack suggests it is possible to describe reinforcing events as actions of the organism rather than as discrete stimuli. Thus, reinforcement involves eating rather than the presentation of food, drinking rather than provision of water, reading rather than the effects of textual stimuli, and so on.

In his 1962 experiment, Premack deprived rats of water for 23 hr and then measured their behavior in a setting in which they could run on an activity wheel or drink water. Of course, the animals spent more time drinking than running. Next, Premack arranged a contingency between running and drinking. The rats received a few seconds' access to a drinking tube when they ran on the wheel. Running on the wheel increased when it produced the opportunity to drink water—showing that drinking reinforced running. In other words, the rats ran on the wheel to get a drink of water.

At this point in the experiment, Premack (1962) gave the rats free access to water. When the rats were allowed to choose between drinking and running, they did little drinking and a lot more running. Premack reasoned that running would now reinforce drinking because running occurred at a higher frequency than drinking. The running wheel was locked, and the brake was removed if the rats licked the water tube for a few seconds. Based on this contingency, Premack showed that drinking water increased when it produced running. That is, the animals drank water to get a chance to run on the wheel.

Generally, this experiment shows that drinking reinforces running when rats are motivated to drink. On the other hand, running reinforces drinking when running is the preferred activity. Thus, when behavior is measured in a situation that allows a choice among different activities, those responses that occur at higher frequency may be used to reinforce those that occur at a lower frequency.

Premack's principle has obvious applied implications, and it provides another way to identify reinforcement in everyday settings. Behavior is measured in a situation where all relevant operants can occur without restriction; any behavior of relatively higher frequency will reinforce an operant of lower frequency. To illustrate, a child is observed in a situation where doing homework, watching television, playing with toys, recreational reading, and so on may all freely occur. Once baseline measures of behavior have been taken, the Premack principle holds that any higher frequency (or longer duration) behavior may serve as reinforcement for any behavior of lower frequency. If television watching is longer in duration than doing homework, watching television may be made contingent on completing homework assignments. This contingency will usually increase the number of homework assignments completed.

An early example of the Premack principle in an applied setting was reported by Homme, deBaca, Devine, Steinhorst, and Rickert, (1963). These investigators modified the behavior of nursery school children who engaged in a variety of disorganized activities. The children were running, screaming, pushing chairs around, and generally having a wonderful time. This behavior was viewed as annoying because the children ignored the teacher's instructions. The researchers reasoned that the teacher could get the children to follow

more instructions if the higher frequency behaviors of running and screaming were made contingent on following instructions.

For example, when the children were sitting quietly and attending, the teacher was told to ring a bell and tell them to run and scream. After the teacher rang the bell, the children usually began to scream and run around the classroom. At this time, the teacher rang the bell again and gave another instruction to do another activity. Eventually, the children earned tokens for engaging in low-probability behavior. These tokens could be used to buy opportunities to engage in higher probability operants like kicking a waste basket, throwing a plastic cup, and pushing an adult around in a caster-equipped chair. The modification was highly successful, and the children quickly learned to follow the teacher's instructions.

Operant Conditioning

Operant conditioning refers to either an increase or a decrease in operant behavior as a function of a contingency of reinforcement. In a simple demonstration of operant conditioning, an experimenter may alter the consequences that follow operant behavior. The effects of environmental consequences on behavior were first described in 1911 by the American psychologist E. L. Thorndike, who reported results from a series of animal experiments that eventually formed the basis of operant conditioning. Cats, dogs, and chicks were placed in situations in which they could obtain food by performing complex sequences of behavior. For example, hungry cats were confined to an apparatus that Thorndike called a puzzle box, shown in Fig. 4.4. Food was placed outside the box, and if the cat managed to pull out a bolt, step on a lever, or emit some other behavior, the door would open and the animal could eat the food.

After some time in the box, the cat would accidentally pull the bolt or step on the lever and the door would open. Thorndike measured the time from closing the trap door until the cat managed to get it open. This measure, called **latency**, tended to decrease with repeated exposures to the box. In other words, the cats took less and less time to escape from the apparatus as they were given more trials. According to Thorndike, the puzzle-box experiment demonstrated learning by trial and error. That is, the cats repeatedly tried to get out of the box and made fewer and fewer errors. Thorndike made similar observations with dogs and chicks and, on the basis of these observations, formulated the **law of effect**. A modern paraphrase of this law is the principle of reinforcement: Operants may be followed
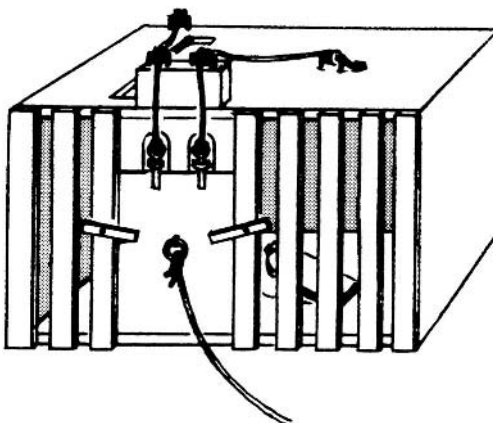
FIG. 4.4. *Thorndike's puzzle box for cats. Food was placed outside the box, and if the cat managed to pull out a bolt, step on a lever, and so on, the door would open and the animal could get out of the box and eat the food. When the cats were given repeated trials in the box, they became faster and faster at getting out* Note: *From* Behavior and Learning, *by H. Rachlin, 1976, San Francisco: Freeman. Reprinted with permission. Based on E. L. Thorndike, 1911.*

by the presentation of contingent consequences that increase the rate (frequency of response divided by time) of this behavior. Skinner (1988) has commented on Thorndike's analysis of trial-and-error learning:

> Thorndike thought he solved his problem by saying that the successful cat used trial-and-error learning. The expression is unfortunate. "Try" [from trial] implies that a response has already been affected by relevant consequences. A cat is "trying to escape" if it engages in behavior which either has been selected in the evolution of the species because it has brought escape from comparable situations or has been reinforced by escape from aversive stimulation during the life of the cat. The term "error" does not describe behavior, it passes judgment on it. The curves for trial-and-error learning plotted by Thorndike and many others do not represent any useful property of behavior—certainly not a single process called problem solving. The changes which contribute to such a curve include the adaptation and extinction of emotional responses, the conditioning of reinforcers, and the extinction of unrelated responses. Any contribution made by an increase in the probability of the reinforced response is hopelessly obscured. (p. 219)

In other words, Skinner suggests that simply measuring the time (or latency) taken to complete a task misses changes that occur across several operant classes. Responses that resulted in escape and food were selected, whereas other behavior decreased in frequency. Eventually those operants that produced reinforcing consequences came to predominate the cat's behavior. For this reason, the cat got out of the box in progressively less time as trials were repeated. Thus, latency was an indirect measure of a change in the animal's operant behavior. Today, **rate of response**, or operant rate (the number of responses in a specified interval), is considered a better measure of operant behavior. Operant rate provides a direct measure of the selection of behavior by its consequences.

Procedures in Operant Conditioning

Operant Rate and Probability of Response

Rate of response refers to the number of operant responses that occur in some defined unit of time. For example, if you ask 5 questions during a 2-hr class, your rate is 2.5 questions per hour. An animal that presses a lever 1,000 times in a 1-hr session generates a rate of 1,000 bar presses per hour (or 16.7 responses per minute). Skinner (1938) proposed that rate of response is the basic datum (or measure) for operant analysis. Operant rate is a measure of the probability of behavior (the probability of response). In other words, an operant that occurs at high rate in one situation has a high probability of being emitted in a similar situation in the future. This increased probability of response is observed as a change in operant rate. Of course, probability of response may decrease and in this case is seen as a decline in rate.

The Free Operant Method

In the **free operant method**, an animal may repeatedly respond over an extensive period of time (see Perone, 1991). The organism is free to emit many responses or none at all. That is, responses can be made without interference from the experimenter. For example, a laboratory rat may press a lever for food pellets. Lever pressing is under the control of the animal, which may press the bar rapidly, slowly, or quit pressing. Importantly, this method allows the researcher to observe changes in rate of response. This is important because rate of response is used as a measure of response probability. Rate of response must be free to vary if it is used to index the future probability of operant behavior.

   The analysis of operant rate and probability of response is not easily accomplished when an organism is given a series of trials (as in the Thorndike experiments). This is because the experimenter largely controls the animal's rate of behavior. For example, a rat that runs down a T-maze for food reward is picked up at the goal box and returned to the starting point. The experimenter sets number of trials and response opportunities. For this reason, changes in rate of response cannot be directly observed and measured. Comparing the T-maze trial procedure to the free operant method, it is clear that the free operant method is more suitable to study the probability of response in a given situation. The free operant method is clearly demonstrated by the procedures used in operant conditioning.

The Operant Chamber

   To study operant conditioning in a laboratory, a device called an **operant chamber** is used (see Ator, 1991). Of course, operant conditioning is also investigated outside laboratories. Nonetheless, investigating the behavior of animals in operant chambers has resulted in the discovery of many principles of behavior. Figure 4.5 shows a student setup of an operant chamber designed to accommodate a laboratory rat. (Note that a research setup would involve much more experimental control, such as a sound attenuating enclosure and "white noise" to mask sounds from outside.) The chamber is a small enclosed box that contains a lever with a light above it and a food magazine or cup connected to an external feeder. The feeder delivers a small food pellet (typically, 45 mg) when electronically activated. In this situation, the food pellet serves as reinforcement for lever pressing. The operant chamber structures the situation so that the desired behavior will occur and incompatible behavior is reduced. Thus, lever pressing is highly likely, and behavior like running away is minimized. A school classroom also attempts to structure the behavior of students with regard to learning.
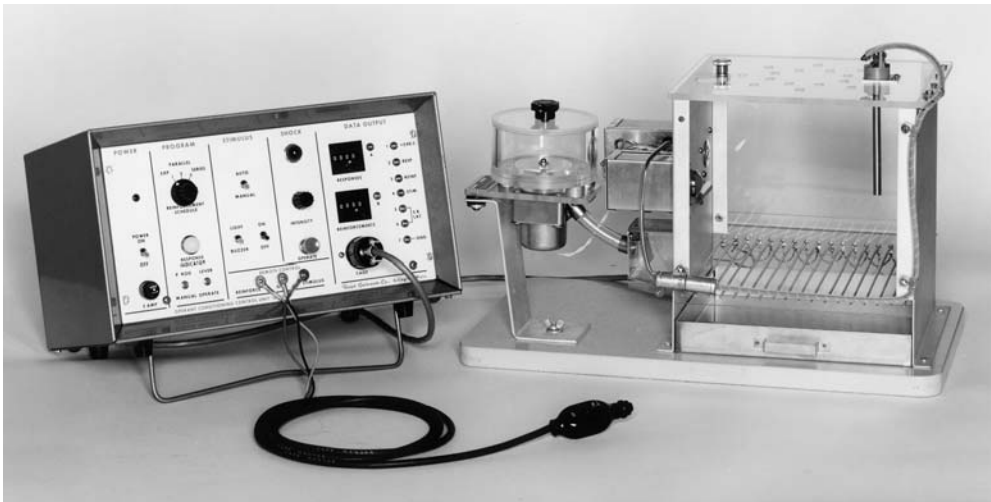
FIG. 4.5.   *A student setup of operant chamber for a rat. The chamber is a small box that has a lever that the animal can press. There is a light above the lever that can be turned on or off. A food magazine or cup is connected to an electronically activated feeder. The feeder delivers a small, 45-mg food pellet to the cup. In this situation, the food pellet serves as reinforcement for lever pressing.* Note: *Reprinted with permission of Gerbrands Corporation, Arlington, MA.*

The classroom, unlike the operant chamber, often contains many distractions (e.g., looking out the window) that interfere with on-task behavior and concentrating on the material being presented.

Deprivation

Because the delivery of food is used as reinforcement, an animal must be motivated to obtain food. An objective and quantifiable measure of motivation for food is the percentage of free-feeding body weight. (Note: another way of quantifying deprivation is a timed cycle that specifies the time since the rat last consumed the reinforcer.) Prior to a typical experiment, an animal is brought from a commercial (or research) colony into a laboratory, placed in a cage, given free access to food, and weighed on a daily basis. The average weight is calculated, and this value is used as a baseline. Next, the daily food ration is reduced until the animal reaches 85% of its free-feeding weight. The procedure of restricting access to food (the potentially reinforcing stimulus) is called a **deprivation operation** (see establishing operations, chap. 2). At this point, the experimenter assumes, but does not know if, food is a reinforcing stimulus. This is because food delivery must increase the frequency of an operant before it can be defined as a reinforcer.

The weight-loss or deprivation criterion is less severe than it first appears. Laboratory animals typically have food freely available 24 hr a day, whereas animals in the wild must forage for their food. The result is that lab animals tend to be heavier than their free-ranging counterparts. Alan Poling and his colleagues (Poling, Nickel, & Alling, 1990) nicely demonstrated this point by showing that captured free-range pigeons gained an average 17% body weight when housed under laboratory conditions. Notice that weight gain, for these birds, is roughly equal to the weight loss typically imposed on laboratory animals.

Magazine Training

After deprivation for food is established, **magazine training** starts. For example, a rat is placed in an operant chamber, and a microcomputer periodically turns on the feeder. When the feeder is turned on, it makes a click, and a small 45-mg food pellet falls into the food magazine. Because the click and the appearance of food are associated in time, you would, after training, observe a typical rat staying close to the food magazine; also, the animal would move quickly toward the magazine when the feeder operated and the click occurred. Because the click of the feeder reliably precedes the appearance of food, it becomes a conditioned positive reinforcer. (See chap. 10 for a more complete discussion of conditioned reinforcement.) A **conditioned reinforcer** is an event or stimulus that acquires its reinforcing function over the lifetime of the organism (ontogeny). In this case, following the click of the feeder by the presentation of food establishes the sound of the feeder as a conditioned reinforcer for the rat.

The Operant Class

Staying close to the food cup and moving toward it are operants that have been selected by their reinforcing consequences. In other words, these responses have been reliably followed by food presentation, and as a result they increase in frequency. However, hovering around a food cup and moving toward it are operants that are difficult to measure objectively. In contrast, a lever press may be easily defined as a switch closure that makes an electrical connection. Any behavior emitted by the rat that results in a switch closure defines the

operant class. A lever press with the left or right paw produces an identical electrical connection. Another advantage of lever pressing as an operant is that it may be emitted at either high or low rates of response. This is an advantage because the primary focus of operant research is on the conditions that affect the rate (probability) of operant behavior.

Operant Level and Continuous Reinforcement

After magazine training, the food-deprived rat is again placed in the operant chamber. The researcher may first want to measure the rate of lever pressing before these responses produce food pellets. Rats emit many exploratory and manipulative responses and as a result may press the lever at some low frequency, even when this behavior is not reinforced with food. This baseline rate of response is called the **operant level**, or the rate of response before any known conditioning. Next, the environment is arranged so that each lever press results in the click of the feeder (conditioned reinforcement) and the delivery of a food pellet (primary reinforcement). When each response produces food, the schedule of reinforcement is called **continuous reinforcement (CRF)**. The food pellets are contingent on lever pressing. This contingency between the operant behavior and food reinforcement increases the frequency of lever pressing above the operant level.

Shaping: The Method of Successive Approximation

In the preceding example, we took advantage of a rat's behavioral repertoire. The animal's **repertoire** refers to the behavior it is capable of naturally emitting on the basis of species and environmental history. Suppose you want to train some response that the animal does not emit. For example, you may want the rat to activate the switch by an upward thrust of its nose. A baseline period of observation shows that the animal fails to emit this response. (In other words, the *operant level is zero*.) In this case, the researcher could use **shaping** or the method of **successive approximation** to establish the response (see Gleeson, 1991). This method involves reinforcing closer and closer approximations to the final performance (i.e., nosing the lever).

At first, the rat is reinforced for standing in the vicinity of the lever. It is important to note that the most immediate consequence is the sound of the pellet feeder, and this conditioned reinforcer may be used to shape the desired response. Once the animal is reliably facing the lever, a movement of the head toward the bar is reinforced with a click of the feeder and presentation of food. Next, closer and closer approximations to lifting the lever with the nose are reinforced. Each step of the procedure involves reinforcing closer approximations and no reinforcement (extinction) of more distant responses. Eventually, the rat emits a response that activates the electrical switch. Many novel forms of behavior may be established by the method of successive approximation or shaping (Pryor, 1999).

Recording Operant Behavior

A commonly used laboratory instrument that records the frequency of operant behavior in time is called a **cumulative recorder**. Figure 4.6 illustrates this device; each time a lever press occurs, the pen steps up one increment. When reinforcement occurs, this same pen makes a downward deflection. Once the pen reaches the top of the paper, it resets to the bottom and starts to step up again. Since the paper is drawn across the roller at a constant speed, the *cumulative recorder depicts a real-time measure of the rate of operant behavior*. The faster the lever presses, the steeper the slope or rise of the cumulative record.
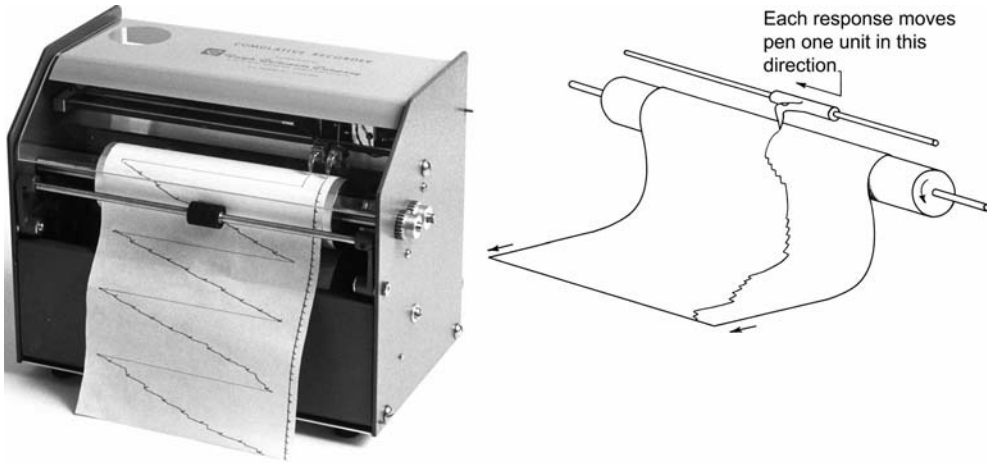
FIG. 4.6. *A laboratory instrument used to record operant responses, called a cumulative recorder. The recorder gives a real-time measure of the rate of operant behavior. The faster the lever presses, the steeper the slope or rise of the cumulative record. This occurs because paper is drawn across the roller at a constant speed and the pen steps up a defined distance for each response.* Note: *Photograph by permission of Gerbrands Corporation, Arlington, MA.*

A cumulative record of key pecking by a pigeon is shown in Fig. 4.7. In this illustration, a bird responded 50 times in order to produce one food delivery. Notice that periods of responding are followed by reinforcement (indicated by the deflection of the pen). After reinforcement, the rate of response is zero, as indicated by the plateaus or flat portions of the cumulative record.

In a modern operant laboratory, the cumulative recorder is used to provide the experimenter with an immediate report of the animal's behavior. Researchers have discovered many basic principles of behavior by examining cumulative records (e.g., Ferster & Skinner, 1957). Today, microcomputers allow researchers to collect and record measures of behavior that are later submitted to complex numerical analyses (see Gollub, 1991). In this book, we present examples of cumulative records and numerical analyses that have been important to the experimental analysis of behavior.
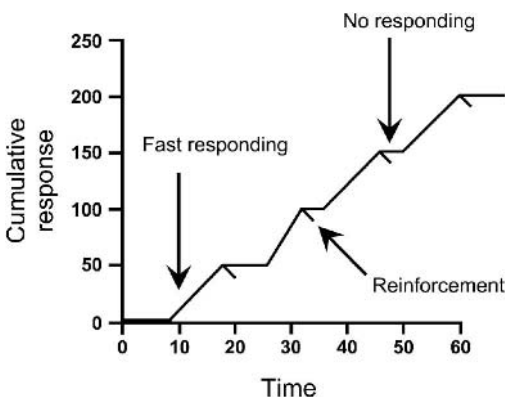
FIG. 4.7. *A cumulative record of key pecking by a pigeon. In this illustration, a bird responded 50 times to produce 1 food delivery. Notice that 50 pecks are followed by reinforcement and that this is indicated by a downward deflection of the pen. Following reinforcement, the rate of response is zero, as indicated by the plateaus or flat portions of the record.*

A Model Experiment

In the previous discussion of operant behavior, some basic principles were illustrated using the laboratory rat. It is important to realize that these same principles can be extended to a variety of species. (Later chapters will focus more on human behavior.) In the following demonstration of operant conditioning, pigeons are used as the experimental subjects. Pigeons are placed in an operant chamber and required to peck a small plastic disk, or key, that is illuminated by a white light. A peck at the key activates a microswitch and makes an electrical connection that controls a food hopper. Presentation of food functions as reinforcement for pecking. A food hopper filled with grain swings forward and remains available for a few seconds. The bird can eat the grain by sticking its head through an opening. Figure 4.8 shows an operant chamber designed for birds. Note that the chamber is very similar to the one used to study the operant behavior of rats.

Before an experiment, the bird is taken from its home colony and is placed alone in a cage. Each pigeon is given free access to food and water. The bird is weighed each day for about a week, and its baseline weight is calculated. Next, the daily food ration is reduced until the bird reaches approximately 80% of free-feeding or **ad libitum weight**. After the deprivation procedure, the pigeon is placed in the operant chamber for magazine training.

When the bird is put in the chamber for the first time, it may show a variety of emotional responses including wing flapping and defecating. This is because the chamber presents a number of novel stimuli that were initially aversive. For example, the operation of the feeder makes a loud sound that may startle the bird. Eventually, these emotional responses are extinguished by repeated exposure to the apparatus. As the emotional responses dissipate, the bird explores the environment and begins to eat from the food magazine. Since the sound
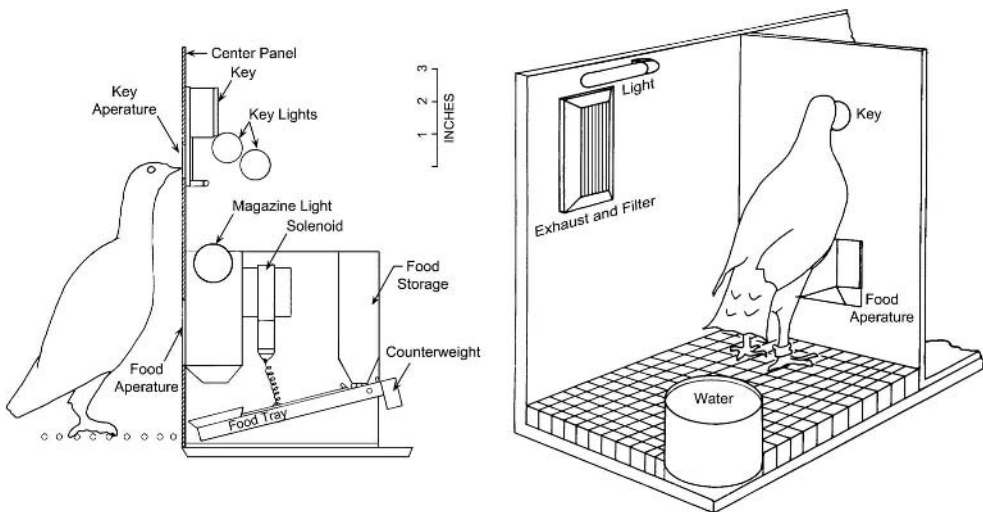
FIG. 4.8. *An operant chamber for birds. The chamber contains a small plastic disk illuminated by a light. A peck at the disk activates a microswitch and makes an electrical connection. When reinforcement is scheduled to occur, the food hopper swings forward and remains available for a few seconds. The bird can eat grain from the hopper by sticking its head through the opening in the chamber wall. In principle, the chamber is similar to the one used to study the operant behavior of rats.* Note: *Adapted from* Schedules of Reinforcement, *by C. B. Ferster and B. F. Skinner, 1957, Appleton–Century–Crafts: New York.*

of the hopper is paired with food, the sound becomes a conditioned positive reinforcer. At this point, the bird is said to be magazine trained.

The purpose of this demonstration is to train the pigeon to peck the key for food reinforcement. To show that the behavior occurs because of the contingency between pecking and food, an operant level or baseline of pecking the key must be measured. This is accomplished by placing the bird in the operant chamber and recording pecks on the key before a peck-food contingency is established. In other words, pecking the key does not produce food during this phase of the experiment. The operant level serves as a baseline or control period for assessing a change in behavior.

A bird's operant level of key pecking is typically very low, and it is convenient to train these responses by the method of successive approximation. Shaping key pecking in pigeons is similar to shaping lever pressing in rats; in both cases, shaping involves reinforcing closer and closer approximations to the final performance (i.e., pecking the key hard enough to operate the microswitch). As each approximation occurs, it is reinforced with the presentation of the food hopper. Earlier approximations are no longer reinforced and reduce in frequency. This process of reinforcing closer approximations, and withholding reinforcement for earlier approximations, eventually results in the pigeon pecking the key with sufficient force to operate the microswitch.

The key peck that operates the microswitch to produce food is the first definable response. The switch closure and electrical connection define the operant class of pecking for food. At this point, a microcomputer is programmed so that each key peck results in the presentation of food for a few seconds. Because each response produces reinforcement, the schedule is called continuous reinforcement, or CRF.

Figure 4.9 shows the acquisition of key pecking on continuous reinforcement. (The bird has presumably been shaped to peck the key for food.) Notice that the rate of response is low when the pigeon is initially placed in the chamber. This period is called the warm-up and probably occurs because of the abrupt change from home cage to the operant chamber. After the brief warm-up period, the rate of response is high and stable.
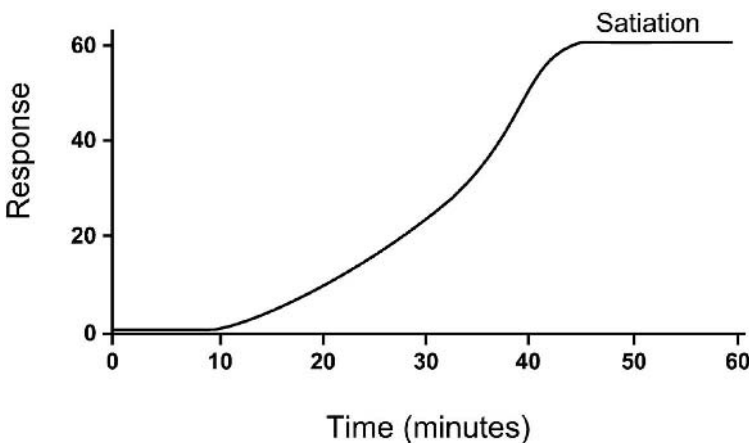
FIG. 4.9. *Typical acquisition of key pecking on CRF or continuous reinforcement. Because every response is reinforced, downward deflections indicating reinforcement are omitted. Rate of response is low when the animal is initially placed in the chamber. After this brief period, the rate of response is high and stable. Finally, the rate of response declines and then levels off. This latter effect is caused by satiation.*
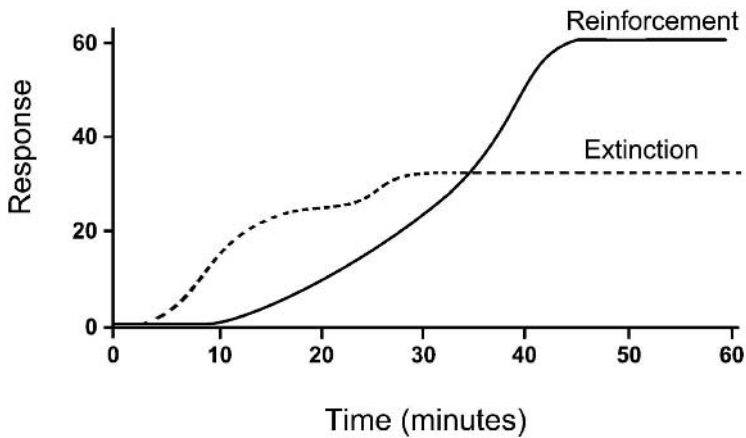
FIG. 4.10. *Performance on CRF and extinction. Responses are maintained when they are re-inforced. However, when responding is no longer reinforced, the rate of response declines and eventually stops.*

Finally, the record shows that the rate of response declines, and the plateau indicates that the bird stops pecking the key. This latter effect is called **satiation**, and it occurs because the bird has eaten enough food. More technically, *the rate of response declines because repeated presentations of the reinforcer weaken its effectiveness.* A satiation operation decreases the effectiveness of reinforcement. This effect is opposite to deprivation, in which withholding the reinforcer increases its effectiveness.

To be sure that an increase in the rate of response is caused by the contingency of reinforcement, it is necessary to withdraw that contingency. In other words, if food is no longer presented, the pigeon should give up pecking the key. If the peck-food contingency caused key pecking, then withdrawal of the contingency will result in a decline in key pecking toward the operant level.

Figure 4.10 presents cumulative records for periods in which pecking produces, or does not produce, food. The initial peck-food contingency produces a steady rate of response. When pecking no longer produces food, the rate of response declines and eventually key pecking stops. Thus, key pecking clearly depends upon the contingency of reinforcement.

Extinction

The procedure of *withholding reinforcement for a previously reinforced response* is called **extinction**. Skinner (1938) conducted the first extensive study of extinction and its re-lated principles. To produce extinction, you would disconnect the food hopper after the bird had been reinforced for key pecking. It is important to note that the procedure of extinction is a contingency of reinforcement. The contingency is defined as zero probabil-ity of reinforcement for the operant response. Extinction is also a behavioral process and, in this case, refers to a *decline in the rate of response caused by withdrawal of reinforcement.* For example, you may raise your hand to ask a question and find that a certain professor ignores you. Asking questions may decline because the professor no longer reinforces this behavior.

Behavioral Effects of Extinction

Extinction produces several behavioral effects in addition to a decline in the rate of response. In the section that follows, we consider the range of effects generated by the cessation of reinforcement. Many of the responses of organisms to the cessation of reinforcement make sense from an evolutionary perspective. Presumably, when things no longer worked (extinction), natural selection favored organisms that (a) repeated behavior that "worked" in the past, (b) made a greater range of responses in the situation (behavioral variability), (c) emitted more forceful responses to the circumstances, and (d) attacked conspecifics associated with the cessation of reinforcement.

Extinction Burst

When extinction is started, operant behavior tends to increase in frequency. That is, organisms repeat behavior that has been reinforced. A pigeon will initially increase the rate of key pecking, and you may raise your hand more often than you did in the past. You may explain your increased tendency to raise your hand by telling a friend, "The instructor doesn't see me; I have an important point to make," and so on. If the bird could talk it might also "explain" why it was pecking at an increased rate. The point is that an initial increase in the rate of response, or **extinction burst**, occurs when reinforcement is first withdrawn.

Operant Variability

In addition to extinction bursts, operant behavior becomes increasingly variable as extinction proceeds (**operant variability**). Behavioral variation increases the chances that the organisms will either reinstate reinforcement or contact other sources of reinforcement. You may wave your hand about in an attempt to catch the professor's eye; the bird may strike the key in different locations and with different amounts of force. A classic experiment by Antonitis (1951) demonstrated this effect. Rats were taught to poke their noses through a 50-cm-long slot for food reinforcement. When this occurred, a photocell was triggered and a photograph of the animal was taken. The position of the rat and the angle of its body were recorded at the moment of reinforcement. After the rat reliably poked its nose through the slot, it was placed on extinction. Following this, reinforcement was reinstated, then extinguished, and, in a final phase, the operant was again reinforced.

Antonitis (1951) reported that reinforcement produced a stereotyped pattern of response. The rat repeatedly poked its nose through the slot at approximately the same location, and the position of its body was held at a particular angle. When extinction occurred, the nose poking and position of the body varied. During extinction, the animal poked its nose over the entire length of the slot. Reinforcing the operant after extinction produced even more stereotyped behavior than the original conditioning.

Pear (1985) found a similar effect with pigeons. When birds were reinforced for pecking a key after an average of only 15 s, they stayed close to the key and emitted routine patterns of head and body movements. When these animals were reinforced on a similar schedule, but one that required an average wait of 5 min, they strayed farther from the key. Both of these patterns developed during extinction, but as extinction continued, their behavior became much more variable.

The effect of reinforcement on response stereotypy is a controversial issue in the field of behavior analysis. On the one hand, Dr. Barry Schwartz of Swarthmore College has interpreted this effect as a negative outcome of reinforcement procedures. Schwartz (1980,

1982a, 1982b) showed that reinforcement produces stereotyped responses in both pigeons and college students. In the human experiment, this effect prevented students from discovering solutions to novel problems. More technically, response stereotypy resulted in students behaving less effectively under new contingencies of reinforcement. On the other hand, Dr. Allen Neuringer of Reed College reports that reinforcement may be used to train variable response patterns in both pigeons and college students (Neuringer, 2002). The human research by Neuringer (1986) showed that students generated random sequences of behavior when given reinforcing feedback for randomness. An implication is that reinforcement contingencies may sometimes produce novel and creative behavior patterns.

FOCUS ON RESEARCH: REINFORCEMENT, PROBLEM SOLVING, AND CREATIVITY

Dr. Barry Schwartz, a former professor of psychology at Swarthmore College in Pennsylvania, stated that he "decided to study the Skinnerian program and come to know it well, so that I would be able to criticize it" (1981, p. 12). As an undergraduate, Schwartz read Skinner's (1953) book *Science and Human Behavior* and was appalled that behaviorists used principles derived from laboratory research with animals to account for human behavior. According to Schwartz, behaviorists who insist on a scientific account of behavior misrepresent human action. Schwartz finds it hard to believe that our commonsense understanding of human nature is wrong. In the everyday account of human action, people refer to desires, intentions, and expectations. From this position, people are said to be free and responsible for their actions. If the commonsense account is correct, then the behavioral interpretation of human behavior must be inaccurate. Furthermore, Schwartz argues that principles of reinforcement may actually interfere with human intellectual capacities.
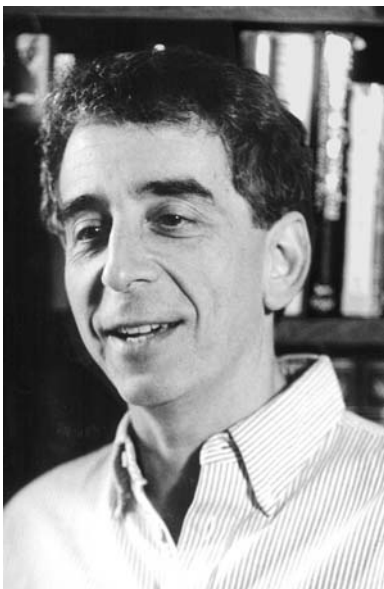
FIG. 4.11. *Dr. Barry Schwartz.* Note: *Photograph by John Brodsky.*
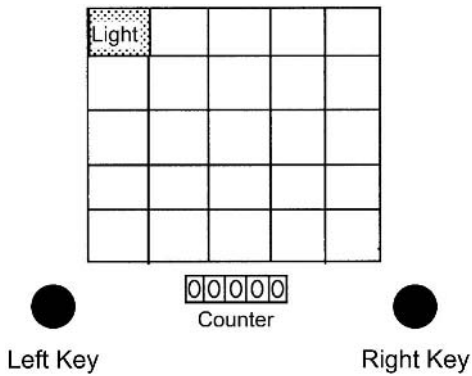
FIG. 4.12. *The matrix task used by Schwartz (1982b). A right press moved the light one square to the right; a left button press moved the light down one square.*

Schwartz (1982a) carried out a series of experiments with pigeons to show that reinforcement produced response stereotypy. In these experiments, reinforcement produced a set pattern of responding that occurred over and over. Once he established this result in pigeons, Schwartz (1982b) used similar procedures with college students to demonstrate the negative effects of reinforcement for human problem solving.

College students were given points on a counter when they completed a complex sequence of responses. The responses were left and right key presses that moved a light on a checkerboard-like matrix of 25 illuminated squares. Figure 4.12 shows the matrix, with the light in the top-left square. The task required that the subject press the keys to move the light from the top-left corner to the bottom-right square. A press on the right key moved the light one square to the right. When the left-hand key was pressed, the light moved one square down. Schwartz required exactly four left (L) and four right (R) presses in any order (e.g., LRLRLRLR, LLLLRRRR, etc.). There were 70 different orders of left and right key presses that would move the light to the bottom-right corner. When the light reached the bottom-right corner, a point registered on the counter. The points were later exchanged for money. If the subject pressed any key a fifth time (e.g., RRRRR), all matrix lights were turned off, and the trial ended without reinforcement.

In a series of experiments, Schwartz found that students developed a stereotyped pattern of responding. That is, they repeated the same sequence over and over. For example, two students produced the same left and right sequences (LLLLRRRR) over and over again. Another subject repeatedly produced the sequence LRLRLRLR to satisfy the contingency. The point is that as soon as a student hit on a correct sequence, he or she repeated it and rarely tried another pattern. Schwartz also asked the students to discover the rule that would result in moving the light to the bottom-right corner. The actual rule was any four presses on the left key and any four on the right. However, students who produced a stereotyped pattern of response had difficulty describing this simple rule. They often described the rule in terms of their stereotyped response pattern. For example, although any four left and right responses resulted in reinforcement, a student might claim that the particular sequence of LLRRLLRR was the necessary pattern. When Schwartz compared such students to others who had not worked on the task, he found that the inexperienced students were better at discovering the actual underlying rule.

In other experiments (Schwartz, 1982b), subjects were explicitly reinforced for varying their response pattern. When this was done, the students developed higher order stereotypes. When students were reinforced for changing their pattern of button presses from trial to trial, they developed a stereotyped set of sequences that occurred in a regular order. For example,
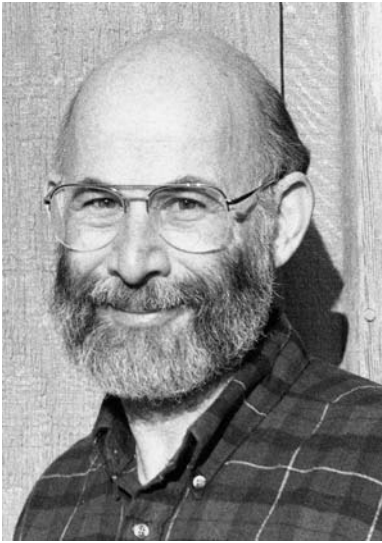
FIG. 4.13. *Dr. Allen Neuringer.* Note: *Photograph by Vera Jagendorf, Portland, OR.*

a subject might respond with LLLLRRRR, then LRLRLRLR, followed by RRRRLLLL. Patterns like this were repeated over and over by the students. From these experiments, Schwartz (1982b) concluded that reinforcement interfered with problem solving, because it produced stereotyped response patterns.

Dr. Allen Neuringer, (Fig. 4.13), at the time of this writing, is a professor of psychology at Reed College in Portland, Oregon. He received his Ph.D. in 1967 from Harvard University, where he was trained as a behavior analyst. Since that time, he has published extensively in the experimental analysis of behavior. Several years ago, Neuringer became interested in variability, randomness, and behavior. He said that this interest developed from a game that involved predicting his own behavior. The game consisted of predicting the movement of his index finger. If he could move his finger up or down in a random fashion, then by definition the behavior was unpredictable. This game prompted Neuringer to investigate the question of randomness, variability, and human behavior.

A review of the literature suggested that humans could not behave in a random manner. At the same time, Neuringer read Schwartz's research on problem solving and disagreed with the conclusion. Schwartz claimed that reinforcement necessarily produced response stereotypy. Neuringer suggested that the contingencies of the Schwartz experiments produced response stereotypy and that this was not an inevitable outcome of reinforcement. The requirement to emit exactly four left and four right responses was arbitrary and may have resulted in response stereotypy.

In their 1985 experiments, Neuringer and his honors student, Suzanne Page (Page & Neuringer, 1985), used the light matrix task to investigate variability of response pattern in pigeons. The birds pecked left and right keys to move the light and were reinforced with food. The researchers designed a contingency that was identical to the one used by Schwartz (1982a, 1982b). They compared this to a condition in which response variability was not constrained by exactly four pecks on each key. Under this condition, the birds could emit any sequence of eight left or right responses to obtain reinforcement. This difference in procedure is important because it increases the number of correct sequences from 70 to 256. The Neuringer procedure increased the rate of reinforcement for response variability and eliminated time out (negative punishment) for emitting novel sequences. To make this

clear, in the Schwartz experiments the fifth left or right response resulted in the lights going out and the end of the trial. In other words, students and pigeons received time out from reinforcement (negative punishment) for varying their response patterns. Time out from reinforcement does not occur when any sequence of eight left and right responses is emitted. Thus, the procedures used by Schwartz punished trying out new patterns. This occurred because a mistake (a fifth left or right response) turned the trial off, and reinforcement was not available. Additionally, the requirement of exactly four left and right presses limited the number of possible sequences to 70.

Page and Neuringer (1985) investigated contingencies of reinforcement that could generate behavioral variability. Pigeons had to peck left and right keys eight times in any order to produce food reinforcement. In their third experiment, the researchers required pigeons to vary their pattern of response on the current trial from the ones produced on the previous trials. In different phases of the experiment, the sequence had to differ from the last 5, 10, 15, 25, or 50 response patterns. For example, at lag 5 there were five preceding sequences (e.g., RRRRRRRR, LLLLLLLL, LLLLRRRR, LLRRRRRR, RRRLLLLL), and the next sequence had to be different from these 5 (e.g., RLLLLLLL). Results showed that the pigeons were able to generate highly variable response patterns when the contingencies required this behavior. Generally, sequence variation increased with the lag requirement. At lag 25, approximately 85% of the emitted response patterns differed from all others for a session. Another experiment showed that behavioral variability, or stereotypy, is an acquired response. Pigeons learned to respond with a variable pattern in the presence of one color and respond with a stereotyped sequence when another color was presented. Apparently, the degree of response variability is a conditionable property of operant behavior. In other words, when variation in response is reinforced, it increases in frequency (see Page & Neuringer, 1985, for evidence that rules out short-term extinction periods as the cause of variability attributed to reinforcement).

A subsequent study by Neuringer (1986) extended the findings on response variability to humans. In two experiments, Neuringer demonstrated that college students could learn to generate random sequences of two numbers on the keyboard of a computer. Subjects were required to press the 1 and 2 keys as randomly as possible. Initially, the students were not able to generate random sequences. However, when they were given feedback from statistical estimates of chance, the students learned to emit sequences that were indistinguishable from computer-generated random numbers. Neuringer concluded, "randomlike behaviors are learned and controlled by environmental feedback, as are other highly skilled activities" (p. 72).

Neuringer's research leads us to the conclusion that variability itself is an operant. As with other operant dimensions, operant variability is expected to show sensitivity to its reinforcing consequences, precise control by contingencies, and control by events or stimuli that precede it (discriminative stimuli). In terms of discriminative stimuli, Page and Neuringer (1985, Experiment 6) showed that birds reinforced for repeating a single LRRLL sequence in the presence of blue key lights, and variable sequences when the lights were red, learned to emit variable patterns in red and to repeat in blue (see also Cohen, Neuringer & Rhodes, 1990). Denney and Neuringer (1998) extended this line of research, using more extensive experimental control procedures. The overall findings support the conclusion that operant variability is controlled by discriminative stimuli. One implication is that discriminative cues (e.g., instructions to "Vary") may be helpful when people are faced with problems requiring novel responses.

In addition to discriminative stimuli, operant variability may come under the control of the contingency and rate of reinforcement. Although the rate of reinforcement and

the contingency of reinforcement regulate variability, recent evidence indicates that the contingency exerts more consistent control over variability than the rate of reinforcement (Machado, 1989, 1992; Neuringer, 2002). That is, a contingency of reinforcement that requires high variability generates more variability than one that stipulates intermediate variability. Also, a requirement for intermediate variability produces greater variability than a contingency that specifies low variability. Such effects of contingencies are obtained even when the rate of reinforcement is held constant.

In summary, Dr. Barry Schwartz argues that reinforcement produces behavioral inflexibility and rigidity. Such inflexibility interferes with finding solutions to complex problems that require innovation and creativity. He argues that in educational settings, the use of reinforcement procedures may be counterproductive, because the natural problem-solving capabilities of humans are overridden by reinforcement contingencies. In contrast, the work of Dr. Allen Neuringer suggests that response stereotypy is not an inevitable outcome of reinforcement. Neuringer's research shows us that the effects of reinforcement depend on the contingencies. If the contingencies of reinforcement support stereotyped behavior, then this will occur. On the other hand, contingencies may generate novel sequences of behavior if these patterns result in reinforcement (see also Machado, 1989, 1992, 1997).

One way to view this issue is to consider that solutions to some problems require flexibility, and solutions to others require rigidity. For example, in writing a poem, operant variability is reinforced. This makes the poem different and may contribute to its artistic merit. On the other hand, solving a long-division problem must be done in a rigid and repetitive manner. Operant variability in long division is not reinforced. Generally, a close analysis of the contingencies is required in problem-solving situations because "what you reinforce is what you get" (stereotypy or variability).

Force of Response

Reinforcement may be made contingent on the force of response (or other properties) resulting in **response differentiation**. Notterman (1959) measured the force that rats used to press a lever during periods of reinforcement and extinction. During reinforcement sessions, animals came to press the lever with a force that varied within a relatively narrow range. When extinction occurred, the force of lever pressing became more variable. Interestingly, some responses were more forceful than any emitted either during reinforcement or during operant level. This increase in response force may be due to emotional behavior generated by extinction procedures.

For example, imagine that you have pushed a button for an elevator, but the elevator does not arrive, and you have an important appointment on the *28th* floor. At first you increase the frequency of pressing the elevator button; you also change the way you hit the button. You probably feel angry and frustrated, and you may smash the button. These responses and accompanying feelings occur because of the change from reinforcement to extinction.

Emotional Responses

Consider what happens when someone puts money in a vending machine and is not reinforced with an item (e.g., a beverage). The person who is placed on extinction may hit the machine, curse, and engage in other emotional behavior. Soda machines once killed several U.S. soldiers. Young soldiers at the peak of physical fitness are capable of emitting forceful operants. When some of the soldiers put money in soda machines that failed to operate, extinction-induced emotional behavior became so powerful that the men pulled

over the 2-ton machines. Thus, their deaths were an indirect outcome of emotional behavior produced by extinction.

A variety of emotional responses occur under conditions of extinction. Birds flap their wings, rats bite the response lever, and humans may swear and kick at a vending machine. One important kind of emotional behavior that occurs during extinction is aggression. Azrin, Hutchinson, and Hake (1966) trained pigeons to peck a key for food. After training, a second immobilized pigeon was placed in the operant chamber. The "target" bird was restrained and placed on an apparatus that caused a switch to close whenever the bird was attacked. Attacks to the target reliably occurred when the contingencies of reinforcement were changed from CRF to extinction. Many of the attacks were vicious and unrelenting, lasting up to 10 min.

Discriminated Extinction

Suppose that a pigeon was reinforced for pecking a key in the presence of a green light. However, when a red light came on, pecking was not reinforced. During the course of training, the animal would emit emotional responses, extinction bursts, and so on, when the red light was turned on. Following training, the bird would not emit this behavior and it would simply stop responding when the light changed from green to red. The red light became a *discriminative stimulus (S^Δ) that signaled a period of extinction.* This effect is called **discriminated extinction** and is commonly observed in human behavior. A sign on a vending machine that reads OUT OF ORDER is an S^Δ that signals extinction for putting money in the machine.

The respondent procedures for conditioned inhibition and rapid extinction (see chap. 3) seem close to the operant procedure of discriminated extinction. Comparing the procedures, we assume that the conditioned response to the light is similar to the emission of an operant on a given occasion. Discriminative extinction involves signaling extinction periods with an extroceptive stimulus, such as a change in key color from green to red. This change from green to red in the operant procedure is like adding the tone during respondent extinction. When the key is green, a pigeon is trained to peck it for food. Every once in a while the key color changes to red, and reinforcement for pecking no longer occurs. During these extinction periods, rate of response should decline. This decline would occur more rapidly when extinction is signaled by a change in color than when the key color remains the same. Finally, since the red key is consistently associated with extinction, it acquires a discriminative function (S^Δ), suppressing responding when it is presented.

Resistance to Extinction

As extinction proceeds, emotional behavior subsides and rate of response declines. When extinction has been in effect long enough, behavior may return to operant level. In practice, however, a return to operant level is rarely accomplished. This is because many extinction sessions are usually required before operant level is attained. Extinction is typically measured as the number of responses emitted in some amount of time. For example, a bird may be reinforced on CRF for 10 consecutive daily sessions; following this, extinction is initiated. The pigeon's responses are recorded over 3 extinction sessions. The number of responses emitted by the bird or the rate of response during the last session may be used to index resistance to extinction. Operants are rapidly extinguished after a few reinforced responses, but when operants are reinforced many times, resistance to extinction increases. Several experiments (Hearst, 1961; Perin, 1942) have shown that resistance to extinction reaches a maximum after 50 to 80 reinforced responses.

The Partial Reinforcement Effect (PRE)

Resistance to extinction is substantially increased when a partial or **intermittent schedule of reinforcement** has been used to maintain behavior. On an intermittent reinforcement schedule, only some responses are reinforced. For example, instead of reinforcing each response (CRF), the experimenter may program reinforcement after 100 key pecks have been emitted. In this situation, the bird must emit 100 pecks before food is presented. This intermittent schedule will generate many more responses during extinction than continuous reinforcement. When people are described as persistent or tenacious, their behavior may reflect the effects of intermittent reinforcement.

Nevin (1988a, 1988b) indicates that the **partial reinforcement effect** (PRE) is the result of two basic processes: reinforcement and discrimination. According to Nevin's analysis, reinforcement has the uniform effect of increasing resistance to change. That is, in a given situation, *the higher the rate of reinforcement for an operant the greater the resistance to change.* The implication is that behavior maintained by a CRF schedule is more resistant to change than behavior controlled by an intermittent schedule of reinforcement.

But, as we have seen, extinction occurs more rapidly on CRF compared to intermittent reinforcement. A reason for the discrepancy in results is that *discrimination* between reinforcement and extinction is more rapid if the schedule-maintaining behavior is CRF rather than intermittent. That is, an organism discriminates the difference between a high and steady rate of reinforcement (CRF) and no reinforcement (extinction) more easily than between a low and intermittent rate of reinforcement and no reinforcement. An alternative interpretation is based on *stimulus generalization.* In this account, the conditions of the low rate of reinforcement on intermittent schedules are more similar to extinction than the conditions of the high rate of reinforcement on CRF. That is, organisms generalize from intermittent reinforcement to extinction, showing greater resistance to change (more time or responses to extinction). In tests for resistance to extinction, Nevin (1988a, 1988b) explains that the discrimination/generalization factor overrides the rate of reinforcement and animals show greater resistance on intermittent than on CRF schedules. If the effects of discrimination/generalization (between reinforcement and extinction) are controlled, Nevin shows that behavior maintained by CRF is in fact more resistant to extinction than behavior on intermittent schedules of reinforcement.

An additional reason for increased resistance to extinction following intermittent reinforcement involves *contact with the contingencies.* For example, a rat that has been reinforced for every 100 responses must emit 100 responses before contacting the change from reinforcement to extinction. In contrast, an animal that is reinforced for each response contacts the extinction contingency immediately. Since each response is a nonreinforced occurrence, the animal repeatedly encounters the change to extinction. If an animal on CRF emits 50 responses during extinction, it has contacted the extinction contingency 50 times. A rat on intermittent reinforcement may have to emit 5,000 responses to have equal experience with the change in contingencies.

Discriminative Stimuli and Extinction

Intermittent reinforcement is not the only factor that determines the return to operant level during extinction. Resistance to extinction is also affected by discriminative stimuli that are conditioned during sessions of reinforcement. Skinner (1950) showed that "maximal responding during extinction is obtained only when the conditions under which the response was reinforced are precisely reproduced" (p. 204).
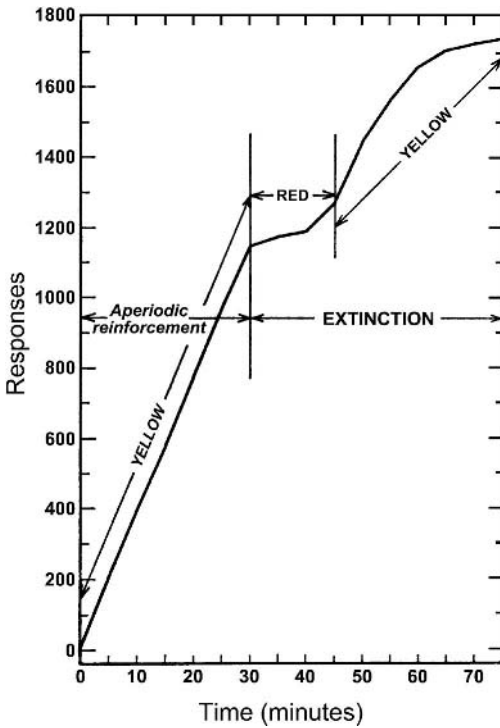
FIG. 4.14. *Responding during extinction as a function of discrimination. Responding in the presence of the yellow triangle is high during the first 30 min of intermittent reinforcement. When the red triangle and extinction are introduced, the rate of response declines. Extinction is continued and the yellow triangle is reinstated. When the yellow triangle is presented, the rate of response recovers and then declines toward extinction.* Note: *From "Are Theories of Learning Necessary?," by B. F. Skinner, 1950,* Psychological Review, 57, *pp. 193–216. Reprinted with permission.*

Pigeons were trained to peck a yellow triangle on an intermittent schedule of food reinforcement. After training, a red triangle was substituted for the yellow one, and extinction was started. During 15 min of extinction in the presence of the red triangle, the rate of response substantially declined. At this point, the yellow triangle replaced the red, but extinction was continued. The effect of introducing the yellow triangle was that rapid responding began immediately, and the usual extinction curve followed. This effect is portrayed in Fig. 4.14, in which responding in the presence of the yellow triangle is at a high rate during the first 30 min of intermittent reinforcement. When the red triangle and extinction were introduced, the rate of response declined. Finally, extinction was continued, and the yellow triangle was reinstated. Notice that the rate of response immediately recovers and then declines toward extinction.

Spontaneous Recovery

An interesting phenomenon that occurs during extinction is called **spontaneous recovery**. After a session of extinction, the rate of response may be close to operant level. At this point, the animal is taken out of the operant chamber and returned to a holding cage. The next day, the organism is again placed in the operant chamber, and extinction is continued. Surprisingly, the animal begins to respond above the operant level, and this defines spontaneous recovery. Over repeated sessions of extinction, the amount of recovery decreases. If many sessions of extinction are provided, the rate of response will no longer recover.

Spontaneous recovery is really not spontaneous. Stimuli that have accompanied reinforced responding are usually presented at the beginning of extinction sessions (habituation

may also be involved; see Pear, 2001, p. 63). Skinner (1950) has noted that handling procedures and the stimulation arising from being placed in an operant chamber set the occasion for responding at the beginning of each extinction session. Skinner (1950) states:

> No matter how carefully an animal is handled, the stimulation coincident with the beginning of an experiment must be extensive and unlike anything occurring in the latter part of an experimental period. Responses have been reinforced in the presence of, or shortly following, this stimulation. In extinction it is present for only a few moments. When the organism is again placed in the experimental situation the stimulation is restored; further responses are emitted as in the case of the yellow triangle [see aforementioned experiment]. The only way to achieve full extinction in the presence of the stimulation of starting an experiment is to start the experiment repeatedly. (pp. 199–200)

Human behavior also shows spontaneous recovery. Imagine that you are stranded in a secluded mountain cabin during a week-long snowstorm. The telephone rings, you answer, but all you get is the dial tone. You shout at the dial tone and bang the disconnect button repeatedly. Next, you try to contact the telephone company and discover that you are not able to dial out. Over the course of the first day, the phone rings many times, you answer, but it does not work. By the end of the day, you may not be inclined to answer the telephone; you just let it keep on ringing. The next morning you are having breakfast and the phone rings. What do you do? The best guess is that you will again answer the phone. You may say to yourself, "Perhaps they have fixed the line." On this second day of extinction, you answer the phone but give up more quickly. On Day 3, the phone rings at 10:00 a.m., and even though you doubt that it will work, you answer it "just to check it out." By Day 4, you have had it with the "damn phone and the stupid telephone company," and extinction is complete.

Extinction and Forgetting

During extinction, operant behavior decreases over time. People often talk about the weakening of behavior as loss of memory or forgetting. An important question concerns the procedural differences between forgetting and extinction. Extinction is a procedure in which a previously reinforced response no longer produces reinforcement. The opportunity to emit the operant remains available during extinction. Thus, the pigeon may still peck the illuminated key, or the rat may continue to press the response lever. In contrast, forgetting is said to occur after the mere passage of time. An organism that has learned a response is tested for retention after some amount of time has passed. In this case, there is no apparent opportunity to emit the behavior.

Skinner (1938) designed an experiment to assess the behavioral loss that occurs after the passage of time. In this experiment, four rats were trained to press a lever, and each animal received 100 reinforced responses. After 45 days of rest, each animal was placed in the operant chamber, and responding was extinguished. The number of responses emitted during extinction was compared to the performance of four other rats selected from an earlier experiment. These animals were similar in age, training, and number of reinforced responses to the experimental subjects. The comparison animals had received extinction 1 day after reinforced bar pressing.

Figure 4.15 shows the results of Skinner's experiment. Results are presented as the cumulative-average number of responses emitted by each group of animals. The group that received extinction 1 day after response strengthening emitted an average of 86 responses in 1 hr. The group that was extinguished after 45 days made an average of 69 responses in 1 hr. Notice that both groups of animals show a similar number of responses during
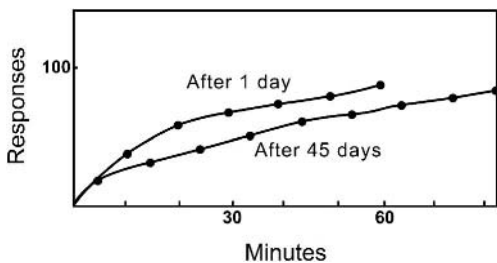
FIG. 4.15. *Average extinction curves of four rats, 1 day after training and 45 days after training.* Note: *From* The Behavior of Organisms, *by B. F. Skinner, 1938, Appleton–Century–Crofts: New York.*

the first few minutes of extinction. In other words, animals in both groups immediately began to press the lever when placed in the operant chamber. This shows that the rats that received extinction after 45 days had not forgotten what to do to get food (Skinner, 1938).

Following the first few minutes of extinction, there is a difference in the cumulative-average number of responses for the two groups. Resistance to extinction is apparently reduced by the passage of time. Rats that were required to wait 45 days before extinction generated fewer responses per hour than those given extinction 1 day after reinforcement. Although the curves rise at different rates, animals in both groups appear to stop responding after approximately 90 nonreinforced lever presses. Overall, the results suggest that the passage of time affects resistance to extinction, but a well-established performance is not forgotten.

As a further illustration of this point, Hal Markowitz and his colleagues in an article titled "Do elephants ever forget?" indicated that they retested three elephants after an 8-year period between training and retest (Markowitz, Schmidt, Nadal, & Squier, 1975). Two of the three animals showed near-perfect performance, and it was determined that the third elephant had gone blind.

A NOTE ON REMEMBERING AND RECALLING

In much of psychology, people and other organisms are said to store information about events in memory. The use of the noun *memory* is an example of reification or treating an action as if it were a thing. In behavior analysis and learning, we use the verb *remembering* (or forgetting) to refer to the effect of some event on behavior after the passage of time (see Donahoe & Palmer, 1994; Palmer, 1991, pp. 324–353). For example, a pigeon that has been reinforced for pecking a green illuminated key, but not for pecking a red one, is removed from the operant chamber and kept in a home cage for 1 year. After 1 year, the pigeon is placed back in the operant chamber and tested for remembering by alternating presentations of the red and green keys. If the pigeon pecks when the key is green, but not when it is red, the pigeon demonstrates remembering of the green/red discrimination. You can see that remembering involves behavior (pecking in the presence of green and red keys) that occurred in the past and now reoccurs after a period of time (see White & Wixted, 1999, for experimental evidence).

For humans, we may say that a person recalls his or her trip to Costa Rica, when a picture of the trip occasions a verbal description of the vacation. From a behavioral perspective, *recalling* "X" (i.e., recalling my trip to Costa Rica) is behavior (mostly verbal) emitted now with respect to events that occurred in the past. That is, remembering and recalling are

treated as behavioral processes rather than as some mysterious thing (memory) within us. Behavior analysts assume that the event recalled is one that was described (if only to oneself) when it first occurred. Recalling (like remembering) refers to the *reoccurrence* of behavior (mostly verbal) that has already occurred at least once.

In a later experiment on forgetting, Skinner (1950) trained 20 pigeons to strike a key with a complex pattern. The pigeons had been used for a World War II naval research project involving missile guidance systems (Project Pigeon, see Skinner, 1960). Skinner had taught the birds to peck at a complex visual image. A particular feature of the New Jersey coastline was projected onto a translucent key. The pigeons were required to strike the specified target in order to obtain food on an intermittent schedule of reinforcement. Reinforcement was contingent on a high and steady rate of pecking at the specified visual feature.

In a personal conversation (1989), Skinner indicated that he kept some of the birds from Project Pigeon when funding was discontinued. The birds were housed in a coop in his garden. Skinner said that over a period of 6 years, he tested the birds for retention. The birds were food deprived and placed in the original apparatus after 6 months, 1 year, 2 years, 4 years, and 6 years.

Unfortunately, Skinner said that most of the data were unavailable. However, he was impressed that the birds responded immediately to the target image at a high and steady rate. All subjects produced extensive extinction curves even after several years had passed since the initial training. One remarkable observation was that "the extinction curves became smaller" with greater passage of time. Again, passage of time does not seem to affect forgetting, since the birds immediately pecked the target. However, as with the rats, resistance to extinction declined as a function of the retention interval.

ON THE APPLIED SIDE: EXTINCTION AS A MODIFICATION PROCEDURE FOR TEMPER TANTRUMS

Williams (1959) has shown how extinction effects play an important role in the modification of human behavior. In this study, a 20-month-old child was making life miserable for his parents by having temper tantrums when put to bed. If the parents stayed up with the child, he did not scream and cry and eventually went to sleep. A well-known source of reinforcement for children is parental attention, and Williams reasoned that this was probably maintaining the bedtime behavior. That is, when the parents left the bedroom, the child began screaming and crying. These tantrums were reinforced by the return of the parents to the bedroom. The parental behavior stopped the tantrum, and withdrawal of screaming by the child reinforced the parental behavior of returning to the bedroom. Based on these contingencies, the parents were spending a good part of each evening in the child's room waiting for him to go to sleep. At this point, the parents were advised to implement extinction by leaving the room and closing the door after the child was put to bed. Figure 4.16 demonstrates the rapid decline in duration of crying when this was done (first extinction).

When extinction was first attempted, the child screamed and cried for 45 min. However, on the next night he did not cry at all. On the third night, the child emitted tantrums for 10 min. By the end of 10 days, the boy was smiling at his parents when they left the
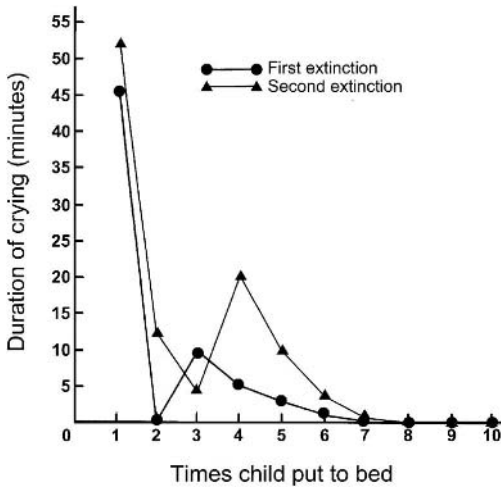
FIG. 4.16. *First and second extinction procedures for a child's temper tantrums.* Note: *Adapted from "The Elimination of Tantrum Behavior by Extinction Procedures," by C. D. Williams, 1959,* Journal of Abnormal and Social Psychology, 59, *p. 269.*

room. Unfortunately, his aunt, who reinforced crying by staying in the room with him, put the boy to bed, and temper tantrums reoccurred. A second extinction procedure was then implemented. Duration of crying was longer for the second than for the first period of extinction. The higher probability of response during the second extinction phase is presumably caused by the intermittent reinforcement of tantrums. Recall that intermittent reinforcement increases resistance to extinction. Fortunately, the boy was not reinforced again, and tantrums eventually declined to a zero rate. At a 2-year follow-up, the parents reported that bedtime tantrums had been completely eliminated.

KEY WORDS

Ad libitum weight
Conditioned positive
  reinforcer
Contingency of
  reinforcement
Continuous reinforcement
  (CRF)
Cumulative recorder
Deprivation operation
Differential reinforcement
Discriminated extinction
Discriminative
  stimulus (S^D)
Elicited
Emitted
Extinction

Extinction burst
Free operant method
Intermittent reinforcement
  schedule
Latency
Law of effect
Magazine training
Negative punishment
Negative reinforcement
Operant
Operant chamber
Operant classs
Operant conditioning
Operant level
Operant variability
Premack principle

Partial reinforcement
  effect (PRE)
Positive punishment
Positive reinforcement
Positive reinforcer
Rate of response
Repertoire
Resistance to extinction
Response differentiation
Satiation
Selection by consequences
Shaping
Spontaneous recovery
Successive approximation
Topography

ON THE WEB

http://psych.athabascau.ca/html/prtut/reinpair.htm The purpose of this site is to teach the concept of positive reinforcement and also to provide an idea of the kind of self-instructional exercises used at Athabasca University.

http://www.wagntrain.com/OC/ A Web site for all those seeking to use positive reinforcement in animals' training. If you have a dog or a cat, you can use the "clicker training" method of positive reinforcement to teach your animal new behavioral sequences and skills.

http://www.karawynn.net/mishacat/toilet.shtml This Web site is about the toilet training of Misha the cat. The trainer does not provide the general principles that lead a cat from the litter box to the toilet, but many of the principles are outlined in chapter 4. See if you can figure out how to train any cat to do what Misha did.

http://serc.gws.uky.edu/pbis/home.html If you want to learn how to handle behavior problems, you need to know how to define behavior, identify contingencies, and use a behavioral model. This site helps you understand behavior problems from a behavioral perspective.

STUDY QUESTIONS

1. How do consequences regulate behavior? (83)
2. Summarize what is meant by "operant conditioning is based on genetic endowment." (83)
3. Discuss operant behavior, voluntary action, and the source of the term operant. (83–84) Name and define one kind of positive consequence of operant behavior. (84)
4. What is meant by the term topography? (84) Operants are emitted, whereas reflexes are elicited. Why? (84). What is an operant class? (84)
5. What is a discriminative stimulus? (84) Give some examples of common S^D's and indicate when an event is operating as a discriminative stimulus. (84–85) What is the relationship between an S^D and the consequences of operant behavior? (85) Compare an S^D to a stimulus that signals extinction (S^Δ) and give an example of an S^Δ function. (85)
6. What is a three-term contingency of reinforcement? (85) Outline the role of the discriminative stimulus in such a contingency. (85) Show that the S^D function depends on reinforcement of operant behavior. (85)
7. Define the four basic contingencies and give everyday examples of each. (Fig. 4.2 and 86, 89–90)
8. **FOCUS ON**: Rewards either do or do not lead to a decrease in intrinsic motivation when they are removed. What evidence supports one or the other view? (87–88) In terms of creativity, reinforcement seems to have several positive effects. What are these effects? (88–89). Taken together, what does Eisenberger and Cameron's research suggest? (89)
9. **FOCUS ON**: How is a stimulus defined as a positive reinforcer? (90) What test could you do to show that money is a positive reinforcer? (90) State the difference between the definition of a reinforcer and explaining behavior. (90–91) What is the Premack principle? (91) Give an example of the Premack principle. (91) The Premack principle provides a way of identifying reinforcers. Explain. (91) What are the applied implications of this principle? (91–92)

10. Discuss Thorndike's early research, his law of effect, and the modern principle of reinforcement. (92)

11. What is wrong with so-called trial-and-error learning and measures of response latency? (92) Why is the rate of response a preferred measure of operant behavior? (93)

12. Define operant rate and probability of response. (93) In operant conditioning, discuss the advantage of the free operant method. (93–94) How does the operant chamber structure the situation for conditioning? (94–95)

13. In a demonstration of operant conditioning, what is the role of deprivation, magazine training, conditioned reinforcers, a well-defined operant class, operant level, continuous reinforcement, successive approximation, and recording of behavior? (95–97) Outline a model operant-conditioning experiment using a pigeon as the subject. (98–100)

14. Define the procedure and processes of extinction. (100) How do the responses of organisms to extincion make evolutionary sense? (101) Discuss the extinction burst and when it occurs. (101) Describe what happens to operant variability during extinction, referring to the Antonitis (1951) experiment. (101) What is the stereotypy–creativity controversy over reinforcement? (101–102)

15. **FOCUS ON**: Summarize the research and findings of Barry Schwartz (1982a, 1982b) on reinforcement and response stereotypy. (102–104) Outline the research and findings of response variability by Allen Neuringer (Page & Neuringer, 1985; Neuringer, 1986). (104–105) What do both lines of research suggest about reinforcement, problem solving, and creativity? (105–106)

16. How does extinction affect response force and emotional responses? (106–107) What is discriminated extinction? (107)

17. Discuss resistance to extinction and return to operant level. (107) What is the partial reinforcement effect (PRE)? (108) According to Nevin (1988a, 1988b) reinforcement increases resistance to change. Why does behavior maintained by intermittent reinforcement take longer to extinguish? (108). Show how contact with the contingency plays a role in resistance to extinction. (108) Discuss the Skinner (1950) experiment and the control of response rate by red and green triangles. (108–109)

18. Define and discuss spontaneous recovery. (109–110) Give a textbook example of human behavior that illustrates spontaneous recovery. (110)

19. Discuss a procedural difference between forgetting and extinction. (110–111) Based on the note concerning remembering and recalling, discuss these behaviors. (111–112) How did Skinner (1938) test the difference between forgetting and extinction, and what did he find? (112)

20. What effect did the passage of time have on the behavior of pigeons used in Project Pigeon (Skinner, 1960)? (112) Draw out the implications of this research for commonsense notions about forgetting. (112)

21. Outline Williams's (1959) study of temper tantrums and the role of extinction in this study. (112) What happened when the boy's aunt stayed in the room when he cried? Why? (113)

BRIEF QUIZ

1. The term operant comes from the verb _____ and refers to behavior that _____.
   (a) opponent; opposes its consequences in a given environment
   (b) opendum; opens the door to its effects on a given occasion

     (c) operates; operates on the environment to produce effects

     (d) opara; presents the opporturnity to respond on a given occasion

2. What defines a contingency of reinforcement?

     (a) discriminative stimulus

     (b) operant

     (c) reinforcement

     (d) all of the above

3. Which of the following is NOT one of the four basic contingencies?

     (a) positive reinforcement

     (b) positive extinction

     (c) negative punishment

     (d) negative reinforcement

4. In terms of rewards and intrinsic motivation, Cameron et al. (2001) conducted a statistical procedure called _____, and one of the findings indicated that verbal rewards _____ performance and interest on tasks.

     (a) multivariate analysis; decreased

     (b) meta-analyis; decreased

     (c) meta-analysis; increased

     (d) multivariate analysis; increased

5. The Premack principle states that a higher frequency behavior will

     (a) function as reinforcement for a lower frequency behavior

     (b) function as punishment for a high-frequency behavior

     (c) function as intermittent reinforcement for a low-frequency behavior

     (d) none of the above

6. In order to experimentally study the probability of response, a researcher uses _____ as the basic measure and follows the _____ method.

     (a) latency; T-maze

     (b) latency; free operant

     (c) operant rate; T-maze

     (d) operant rate; free operant

7. Shaping of behavior involves

     (a) the molding of a response class by the physical arrangement of the operant chamber

     (b) reinforcing closer and closer approximations to the final performance

     (c) withholding and giving food for correct performance of a specified level of response

     (d) none of the above

8. A classic experiment on the effects of extinction by Antonitis (1951) involved

     (a) nose poking by rats for food reinforcement

     (b) photographs of the rats' position and body angle

     (c) increased variablility of nose poking during extinction

     (d) all of the above

9. In terms of response stereotypes, variability, and reinforcement, the work by Barry Schwartz (1982a, 1982b) shows that reinforcement can produce _____ patterns of behavior, whereas the work of Neuringer and his colleagues (Page & Neuringer, 1985; Neuringer, 1986) indicates that reinforcement can produce _____.

     (a) stereotyped; response variability

     (b) response variability; stereotypes

     (c) stereotyped; response stability

     (d) response stability; response variability

10. Which of the following is (are) involved in the partial reinforcement effect?
    (a) longer extinction on intermittent reinforcement compared to CRF
    (b) the higher the rate of reinforcement the greater the resistance to change
    (c) discrimination between reinforcement and extinction is more rapid on CRF
    (d) all of the above

Answers to brief quiz (*page*): c(84); d(85); b(86 Fig. 4.2); c(88); a(91); d(93); b(96); d(101); a(105); d(108)

CHAPTER 5
Schedules of Reinforcement

IN THIS CHAPTER

1. Learn about schedules of reinforcement and why they are important.
2. Discover how schedules of reinforcement generate characteristic patterns of behavior.
3. Find out about the Mechner system of notation and its application to an analysis of schedules of reinforcement.
4. Investigate rates of reinforcement and behavioral momentum or how behavior is made resistant to change.
5. Learn about behavior in transition between schedules of reinforcement and how this applies to human behavior.
6. Discover how schedules of reinforcement are important to people who want to stop smoking.

The stimuli that precede operants and the consequences that follow them may be arranged in many different ways. A **schedule of reinforcement** describes this arrangement. In other words, a schedule of reinforcement is a prescription that states how and when discriminative stimuli and behavioral consequences will be presented (Morse, 1966). In the laboratory, sounding a buzzer in an operant chamber may be a signal (S^D) that sets the occasion for each lever press (operant) to produce food (consequence). A similar schedule operates when a dark room sets the occasion for a person to turn on a lamp, which, of course, is followed by light in the room.

At first glance, a rat pressing a lever for food and a person turning on a light seem to have little in common. Humans are very complex organisms: They build cities, write books, go to college, go to war, conduct experiments, and do many other things that rats cannot do. In addition, pressing a bar for food appears to be very different from switching on a light. Nonetheless, performances controlled by schedules of reinforcement have been found to be remarkably similar for different organisms, many types of behavior, and a variety of reinforcers. When the schedule of reinforcement is the same, a child solving math problems for teacher approval may generate a pattern of behavior that is comparable to a bird pecking a key for water.

The Importance of Schedules of Reinforcement

Schedules of reinforcement have been investigated over the last 5 decades. They were first described by B. F. Skinner in the 1930s and were a major discovery. Charles Ferster and B. F. Skinner reported (Ferster & Skinner, 1957) the first and most comprehensive study

of schedules ever conducted. Their work on this topic is unsurpassed and represents the most extensive study of this critical independent variable in behavior science. Today, few studies focus directly on simple schedules of reinforcement. However, the lawful relations that have emerged from the analysis of schedules remain an important part of the science of behavior and are used in virtually every study reported in the *Journal of the Experimental Analysis of Behavior*.

FOCUS ON ISSUES: SCIENCE AND BEHAVIOR ANALYSIS

The experimental analysis of behavior is a progressive enterprise. Research findings are accumulated and integrated to provide a general account of the behavior of organisms. Often, simple animals in highly controlled settings are studied. The strategy is to build a comprehensive theory of behavior that rests on direct observation and experimentation.

The field emphasizes a descriptive approach and discourages speculations that go beyond the data. Such speculations include reference to the organism's memory, thought processes, expectations, and undocumented accounts based on presumed physiological states. For example, a behavioral account of schedules of reinforcement provides a description of how behavior is altered by contingencies of reinforcement. One such account is based on evidence that a particular schedule sets up differential reinforcement of the time between responses (interresponse times, or IRT; see later in this chapter). This sort of analysis provides an understanding of an organism's performance in terms of specific environment–behavior relationships.

Behavior analysts study the behavior of organisms, including people, for its own sake. Behavior is not studied in order to make inferences about hypothetical mental states or real physiological processes. Although most behaviorists emphasize the importance of biology and physiological processes, they focus on the interplay of behavior and environment.

To maintain this focus, the evolutionary history and biological status of an organism are examined as part of the context for specific environment–behavior interactions. For example, some people seem more influenced by sexual stimuli than others. Natural selection may have resulted in a distribution of susceptibility to sexual reinforcement. (Of course, cultural conditioning will also contribute.) People who are strongly affected by sexual consequences may develop a broad repertoire of behavior that leads to sexual gratification. When given a choice between sexual and nonsexual reinforcement, the person will often select the sexual alternative. In extreme cases, behavior regulated by sexual stimuli may be so exaggerated that the person is called a criminal and is subjected to legal sanctions. A man who makes obscene phone calls is strongly reinforced by a woman's reaction to his words. The woman's reaction is a conditioned reinforcer for his call. Although he has learned the relationship between obscene talk and listener reaction, his biological history plays a role in the effectiveness of the reinforcement contingency.

Accumulating information about environment–behavior relations has, in recent years, led to the formulation of several principles of behavior. For example, animals and people are much more persistent on a task when they have been reinforced on a schedule that only pays off occasionally. This persistence is especially pronounced during extinction and is called the *partial reinforcement effect* (as discussed in chap. 4). One can observe this phenomenon by contrasting behavior at a vending machine that delivers products on a regular basis and at a slot machine that delivers payouts intermittently. If the vending machine does not work, the operater quits inserting coins; but the same person may persist for hours

at operating a slot machine that provides highly intermittent payoffs. Other principles of behavior (e.g., discrimination, motivation, and conditioned reinforcement) also have been identified through the experimental analysis of schedule effects.

As more information becomes available, the goal of a comprehensive behavior theory comes closer. Chapter 9 presents work on concurrent schedules of reinforcement. This research has been prominent over the recent past and today is used to formulate theories and models of behavioral choice and preference. These theories draw on earlier work and become more complete and sophisticated as data accumulate.

Contemporary behavior analysis continues to build on previous research. The extension of behavior principles to more complex processes and especially to human behavior is of primary importance. The analysis remains focused on the environmental conditions that regulate the behavior of organisms. Schedules of reinforcement concern the arrangement of environmental events that support behavior. The analysis of schedule effects is currently viewed within a biological context. In this analysis, biological factors play several roles. One way biology affects behavior is through specific physiological events that function as reinforcement and discriminative stimuli (see chap. 1). Biological variables may also constrain or enhance environment–behavior relationships, as we have noted. As behavior analysis and the other biological sciences progress, an understanding of biological factors becomes increasingly important for a comprehensive theory of behavior.

The knowledge that has accumulated about the effects of schedules is central to understanding behavior regulation. G. S. Reynolds (1966b) underscored this point and wrote that:

> schedules of reinforcement have regular, orderly, and profound effects on the organism's rate of responding. The importance of schedules of reinforcement cannot be overestimated. No description, account, or explanation of any operant behavior of any organism is complete unless the schedule of reinforcement is specified. Schedules are the mainsprings of behavioral control, and thus the study of schedules is central to the study of behavior. . . . Behavior that has been attributed to the supposed drives, needs, expectations, ruminations, or insights of the organism can often be related much more exactly to regularities produced by schedules of reinforcement. (p. 60)

Modern technology has made it possible to analyze performance on schedules of reinforcement in increasing detail. Nonetheless, early experiments on schedules remain important. The experimental analysis of behavior is a progressive science in which observations and experiments build on one another. In this chapter, we will present early and later research on schedules of reinforcement. The analysis of schedule performance will range from a global consideration of cumulative records to a detailed consideration of the time between responses.

Schedules and Patterns of Response

Patterns of response develop as a result of the organism interacting with a schedule of reinforcement (Ferster & Skinner, 1957). These patterns come about after an animal has experience with the *contingency of reinforcement* ($S^D : R \rightarrow S^r$ arrangement) defined by a particular schedule. Subjects are exposed to a schedule of reinforcement, and, following an acquisition period, behavior typically settles into a consistent or *steady-state performance* (Sidman, 1960). It may take many experimental sessions before a particular pattern emerges, but once it does, the orderliness of behavior is remarkable.

The first description of schedule performance was provided by B. F. Skinner (1938) in his book, *The Behavior of Organisms*. In the preface to the seventh printing of that book, Skinner writes that "the cumulative records . . . purporting to show orderly changes in the behavior of individual organisms, occasioned some surprise and possibly, in some quarters, suspicion" (p. xii). Any suspicion was put to rest when Skinner's observations were replicated in many other experiments (see Morse, 1966, for a review of early work on schedules of reinforcement).

The steady-state behavior generated when a fixed number of responses is reinforced illustrates one of these patterns. For example, a hungry rat might be required to press a lever 10 times to get a food pellet. Following reinforcement, the animal has to make another 10 responses to produce the next bit of food, then 10 more responses, and so on. In industry this requirement is referred to as piece rate.

When organisms (rat, pigeon, or man) are reinforced after a fixed number of responses, a pause-and-run pattern of behavior develops. Responses required by the schedule are made rapidly and result in reinforcement. Following each reinforcement, there is a pause in responding, then another quick burst of responses. (See the section on fixed ratio later in this chapter for more detail.) This pattern repeats over and over and occurs even when the size of the schedule is changed. A pause-and-run pattern has been found for many species including horses (Myers & Mesker, 1960), chickens (Lane, 1961), a vulture (Witoslawski, Anderson, & Hanson, 1963), and children (Orlando & Bijou, 1960).

Schedules and Natural Contingencies

In the everyday environment, behavior is often reinforced on an intermittent basis. That is, operants are reinforced occasionally rather than each time they are emitted. Every time a child cries, he or she is not reinforced with attention. Each time a predator hunts, it is not successful. When you dial the number for airport information, you get through sometimes, but often the exchange is busy. Buses do not immediately arrive when you go to a bus stop. It is clear that persistence is often essential for survival, and therefore being able to account for such behavior on the basis of the schedule that maintains it is a major discovery. In concluding his review of schedule research, Dr. Michael Zeiler (1977) states:

> it is impossible to study behavior either in or outside the laboratory without encountering a schedule of reinforcement: whenever behavior is maintained by a reinforcing stimulus, some schedule is in effect and is exerting its characteristic influences. Only when there is a clear understanding of how schedules operate will it be possible to understand the effects of reinforcing stimuli on behavior. (p. 229)

Consider a bird foraging for food. The bird turns over sticks or leaves and once in a while finds a seed or insect. These bits of food occur only every now and then, and the distribution of reinforcement is the schedule that maintains the animal's foraging behavior. If you were watching this bird hunt for food, you would probably see the animal's head bobbing up and down. You might also see the bird pause and look around, change direction, and so on. This sort of activity is often attributed to the animal's instinctive behavior patterns. However, labeling the behavior as instinctive does not explain it. Although biology certainly plays some role in this episode, perhaps more importantly, so does the schedule of food reinforcement.

Dr. Carl Cheney and his colleagues created a laboratory analog of foraging that allowed pigeons to choose between two food patches by pecking keys (Cheney, Bonem, & Bonem, 1985). The density of food available from pecking either key was based on two concurrent **progressive ratio** schedules of reinforcement that increased or decreased with the amount of

foraging. As reinforcers were removed from one patch, they became more scarce and therefore required more responses to produce; this was a progressively increasing ratio schedule (or depleting patch of food). Concurrently, the number of responses for each reinforcement decreased in the other patch (or a repleting patch of food). As would be expected, this change in reinforcement density up and down generated switching back and forth from patch to patch as density decreased and increased. However, in order to change patches, the center key had to be pecked, which simulated travel time and effort between patches (the side keys). The researchers found that the cost of hunting (the schedule of reinforcement for pecking) in a patch, the effort (number of responses) required to change patches, and the rate of replacement in the alternative patch all contributed to the likelihood that an animal would change patches. This research is an interesting laboratory model of animals foraging in the wild that uses schedules of reinforcement to simulate several natural contingencies.

Schedules of intermittent reinforcement play an important role in the regulation of human social interaction. In this case, the behavior of one person affects what another individual does and vice versa. For example, Paul asks his friend Erin, who is looking out the window, if the pizza delivery person has arrived yet. The operant is Paul's question, "Is the pizza here?" Reinforcement for the question is the reply from Erin. Importantly, Erin's reply is not certain and depends on many factors. Erin may not hear the question; she may be preoccupied with other things; she may have just had an argument with Paul and refuse to talk. No matter what the reason, Paul's question may not be reinforced on this occasion. Of course, most of the time Erin answers when asked a question. This means that Paul's verbal behavior is on an intermittent schedule of social reinforcement. Thus, one reason schedules are important is that they approximate some of the complex contingencies that operate with humans in the everyday environment. This type of interactive verbal conversation is cleverly simulated with pigeons in the video *Cognition, Creativity and Behavior* (Baxley, 1982).

Ongoing Behavior and Schedule Effects

Zeiler's (1977) point that schedules of reinforcement typically affect operant behavior is well taken. Experimenters risk misinterpreting results when they ignore possible schedule effects. This is because schedules of reinforcement may interact with a variety of other independent variables and produce characteristic effects. For example, Azrin (1959) found that when every response on a fixed-ratio schedule of reinforcement (reinforcement occurs after a fixed number of responses) was punished, the pause length after reinforcement increased. However, once the animal emitted the first response, the operant rate to finish the run was unaffected. In other words, the pause increased, but otherwise behavior on the schedule remained the same. A possible conclusion is that punishment reduces the tendency to begin responding; however, once started, behavior is not suppressed by contingent aversive stimulation.

This conclusion is not completely correct, because further experiments have shown that punishment has other effects when behavior is maintained on a different schedule of reinforcement (Azrin, 1958; Azrin & Holz, 1961). When behavior is reinforced after a fixed amount of time (rather than responses), an entirely different result occurs. On this kind of schedule, when each operant is punished, the pattern of behavior remains the same and the rate of response declines. It is obvious that conclusions concerning the effects of punishment on both the pattern and rate of response cannot be made without considering the schedule of reinforcement-maintaining behavior.

In summary, schedules of reinforcement are important for an analysis of behavior regulation. The interplay of punishment and reinforcement schedule performance is one example

of how behavior regulated by schedules of reinforcement may interact with other independent variables. Schedules produce reliable patterns of response, and these patterns are consistent for different reinforcers, organisms, and for a variety of different operants. In our everyday environment, schedules of reinforcement are so common that we take such effects for granted. We wait for a taxi to arrive, line up at a bank to negotiate a transaction, solve 10 math problems for homework, and so on. All of these behavior–environment interactions illustrate schedules of reinforcement in our everyday lives. Social or behavioral scientists who ignore schedules of reinforcement do so at considerable risk of missing a major controlling variable.

FOCUS ON TEACHING: A SYSTEM OF NOTATION

We have found that using a notation system greatly improves the understanding of contingencies among antecedents, behavior, and consequences. This notation system is based on Mechner's (1959) description of reinforcement contingencies. We have simplified the notation and relabeled some of the symbols. The system of notation only describes independent variables and is similar to a flow chart sometimes used in computer programming. That is, **Mechner notation** describes what the experimenter (instrumentation or computer) does, not the behavior of organisms. In other words, Mechner notation represents the way (sequence of events, the requirements, etc.) that schedules of reinforcement are arranged. Cumulative records or other data collected by computers describe what a subject does (i.e., the dependent variable) on those schedules.

Event	Symbols
S	Stimulus or event
S^r	Reinforcer
S^{r+}	Positive reinforcer
$Sr-$	Negative reinforcer (aversive stimulus)
S^D	Discriminative stimulus (event signaling reinforcement)
S^Δ	S-delta (a discriminative stimulus that signals extinction)
S^{ave}	Conditioned aversive stimulus (an event that has signaled punishment)
R	Response (operant class)
R_a	Response of type a (i.e., a response on lever a)

Time and Number Symbols	
F	Fixed
V	Variable
T	Time
N	Number

Relationships

The horizontal arrow connecting two events (i.e., A → B) indicates that one event follows another. When the arrow leads to a consequence, as in R → S^r, the arrow is read as produces. In this case, a response (R) *produces* a consequence (S^r). If the arrow leads to a response, as in R_a → R_b, it is read as *produces a condition where*. In other words, response R_a "sets up" or allows response R_b to produce an effect. For example, a press on lever *a* creates a situation where a press on lever *b* results in food.

Brackets

All conditions listed vertically inside a bracket go into effect simultaneously. For example, A and B are conditions that occur at the same time, and the occurrence of B leads to event C.
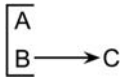
When a vertical arrow cuts across a horizontal arrow, it means that the diagrammed event is prevented. In the following example, A and B occur at the same time. Event A leads to condition C, but event B blocks the A → C relationship. In other words, A leads to C, but not if A and B occur together.
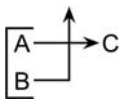
When events repeat, this may be shown by a horizontal arrow that starts at the end of a sequence and goes back to the beginning.
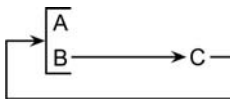
In the presence of A, the event B produces C, and after C occurs, the sequence repeats.

Mechner notation is especially helpful when complex contingencies are involved and the experimenter has to program a computer or other instrumentation for contingencies arranged in an operant chamber. Using this notation system also aids students in specifying exactly what the events, requirements, and their interactions are in an experiment. Finally, the notation makes explicit the programmed contingencies that control the behavior of organisms.

Schedules of Positive Reinforcement

Continuous Reinforcement

Continuous reinforcement, or **CRF**, is probably the simplest schedule of reinforcement. On this schedule, every operant required by the contingency is reinforced. For example, every time a hungry pigeon pecks a key, food is presented. When every operant is followed by a reinforcer, responses are emitted relatively quickly depending upon the consumatory time for the reinforcer. The organism continues to respond until it is satiated. Simply put, when the bird is hungry (food deprived), it rapidly pecks the key and eats the food until
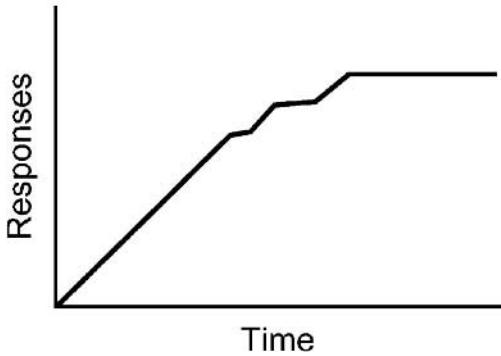
FIG. 5.1. *Performance on a continuous reinforcement schedule. Hatch marks indicating reinforcement are omitted since each response is reinforced. The flat portion of the record occurs when the animal stops making the response because of satiation.*

it is full (satiated). If the animal is again deprived of the reinforcer and exposed to a CRF schedule, this pattern of responding followed by satiation occurs again. Figure 5.1 is a typical cumulative record of performance on continuous reinforcement. As mentioned previously in this chapter, the typical vending machine pays off on a continuous (CRF) schedule.

CRF and Resistance to Extinction

Continuous reinforcement generates little resistance to extinction. Recall from chapter 4 that *resistance to extinction* is a measure of persistence when reinforcement is discontinued. This perseverance can be measured in several ways. The most obvious way to measure resistance to extinction is to count the number of responses and measure the length of time until the *operant level* is reached. Again, remember from chapter 4 that operant level refers to the rate of a response before behavior is reinforced. For example, a laboratory rat could be placed in an operant chamber with no explicit contingency of reinforcement in effect. The number of times the animal pressed the response bar during a 2-hr exploration of the chamber is a measure of the operant level, or in this case the baseline. Once extinction is in effect, measuring the time taken and the number of responses made until the operant level is attained is the best gauge of resistance to extinction.

Although continuing extinction until the operant level is obtained provides the best measure of behavioral persistence, this method requires considerable time and effort. For this reason, arbitrary measures that take less time are usually used. Resistance to extinction may be estimated by counting the number of responses emitted over a fixed number of sessions. For example, after exposure to CRF, reinforcement could be discontinued and the number of responses made in three daily 1-hr sessions counted. Another index of resistance to extinction is based on how fast the rate of response declines during nonreinforced sessions. The point at which no response occurs for 5 min may be used to index resistance. The number of responses and time taken to that point are used as an estimate of behavioral persistence. These measures and others may be used to indicate resistance to extinction. The important criterion is that the method must be quantitatively related to extinction responding.

Hearst (1961) investigated the resistance to extinction produced by CRF and intermittent schedules. In this experiment, birds were trained on CRF and two intermittent schedules that provided reinforcement for pecking a key. The number of extinction responses that the animals made during three daily sessions of nonreinforcement were then counted. Basically, Hearst found that the birds made many more extinction responses after training on an intermittent schedule than after exposure to continuous reinforcement.

FOCUS ON RATE OF REINFORCEMENT AND BEHAVIORAL MOMENTUM

John A. (Tony) Nevin studied engineering at Yale and received a Ph.D. in psychology from Columbia. He recently retired from the University of New Hampshire and now does a bit of sailing. He has combined his two disciplines and developed an analysis of operant behavior he calls behavioral momentum (Nevin, 1992). The concept of momentum derives from a combination of response rate, as generated by schedules of reinforcement, and the behavioral dynamic of resistance to change, both of which are important dimensions of operant behavior and analogous to velocity and mass in physics. When response rate, corresponding to velocity, is steady under constant conditions, the fact that it is difficult to change even when the schedule is changed indicates a certain amount of momentum. Behavior that is resistant to change in the presence of stimulus conditions that were present during reinforcement corresponds to the concept of mass. So, **behavioral momentum** refers to behavior persisting in the presence of a particular stimulus despite disruptive factors. The response rate declines more slowly relative to its baseline level, in the presene of a signal for high-density reinforcement than in the presence of a signal for low-density reinforcement (Shull, Gaynor, & Grimer, 2002). If you are working at the computer, and you keep working even though you are called to dinner, that is an example of behavioral momentum. Also, if you have a tendency to do some specific activity, despite alternative sources of reinforcement, that too shows behavioral momentum.

The analysis of behavioral momentum emerged when it was observed that behavior associated with a higher rate of response and reinforcement was less disrupted than behavior associated with lower rates, when challenged with some distraction. The procedure employed by Nevin (1974) involved a multiple schedule of reinforcement with two separate variable-interval (VI) reinforcement conditions, each with a discriminated stimulus (S^D) and separated by a third dark component. Rates of responding were naturally higher in the richer VI component. Then, when free food was provided in the third component (disruption), responding decreased less in the component with the higher VI rate of reinforcement. That is, behavior in the component with the richer VI schedule (higher rate of reinforcement) showed greater momentum.

Momentum and the Partial Reinforcement Effect

In seeming contrast to this finding, bar pressing maintained on an *intermittent reinforcement schedule is more resistant to extinction* than is behavior maintained on a continuous reinforcement (CRF) schedule (see Jenkins & Stanley, 1950, for a review). This finding is known as the *partial reinforcement effect* (PRE), as described in chapter 4. The PRE is the observation that behavior that is continually reinforced will extinguish faster, appearing to have lower momentum, than infrequently reinforced behavior, which is more difficult to change and therefore seems to have greater momentum. The vending machine versus the slot machine serves as a crude example. If the vending machine, which has always paid off in the past (frequent reinforcement), suddenly delivers nothing, you do not insert any more money; you stop operating it. But, when playing a slot machine (infrequent reinforcement), the player often receives nothing and still continues to play, showing high momentum.

There are explanations that may reconcile these apparently opposite findings. For example, the stimulus conditions present during a CRF schedule are very different from those during extinction. (See discrimination as a factor in PRE in chap. 4.) Actually, the conditions during extinction are more similar to the conditions present during intermittent

reinforcement than during CRF. Therefore, given the probability of stimulus generalization, one should expect more responding in extinction after a low rate of reinforcement than after a high rate, and there is.

Nevin (1988a, 1988b) discusses the issue of the PRE as being "thoroughly confounded." He says that when the confounding issues of measures of resistance to extinction, level of responding, slope of the extinction curve, stimulus change, length of training, and the extinction procedure itself are controlled, the rate of response decrease in extinction is lower with CRF than with intermittent reinforcement. According to behavioral momentum theory, CRF and extinction are extreme conditions with which to investigate momentum, and when other factors are controlled, only one principle is necessary (Harper & McLean, 1992).

More on Momentum

The behavioral momentum model (Nevin, 1992) was developed to characterize the resistance to change when response rate is steady and alternative sources of reinforcement are made available. (See chap. 9 and concurrent schedules of reinforcement.) Various and extensive approaches to investigating the critical parameters of behavioral momentum have appeared, as is usually the case in an experimental analysis of behavior (Cohen, 1998). Attempts are made to reduce the necessary and sufficient conditions to as few as possible, so as to best isolate the critical independent variables (Lattal, Reilly, & Kohn, 1998). Many researchers have investigated predictions and analyses based on momentum theory (e.g., Harper & McLean, 1992), and suggestions for applications have also appeared based on human research (Dube & McIlvane, 2001).

In an applied study, for example, each of two individuals with severe mental retardation performed self-paced discriminations on a computer with a touch-sensitive screen and were reinforced with food (Dube & McIlvane, 2001). Two separate problem types were differentially reinforced. In support of momentum theory, Dube and McIlvane found that the task with the higher reinforcement rate was the most resistant to change when prefeeding, free snacks, or alternative activities were provided. Thus, the disruptive factors reduced task performance depending on the prior rates of reinforcement. That is, when performance on a task received a high rate of reinforcement it was relatively impervious to distraction.

The behavior momentum model continues to be investigated in the search for a better understanding of how people sometimes either cling to certain ways of doing things or give them up. Knowing the conditions and events leading to persistence (resistance to change), or its absence, will contribute to improving human behavior (Nevin & Grace, 2000).

Response Stereotypy on CRF

On continuous reinforcement schedules, the form or topography of response becomes stereotyped, or highly regular. In a classic study, Antonitis (1951) found that on CRF, operants were repeated with very little change or variability in topography. In this study, rats were required to poke their noses anywhere along a 50-cm horizontal slot in order to get a food pellet (see Fig. 5.2). Although not required by the contingency, the animals frequently responded at the same position on the slot. Only when the rats were placed on extinction did responses become more variable. These findings are not limited to laboratory rats and may reflect a principle of behavior.

Further research with pigeons suggests that response variability may be inversely related to the rate of reinforcement. In other words, as more and more responses are reinforced, less and less variation occurs in the members of the operant class. Herrnstein (1961a) reinforced
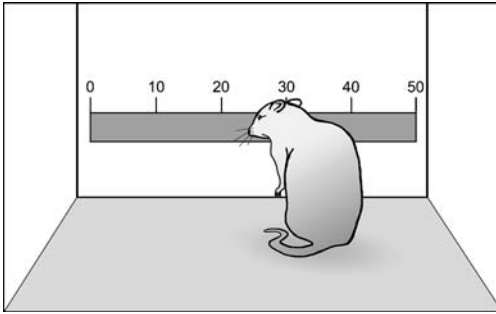
FIG. 5.2. *The apparatus used by Antonitis (1951). Rats could poke their noses anywhere along the 50-cm horizontal slot to obtain reinforcement.*

pigeons for pecking on an intermittent schedule. The birds pecked at a horizontal strip and were occasionally reinforced with food. When some responses were reinforced, most of the birds pecked at the center of the strip—although they were not required to do so. During extinction, the animals made fewer responses to the center and more to other positions on the strip. Eckerman and Lanson (1969) replicated this finding in a subsequent study also with pigeons. They varied the rate of reinforcement and compared response variability under CRF, intermittent reinforcement, and extinction. Responses were stereotyped on CRF and became more variable when the birds were on either extinction or an intermittent schedule.

One interpretation of these findings is that organisms become more variable in their responding as reinforcement becomes less frequent or predictable. When a schedule of reinforcement is changed from CRF to intermittent reinforcement, the rate of reinforcement declines and response variability increases. A further change in rate of reinforcement occurs when extinction is started. In this case, operants are no longer reinforced and response variation is maximum. The general principle appears to be, "When things no longer work, try new ways of behaving." Or, as the saying goes, "If at first you don't succeed, try, try again." In solving a problem, people usually employ a solution that has worked in the past. When the usual solution does not work, people try novel approaches to solving the problem. Pretend that you are a camper who is trying to start a fire. Most of the time, you gather leaves and sticks, place them in a heap, strike a match, and start the fire. This time the fire does not start. What do you do? If you are like most of us, you try different ways to get the fire going, many of which may have worked in the past. You may change the kindling, add newspaper, use lighter fluid, swear at the fire pit, or even build a shelter. Clearly, your behavior becomes more variable when reinforcement is withheld after a period of success. This increase in topographic variability during extinction after a period of reinforcement has been referred to as **resurgence** (Epstein, 1983, 1985) and can contribute to the development of creative or original behavior.

In summary, CRF is the simplest schedule of positive reinforcement. On this schedule, every response produces a reinforcer. Continuous reinforcement produces little resistance to extinction. This schedule also generates stereotyped response topography. Both resistance to extinction and variation in form of response increase on intermittent schedules**.**

Ratio and Interval Schedules of Reinforcement

On intermittent schedules of reinforcement, some rather than all responses are reinforced. **Ratio schedules** are response based; that is, these schedules are set to deliver reinforcement following a prescribed number of responses; the ratio specifies the number of responses for each reinforcer. **Interval schedules** pay off when one response is made after some amount

FIG. 5.3. *A table of the four basic sched-ules of positive reinforcement.* Note: *Adapted from* Behavior Principles, *by C. B. Ferster, S. Culbertson, and M. C. P. Boren, 1975, Englewood Cliffs, NJ: Prentice-Hall.*

of time has passed. Interval and ratio schedules may be fixed or variable. Fixed schedules set up reinforcement after a fixed number of responses, or a constant amount of time, have passed. On variable schedules, response and time requirements vary from one reinforcer to the next. Thus, there are four basic schedules: fixed ratio, variable ratio, fixed interval, and variable interval. In this section, we describe these four basic schedules of reinforcement (shown in Fig. 5.3) and illustrate the typical effects they produce. Following this discussion, some of the reasons for these effects are analyzed.

Ratio Schedules

Fixed Ratio

A **fixed-ratio**, or FR, schedule is programmed to deliver reinforcement after a fixed number of responses is made. Continuous reinforcement is FR 1; that is, the ratio is one re-inforcer for one response. Figure 5.4 presents a fixed-ratio schedule diagrammed in Mechner notation. The notation is read, "In the presence of a discriminative stimulus (S^D), a fixed number (N) of responses (R) produces an unconditioned reinforcer (S^{R+})." In a simple animal experiment, the S^D is sensory stimulation arising from the operant chamber, the response is a lever press, and food functions as reinforcement. On fixed-ratio 25 (FR 25), 25 lever presses must be made before food is presented. After reinforcement, the returning arrow indicates that another 25 responses will again produce the reinforcer.

The symbol N is used to indicate that fixed-ratio schedules can assume any value. Of course, it is unlikely that very high values (say, FR 100,000,000) would ever be completed. Nonetheless, this should remind you that Mechner notation describes independent vari-ables, not what the organism does. Indeed, FR 100,000,000 could be easily programmed, but this schedule is essentially an extinction contingency, because the animal will never complete the response requirement for reinforcement.
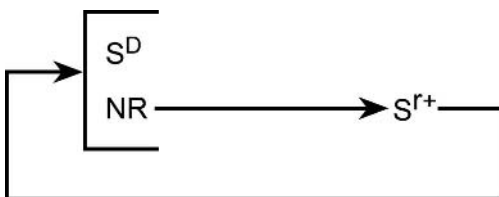
FIG. 5.4. *A fixed-ratio schedule of positive reinforcement diagrammed in Mechner nota-tion. In the presence of an S^D, a fixed number of responses results in reinforcement (S^{r+}). As indicated by the returning arrow, the se-quence repeats such that another fixed num-ber of responses will again produce reinforce-ment, and so on.*
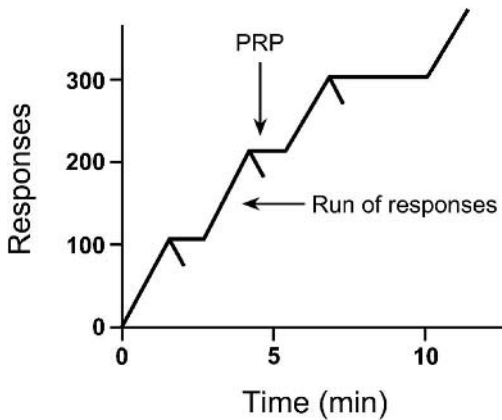
FIG. 5.5. *A cumulative record of well-developed performance on FR 100. The typical pause-and-run pattern is presented. Reinforcement is indicated by the hatch marks. This is an idealized record that is typical of performance on many fixed-ratio schedules.*

In 1957, Ferster and Skinner published a catalog of schedule contingencies and the characteristic effects, patterns and rates, produced by about 15 schedules of reinforcement. Their observations remain valid after literally thousands of replications: FR schedules produce a rapid run of responses, followed by reinforcement, and then a pause in responding (Ferster & Skinner, 1957; Weissman & Crossman, 1966). A cumulative record of behavior on fixed ratio is presented in Fig. 5.5. The record looks somewhat like a set of stairs (except at very small FR values, as shown by Crossman, Trapp, Bonem, & Bonem, 1985). There is a steep period of responding (the run), followed by reinforcement, and finally a flat portion. The flat part of the cumulative record is called the **postreinforcement pause**, or **PRP** to indicate where it occurred.

The pause in responding after the reinforcer is delivered does not occur because the organism is consuming the reinforcer. Research shows that the length of the PRP generated in FR schedules is due to the *upcoming ratio requirement*. Mixed FR schedules described later in this chapter also illustrate the influence of to-be-completed response requirements on FR pausing. The number of responses required and the size of the reinforcer have both been shown to influence PRP (Inman & Cheney, 1974). Calling this pause a "post" reinforcement event accurately locates the pause, but the upcoming requirements are what control it. Hence, many researchers refer to the PRP as a **preratio pause** (still PRP, e.g., Derenne & Baron, 2002).

Conditioned reinforcers like money, praise, and successful completion of a task also produce a pause when they are scheduled on fixed ratio. Consider what you might do if you had five sets of 10 math problems to complete for a homework assignment. A good bet is that you would solve 10 problems, then take a break before starting on the next set. When constructing a sun deck, one of the authors bundled nails into lots of 50 each. This had an effect on the "nailing behavior" of friends who were helping build the deck. The pattern that developed was to put in 50 nails, then stop, drink some beer, look over what was accomplished, have a chat, and finally start nailing again. In other words, a pause-and-run pattern typical of FR was generated by this simple scheduling of the nails.

In a factory, piece rates of payment are examples of fixed-ratio schedules. A worker may receive a dollar for sewing 20 pieces of elastic waistband. When the ratio of responses to reinforcement is large, FR schedules produce long pauses following reinforcement. This means that the overall productivity of the workers may be low and plant managers may complain about slacking off by the employees. The problem, however, is the schedule of reinforcement that relates a fixed number of responses to payment.

Piece work has been a contentious issue between management and workers. The fixed ratio may be gradually increased so that the company's labor cost remains the same, whereas the number of units produced spirals upward (an increase in profit). A similar effect may be obtained in the laboratory when an animal is given the same amount of food for more and more lever presses. If carefully engineered, gradual increases in the ratio requirement may support an enormous amount of behavior for a single delivery of reinforcement. One of the roles of labor unions is the negotiation of the schedules of payment to the advantage of the workers. For instance, a union may negotiate the size of the fixed ratio, the amount of payment (magnitude of reinforcement), and alternative schedules that are based on both time and productivity. The rate at which different workers complete their requirements will usually differ, and this observation is also a contentious issue between unions and management.

Variable Ratio

Variable-ratio, or **VR**, schedules are similar to FRs, except that the number of responses required for reinforcement changes after each reinforcer is presented. A variable-ratio schedule is literally a series of FRs with each FR of a different size. The average number of responses is used to define the schedule. A subject may press a lever for reinforcement 5 times, then 15, 7, 3, and 20 times. Adding these response requirements for a total of 50 and then dividing by the number of separate response runs (5) yields the schedule value, VR 10. The symbol V in Fig. 5.6 indicates that the number of responses required for any one reinforcer is variable. Other than this change, the contingency is identical to fixed ratio (see Fig. 5.4).

In general, ratio schedules produce a high rate of response. When VR and fixed-ratio schedules are compared, responding is typically faster on variable ratio. One reason for this is that pausing after reinforcement (PRP) is reduced or eliminated when the ratio contingency is changed from fixed to variable. This provides further evidence that the PRP does not occur because the animal is tired or is consuming the reinforcer (i.e., eating food). A rat or pigeon responding for food on VR does not pause as many times, or for as long after reinforcement. When VR schedules are not excessive, postreinforcement pauses may occur (Kintsch, 1965; Webbe, DeWeese, & Malagodi, 1978). However, these pauses are typically smaller than those generated by fixed-ratio schedules (Mazur, 1983). Figure 5.7 portrays a typical pattern of response on a variable-ratio schedule of positive reinforcement.

A VR schedule with a low mean ratio can contain some very small ratio requirements. For example, on a VR 10 schedule there cannot be many ratio requirements above 20 because, to offset those high ratios and average 10, there would have to be many very low ratios. It is the occasional occurrence of a reinforcer right after another reinforcer that reduces the likelihood of pausing on a VR schedule of reinforcement. Variable-ratio schedules with
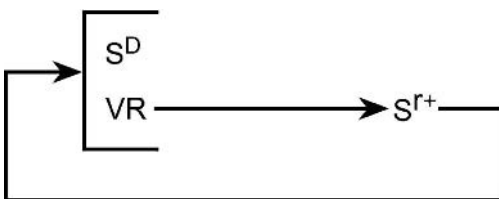
FIG. 5.6. *A variable-ratio schedule of positive reinforcement. The symbol V indicates that the number of responses required for reinforcement is varied from one sequence to the next. The schedule is indexed by the average number of responses required for reinforcement. That is, a VR 10 requires an average of 10 responses before reinforcement is presented.*
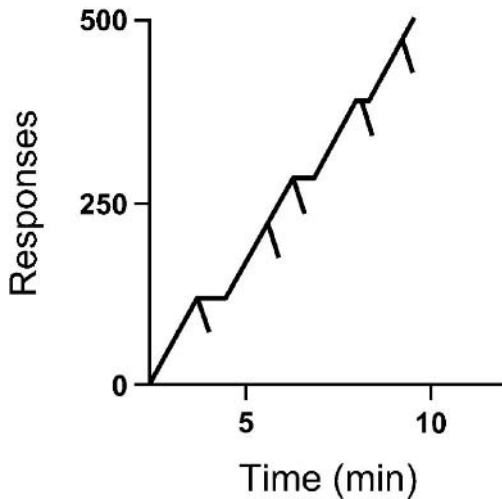
FIG. 5.7. *A cumulative graph of typical responding on a variable-ratio schedule of reinforcement. Reinforcement is indicated by the hatch marks. Notice that PRPs are reduced or eliminated when compared to fixed-ratio performance.*

high mean ratios (e.g., VR 100) have fewer short ratios following one another and typically generate longer PRPs.

In everyday life, variability and probability are routine; for this reason, ratio schedules involving probabilistic payoffs are more common than strict VR or FR contingencies. One may have to hit 1 nail 3 times to drive it in, and the next may take 6 swings of the hammer. It may, on the average, take 70 casts with a fly rod to catch a trout, but any 1 strike is unpredictable. In baseball, the batting average refers to the player's schedule of reinforcement. A batter with a .300 average gets 3 hits for 10 times at bat on average, but nothing guarantees a hit for each time at bat. The schedule depends on a complex interplay among conditions set by the pitcher and the skill of the batter.

Many contingencies set by games of chance involve probabilistic payoffs that are similar in their effects to VR schedules. Gambling is often called addictive, but from a behavioral perspective it may be understood as a persistent high-rate behavior generated by probabilistic and variable contingencies of reinforcement. A bird on a standard VR schedule may make thousands of responses for a few brief presentations of grain. When reinforcement is withdrawn, the animal will continue to respond at a high rate for a long period of time. It is possible to set the average ratio requirement so high that an animal will spend all of its time working for a small amount of food. The animal will show a net energy loss where effort expended exceeds caloric intake. A similar self-defeating response is sometimes seen in the behavior of gambling. Gambling involves the operant behavior of placing a bet that is reinforced with money on a probabilistic rather than on a VR basis. A person may feed money into a slot machine, even though the overall payoff does not cover the cost of gambling. The seemingly irrational behavior of the gambler (spending more than winning) is generated by an unfavorable probabilistic schedule of reinforcement (Crossman, 1983).

Two issues might be mentioned here with regard to gambling. Card playing with others is different from machine playing. In card playing there is nothing that requires a player to ever win even occasionally. However, with machine gambling the device is set to provide a minimum amount of pay-back on a probabilistic basis. Also, it is not gambling per se that is the individual or social problem; it is losing. Many professional gamblers are not irrational or excessive because they do not lose excessively.
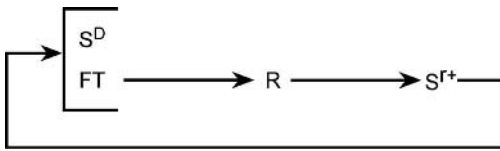
FIG. 5.8. *A fixed-interval schedule. In the presence of an S^D, one response is reinforced after a fixed amount of time. Following reinforcement, the returning arrow states that the sequence starts again. This means that the fixed-time interval starts over and, after it has elapsed, one response will again be reinforced.*

Interval Schedules

Fixed Interval

On **fixed-interval (FI)** schedules, an operant is reinforced after a fixed amount of time has passed. For example, on a fixed-interval 90-s schedule (FI 90), one bar press after 90 s results in reinforcement. Following reinforcement, another 90-s period goes into effect, and after this time has passed, another response will produce reinforcement. It is important to note that responses made before the time period has elapsed have no effect. Notice that in Fig. 5.8 one response (R) produces reinforcement (S^{r+}) after the fixed time period (FT) has passed. (Note: there is a schedule called *fixed time [FT]* in which reinforcement is delivered without a response following a set, or fixed, length of time. This is also referred to as a *response independent schedule*. Unless otherwise specified, one should always assume a response is required on whatever schedule is in effect.)

When organisms are exposed to interval contingencies and they have no way of telling time, they typically produce many more responses than the schedule requires. Fixed-interval schedules produce a characteristic pattern of responding. There is a pause after reinforcement (PRP), then a few probe responses, followed by more and more rapid responding as the interval times out. This pattern of response is called **scalloping**. Figure 5.9 is an idealized cumulative record of FI performance. Each interreinforcement interval can be broken into three distinct classes. The first is the PRP, followed by a period of gradually increasing rate, and finally by a high terminal rate of responding.

Pretend that you have volunteered to be in an operant experiment. You are brought into a small room, and on one wall there is a lever with a cup under it. Other than those objects, the room is empty. You are not allowed to keep your watch while in the room, and you are told, "Do anything you want." After some time, you press the lever to see what it does. Ten
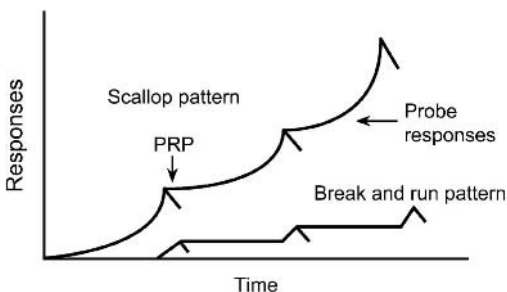
FIG. 5.9. *Fixed-interval schedules usually produce a pattern that is called scalloping. There is a PRP following reinforcement, then a gradual increase in rate of response to the moment of reinforcement. Less common is the break-and-run pattern. Break and run occasionally develops after organisms have considerable experience on FI schedules. There is a long pause (break) after reinforcement, followed by a rapid burst (run) of responses.*

dollars falls into the cup. A good prediction is that you will press the lever again. You are not told this, but the schedule is FI 5 min. You have 1 hr per day to work on the schedule. If you collect all 12 (60 min ÷ 5 min = 12) of the scheduled reinforcers, you can make $120 a day.

Assume you have been in this experiment for 3 months. Immediately after collecting a $10 reinforcer, there is no chance that a response will pay off (discriminated extinction). However, as you are standing around, or doing anything else, the interval is timing out. You check out the contingency by making a probe response. (You guess the time might be up.) The next response occurs more quickly because even more time has gone by. As the interval continues to time out, the probability of reinforcement increases and your responses are made faster and faster. This pattern of responding is described by the scallop given in Fig. 5.9 and is typical of fixed-interval schedules (Dews, 1969; Ferster & Skinner, 1957).

Following considerable experience with FI 5 min, you may get very good at judging the time period. In this case, you would wait out the interval and then emit a burst of responses. Perhaps you begin to pace back and forth during the session, and you find out that after 250 steps the interval has almost elapsed. This kind of mediating behavior may develop after experience with FI schedules (Muller, Crow, & Cheney, 1979). Other animals behave in a similar way and occasionally produce a **break-and-run** pattern of responding (Ferster & Skinner, 1957).

FOCUS ON RESEARCH: THE GENERALITY OF SCHEDULE EFFECTS

Many behavior analysts assume that basic research with animals will yield general principles that extend to many different species, including humans. This assumption applies to the research on schedules of reinforcement. In this context, experimenters who describe patterns of behavior on a given schedule believe that similar regularities will develop for any species that has evolved the capacity for operant conditioning. The **assumption of generality** implies that the effects of contingencies of reinforcement extend over species, reinforcement, and behavior. For example, a fixed-interval schedule is expected to produce the scalloping pattern not only for a pigeon pecking a key for food but also for a child solving mathematics problems for teacher approval.

This assumption is clearly stated in a variety of passages from books in behavior analysis. In their popular text, Whaley and Malott (1971) comment that "past research has shown that nearly all of the results of animal experimentation are just as true of humans as they are of animals" (Whaley & Malott, 1971, p. 8). A similar view was expressed by Morse (1966) in the early handbook of operant behavior. He wrote that "any member of most species will give a similar performance on the same schedules" (Morse, 1966, p. 59). Finally, B. F. Skinner (1969) supported the assumption of generality when he suggested that "the fact is that methods first developed for the study of lower organisms, as well as the concepts and principles arising from that study have been successfully applied to human behavior, both in basic analysis and in many technological applications" (1969, p. 101).

Dr. Fergus Lowe (Fig. 5.10), a professor of psychology at the University College of North Wales, has questioned the generality of schedule effects. He states that "the question which provides the main focus of my research is one which should be central to all behavior analysis; namely, how do the principles of behavior derived from animal experiments apply to human behavior?" (personal communication, March 20, 1989). Lowe devoted much

FIG. 5.10. *Fergus Lowe. Reprinted with permission.*

research to an analysis of performance on fixed-interval schedules of reinforcement. He has investigated the operant behavior of rats, pigeons, chimpanzees, human adults, and children of differing ages and language ability.

Lowe (1979) has conducted numerous studies of fixed-interval performance with humans, who press a button to obtain points that are later exchanged for money. Figure 5.11 shows typical performances on fixed-interval schedules by a rat and two human subjects. Building on research by Harold Weiner (1969), Lowe argues that animals show the characteristic scalloping pattern, and humans generally do not. Humans often produce one of two patterns—either an inefficient high, steady rate of response or an efficient low-rate, break-and-run performance. Experiments by Lowe and his colleagues have focused on the conditions that produce the high- or low-rate patterns in humans. Of course one obvious controlling factor is the effort required to make the operant response. The greater (lower) the response cost the lower (higher) will be the rate of responding.

Other than effort, the basic idea is that schedule performance in humans reflects the influence of language. (See chap. 12 on verbal behavior.) In conditioning experiments, people generate some verbal rule and proceed to behave according to the rule rather than to the experimentally arranged contingencies. Lowe, Beasty, and Bentall (1983) commented that:

> Verbal behavior can, and does, serve a discriminative function that alters the effects of other variables such as scheduled reinforcement. Unlike animals, most humans are capable of describing to themselves, whether accurately or inaccurately, environmental events and the ways in which those events impinge upon them; such descriptions may greatly affect the rest of their behavior. (p. 162)
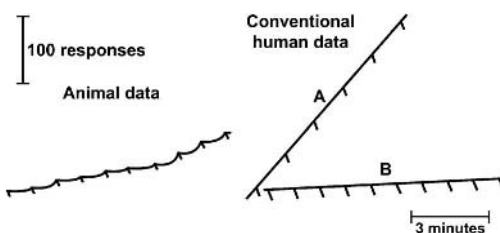
FIG. 5.11. *Typical animal performance on FI and the high- and low-rate performance usually seen with adult humans.* Note: *The data are adapted from* Reinforcement and the Organization of Behavior *(p. 162), by F. C. Lowe, 1979, New York: Wiley.*

In most cases, people who follow self-generated rules satisfy the requirements of the schedule, obtain reinforcement, and continue to follow the rule. For example, one person may say, "I should press the button fast," whereas another says that "I should count to 50 and then press the button." Only when the contingencies are arranged so that self-generated rules conflict with programmed reinforcement do people reluctantly abandon the rule and behave in accord with the contingencies (Baron & Galizio, 1983).

Although conditions may be arranged to override the effects of rules, most adult human behavior is rule governed (see Skinner, 1969). The implication is that humans who have not developed language skills will show characteristic effects of schedules. Lowe et al. (1983) designed an experiment to show typical FI performance by children less than a year old. The infants sat in a high chair and were able to touch a round metal cylinder. When the cylinder was touched, one infant (John) received a small bit of food (pieces of fruit, bread, or candy) on fixed-interval schedules of reinforcement. A second infant, Ann, was given 4 s of music played from a variety of music boxes on the same schedules. Both infants produced a response pattern similar to the rat's performance in Fig. 5.11. Thus, infants who are not verbally skilled behave in accord with the FI contingencies and are substantially different from adult humans.

Based on this finding and other research, Lowe argues that "these studies have shown 1) that the operant behavior of verbally able humans differs very markedly from that of non-verbal organisms (i.e., animals and human infants) and 2) that verbal behavior plays a major role in bringing about these differences" (personal communication, 1989). These conclusions have encouraged Dr. Lowe to increasingly concentrate his investigations on the interactions between verbal and nonverbal behavior, particularly in early childhood when verbal control of behavior is first established.

Although the effects of verbal behavior and self-instruction may account for human performance on FI schedules, there are alternative possibilities. Dr. Michael Perone and his colleagues, Drs. Mark Galizio and Alan Baron, in an article concerning the relevance of animal-based principles for human behavior, noted:

> when comparisons are made between the performances of humans and animals, discrepancies . . . are not difficult to find and, in themselves, provided little basis for satisfaction. The challenge for the student of human operant conditioning is to identify the similarities in the variables underlying the discrepant performances and ultimately to bring them under experimental control. (Perone, Galizio, & Baron, 1988, p. 80)

There is no doubt that humans become more verbal as they grow up. However, there are many other changes that occur in the movement from infancy to adulthood. An important consideration is the greater experience that adults have with ratio-type contingencies of reinforcement. Infants rely on the caregiving of other people. This means that most of the infant's reinforcement is delivered on the basis of time and behavior. A baby is fed when the mother has time to do so, although fussing may decrease the interval. As children get older, they begin to crawl and walk, and reinforcement is delivered more and more on the basis of their behavior. When this happens, many of the contingencies of reinforcement change from interval to ratio schedules. This experience with ratio schedules of reinforcement may contribute to the differences between adult human and animal performance on fixed-interval schedules.

Research by Wanchisen, Tatham, and Mooney (1989) has shown that rats perform like adult humans on FI schedules after a history of ratio reinforcement. The animals were exposed to variable-ratio reinforcement and then were given 120 sessions on a fixed-interval 30-s schedule (FI 30 s). Two patterns of response developed on the FI schedule—a high-rate

pattern with little pausing and a low-rate pattern with some break-and-run performance. These patterns of performance are remarkably similar to the schedule performance of adult humans (see Fig. 5.11). One implication is that human performance on schedules may be explained by a special history of reinforcement rather than by self-generated verbal rules. At this time, it is reasonable to conclude that both reinforcement history and verbal ability contribute to fixed-interval performance of humans.

Variable Interval

On a **variable-interval**, or **VI**, schedule responses are reinforced after a variable amount of time has passed (see Fig. 5.12). For example, on a VI 30-s schedule, the time to each reinforcement changes, but the average time is 30 s. The symbol V indicates that the time requirement varies from one reinforcer to the next. The average amount of time required for reinforcement is used to index the schedule.

Interval contingencies are common in the ordinary world of people and other animals. People line up, sit in traffic jams, wait for elevators, time a boiling egg, and are put on hold. In everyday life, variable time periods occur more frequently than fixed ones. Waiting in line to get to a bank teller may take 5 min one day and half an hour the next time you go to the bank. A wolf pack may run down prey following a long or short hunt. A baby may cry for 5 s, 2 min, or a quarter of an hour before a parent picks up the child. A cat waits varying amounts of time in ambush before a bird becomes a meal. Waiting for a bus is rarely reinforced on a fixed schedule, despite the efforts of transportation officials. The bus will arrive around an average specified time and will wait only a given time. A carpool is another example of such a VI with limited hold. The car arrives more or less at a specified time but will wait for a rider only a limited, and usually brief, time. This **limited hold** addition (where the reinforcer is available for a set time after a variable interval) to a VI schedule will increase the rate of responding by reinforcing short interresponse times.

Figure 5.13 portrays the pattern of response generated on a VI schedule. On this schedule, the rate of response is moderate and steady. The pause after reinforcement that occurs on FI usually does not appear in the variable-interval record. Because the rate of response is steady and moderate, VI performance is often used as a *baseline for evaluating other independent variables*. The rate of response on VI schedules may increase or decrease as a result of experimental manipulations. For example, tranquilizing drugs such as chlopromazine decrease the rate of response on variable-interval schedules (Waller, 1961), whereas stimulants increase VI performance (Segal, 1962). Murray Sidman (1960) has commented on the usefulness of VI performance as a baseline.

> An ideal baseline would be one in which there is as little interference as possible from other variables. There should be a minimal number of factors tending to oppose any shift in behavior that might result from experimental manipulation. A variable-interval schedule, if skillfully programmed, comes close to meeting this requirement. (p. 320)
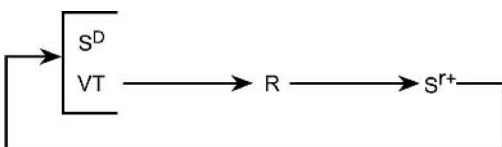
FIG. 5.12. *A variable-interval schedule. The symbol V stands for variable and indicates that the schedule is indexed by the average time requirement for reinforcement.*
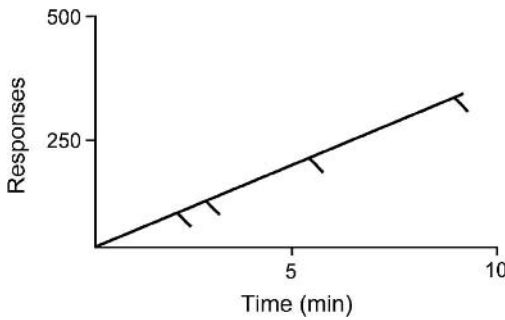
FIG. 5.13.   *Idealized cumulative pattern of response produced by a variable-interval schedule of reinforcement.*

In summary, VI contingencies are common in everyday life. These schedules generate a moderate steady rate of response. Because of this pattern, variable-interval performance is frequently used as a baseline.

ADVANCED ISSUE: ANALYSIS OF SCHEDULE PERFORMANCE

Each of the basic schedules of reinforcement (FR, FI, VR, VI) generates a unique pattern of responding. Ratio schedules produce a higher rate of response than interval schedules. A reliable pause after reinforcement (PRP) occurs on fixed-ratio and fixed-interval schedules but not on variable-ratio or variable-interval schedules.

Rate of Response on Schedules

The issue about what produces rapid responding on ratio schedules and moderate rates on interval schedules has not been resolved. The two major views concern molecular versus molar conceptions of schedule control. **Molecular accounts of schedule performance** focus on small moment-to-moment relationships between behavior and its consequences. **Molar accounts of schedule performance** are concerned with large-scale factors that may occur over the length of an entire session.

Molecular Account of Rate of Response

The time between any two responses, or what is called the **interresponse time (IRT)**, may be treated as an operant. Consider Fig. 5.14 in which 30-s segments of performance
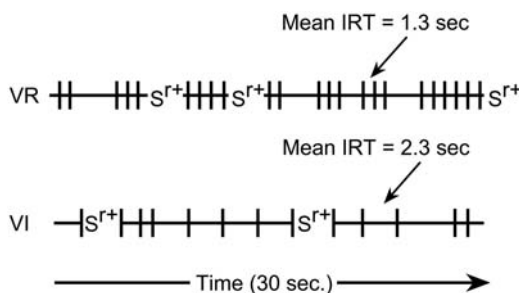
FIG. 5.14.   *Idealized distributions of response on VR and VI schedules of reinforcement. Responses are represented by the vertical marks, and S^{r+} stands for reinforcement.*

on VR and VI schedules are presented. Responses are portrayed by the vertical marks, and the occurrence of reinforcement is given with the familiar symbol S^{r+}. As you can see, IRTs are much longer on VI than on variable ratio. On the VR segment, 23 responses occur in 30 s, which gives an average time between responses of 1.3 s. The VI schedule generates longer IRTs, with a mean of 2.3 s.

Generally, ratio schedules produce shorter IRTs and consequently higher rates of response than interval schedules. Skinner (1938) suggested that this came about because ratio and interval schedules reinforce short or long interresponse times, respectively. To understand this, consider the definition of an operant class. It is a class of behavior that may either increase or decrease in frequency on the basis of contingencies of reinforcement. In other words, if it could be shown that the time between responses changes as a function of selective reinforcement, then the IRT is by definition an operant in its own right. To demonstrate that the IRT is an operant, it is necessary to identify an IRT of specific length (e.g., 2 s between any two responses) and then reinforce that interresponse time, showing that it increases in frequency.

Computers and other electronic equipment have been used to measure the IRTs generated on various schedules of reinforcement. A response is made, and the computer starts timing until the next response is emitted. Typically, these interresponse times are slotted into time bins. For example, all IRTs between 0 and 2 s are counted, then those that fall in the 2- to 4-s range, next the number of 4- to 6-s IRTs, and so on. This method results in a distribution of interresponse times. Several experiments have shown that the distribution of IRTs may in fact be changed by selectively reinforcing interresponse times of a particular duration (for a review, see Morse, 1966). Figure 5.15 shows the results of a hypothetical experiment in which IRTs of different duration are reinforced on a VI schedule. On the standard VI, most of the IRTs are 2 to 4 s long. When an additional contingency is added to the VI schedule that requires IRTs of 10 to 12 s, the IRTs increase in this category. Also, a new distribution of IRTs is generated. Whereas on a VR the next response may be reinforced regardless of the IRT, on VI the combination pause plus response is required for reinforcement.

Anger (1956) conducted a complex experiment demonstrating that IRTs are a conditionable property of behavior. In this experiment, the interresponse time was considered to be a stimulus that set the occasion for the next response (i.e., an S^D). Reynolds
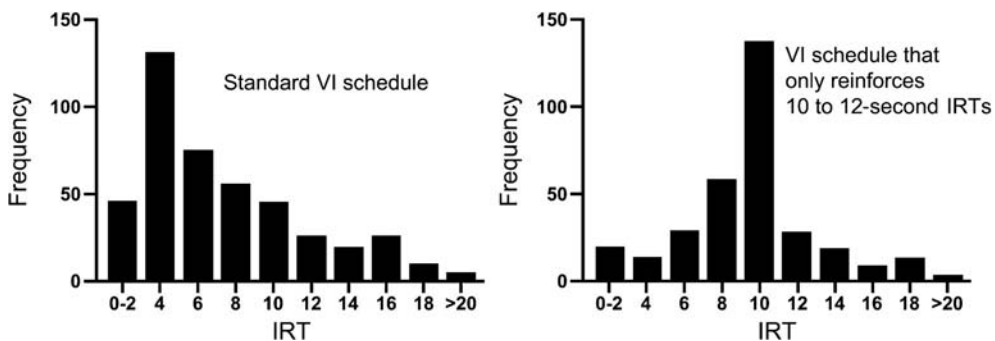
FIG. 5.15. *Hypothetical distributions of interresponse times (IRTs) for an animal responding on a standard VI schedule of reinforcement and on a VI that only reinforces IRTs that fall between 10 and 12 s.*

(1966a), in fact, showed that the IRT could affect performance that followed it. In other words, interresponse times can function as discriminative stimuli. The difficulty with this conception is that stimulus properties are inferred from performance. Zeiler (1977) has pointed out:

> if the IRT is treated as a differentiated response unit [an operant], unobservable stimuli need not be postulated as controlling observable performance. Given the one-to-one correspondence between response and inferred stimulus properties, however, the two treatments appear to be equivalent. (p. 223)

For these reasons, we treat the IRT as an operant rather than as a discriminative stimulus. As an operant, the IRT is considered to be a conditionable property of the response that ends the time interval between any two responses. For example, a rat may press a lever R_1, R_2, R_3, R_4, and R_5 times. The time between lever presses R_1 and R_2 is the interresponse time associated with R_2. In a similar fashion, the IRT for R_5 is the elapsed time between R_4 and R_5, and so on. This series can be said to constitute a homogenous chain that is divisible into discrete three-term-contingency links.

As part of Anger's (1956) experiment, animals were placed on a VI 300-s schedule of reinforcement. On this schedule, the response that resulted in reinforcement had to occur 40 s or more after the previous response. If the animal made many fast responses with IRTs of less than 40 s, the schedule requirements would not be met. In other words, IRTs of more than 40 s were the operant that was reinforced. Anger found that this procedure shifted the distribution of IRTs toward 40 s. Thus, the IRT that is reinforced is more likely to be emitted than other interresponse times. Additional experiments have demonstrated a similar effect (Dews, 1963; Ferster & Skinner, 1957; Kelleher, Fry, & Cook, 1959; Platt, 1979; Shimp, 1969), and Morse (1966) provides a formal analysis supporting the conclusion that IRTs are a conditionable property of operant behavior. Lattal and his colleagues at West Virginia University have extended these findings. Their research on delay of reinforcement suggests that basic behavioral units, like IRTs, are conditioned even when the contingencies of reinforcement do not directly require it (Arbuckle & Lattal, 1988; Lattal, 1984; Lattal & Ziegler, 1982).

Ratio schedules generate rapid sequences of responses with short interresponse times (Gott & Weiss, 1972; Weiss & Gott, 1972). On a ratio schedule, consider what the probability of obtaining reinforcement is following either a burst of very fast responses (short IRTs) or a series of responses with long IRTs. Recall that ratio schedules are based on the number of responses that are emitted. Bursts of responses with short IRTs count down the ratio requirement and are more probably reinforced than sets of slow responses. Responses that occur slowly do not excessively affect the schedule requirements and are less likely to be reinforced. Thus, ratio schedules, because of the way they are constructed, differentially reinforce short IRTs. According to the molecular IRT view of schedule control, this is why rate of response is high on these schedules.

When compared to ratio schedules, interval contingencies generate longer IRTs and consequently a lower rate of response. Interval schedules pay off after some amount of time has passed and a response is made. As IRTs become longer, more and more of the time requirement on the schedule elapses. This means that the probability of reinforcement for a response increases with longer IRTs. In other words, longer IRTs are differentially reinforced on interval schedules (Morse, 1966). In keeping with the molecular view, interval contingencies differentially reinforce long IRTs, and the rate of response is moderate on these schedules.

Molar Accounts of Rate Differences

There are several problems with the IRT account of rate differences on ratio and interval schedules. A logical objection is that showing that the reinforcement of IRTs can change behavior does not mean that this is what is happening on other schedules. In other words, demonstrating that IRTs can be selectively reinforced does not prove that this occurs on either interval or ratio schedules. Also, there is evidence that when long IRTs are reinforced, organisms continue to emit short bursts of rapid responses. Animals typically produce these bursts even on schedules that never reinforce a fast series of responses (i.e., differential reinforcement of low rate, DRL). For these reasons, molar hypotheses about the rate of response difference have been advanced.

Molar explanations of rate differences are concerned with the global relationship between responses and reinforcement. In general terms, the correlation between responses and reinforcement produces the difference in the rate on interval and ratio schedules. Generally, if a high rate of response is associated with a higher frequency of reinforcement, then subjects will respond rapidly. When the increased rate of response does not affect the rate of reinforcement, organisms do not respond faster (Baum, 1993).

Consider a VR 100 schedule of reinforcement. On this schedule, a subject could respond 50 times per minute and in a 1-hr session obtain 30 reinforcers. On the other hand, if the rate of response was 300 per minute (not outside the range of pigeons or humans), the number of reinforcers earned would increase to 180 an hour. According to supporters of the molar view, this correlation between increasing the rate of response and the increased frequency of reinforcement is responsible for rapid responding on ratio schedules.

A different correlation between the rate of response and the frequency of reinforcement is set up on interval schedules. Recall that interval schedules program a reinforcer after time has passed and one response is made. Suppose you are responding on a VI 3-min schedule for $5 reinforcers. You have 1 hr a day to work on the schedule. If you respond at a reasonable rate, say 30 lever presses per minute, you will get most or all of the 20 scheduled reinforcers. Now pretend that you increase your rate of response to 300 a minute. The only consequence is a sore wrist, and the rate of reinforcement stays at 20 per hour. In other words, after some moderate value, it does not pay to increase the rate of response on interval schedules; hence, lower rates are maintained on interval schedules.

Postreinforcement Pause on Fixed Schedules

Fixed-ratio and fixed-interval schedules generate a pause that follows reinforcement. Accounts of pausing on fixed schedules also may be classified as either molecular or molar. Molecular accounts of pausing are concerned with the moment-to-moment relationships that immediately precede reinforcement. Such accounts are concerned with the relationship between the number of bar presses that produce reinforcement and the subsequent postreinforcement pause. In contrast, molar accounts of pausing focus on the overall rate of reinforcement for a session and the average pause length.

Generally, it is well established that the postreinforcement pause is a function of the **interreinforcement interval (IRI)**. As the time between reinforcements becomes longer, the PRP increases. On fixed-interval schedules, in which the time between reinforcement is controlled by the experimenter, the postreinforcement pause is approximately one-half the interreinforcement interval. For example, on a FI 300-s schedule (in which the time

between reinforcements is 300 s), the average PRP will be 150 s. On fixed ratio, the evidence suggests similar control by the IRI (Powell, 1968)—as the ratio requirement increases, the PRP becomes longer.

There is, however, a difficulty with analyzing the postreinforcement pause on FR schedules. On ratio schedules, the time between reinforcements is partly determined by what the animal does. That is, the animal's rate of pressing the lever affects the time between reinforcements. Another problem with ratio schedules, for an analysis of pausing, is that the rate of response goes up as the size of the ratio is increased (Boren, 1961). Unless the rate of response exactly coincides with changes in the size of the ratio, adjustments in ratio size alter the interreinforcement interval. For example, on FR 10 a rate of 5 responses per minute produces an IRI of 2 min. This same rate of response produces an IRI of 4 min on a FR 20 schedule. Thus, changes in postreinforcement pause as ratio size is increased may be caused by the ratio size, the interreinforcement interval, or both.

A Molar Interpretation of Pausing

We have noted that the average PRP is one half of the interreinforcement interval. Another finding is that the postreinforcement pauses are normally distributed (bell-shaped curve) over the time between reinforcements. In other words, on a FI 320-s schedule, pauses will range from 0 to 320 s with an average pause around 160 s. As shown in Fig. 5.16, these results can be accounted for by considering what would happen if the normal curve moved upward so that the mean pause was 225 s. In this case, many of the pauses would exceed the FI interval and the animal would get fewer reinforcements for the session. An animal that was sensitive to the overall rate of reinforcement (maximization) should come to emit pauses that are on average one half the FI interval, assuming a normal distribution. Thus, maximization of reinforcement provides a molar account of the postreinforcement pause (Baum, 2002).
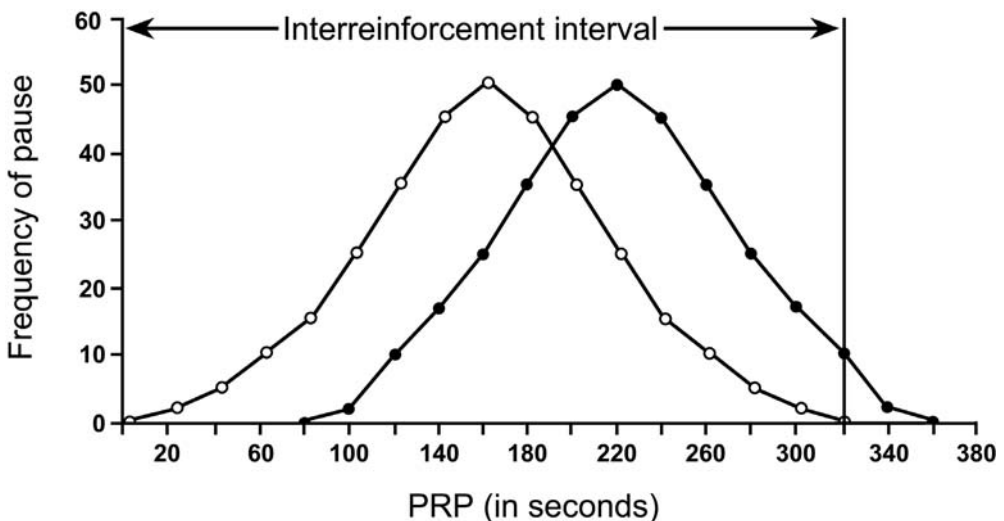
FIG. 5.16. *Two possible distributions of PRPs on a fixed-interval 320-s schedule. The distribution given by the open circles has a mean of 160 s and does not exceed the interreinforcement interval set on the FI schedule. The bell curve for the distribution with the dark circles has an average value at 225 s, and many pauses are longer than the IRI.*

Molecular Interpretations of Pausing

There are two molecular accounts of pausing on fixed schedules that have some amount of research support. One account is based on the observation that animals often emit other behavior during the postreinforcement pause (Staddon & Simmelhag, 1971). For example, rats may engage in grooming, sniffing, scratching, and stretching after the presentation of a food pellet. Because this behavior reliably follows reinforcement, it is said to be induced by the schedule. Schedule-induced behaviors (see chap. 6) may be viewed as operants that automatically produce reinforcement. For example, stretching may relieve muscle tension, and scratching may eliminate an itch. One interpretation is that pausing occurs because the animal is maximizing local rates of reinforcement. That is, the rat gets food for bar pressing as well as the automatic reinforcement from the induced activities (see Shull, 1979). The average pause should therefore reflect the allocation of time to induced behavior and to the operant that produces scheduled reinforcement (e.g., food). At present, experiments have not ruled out or clearly demonstrated the induced-behavior interpretation of pausing (e.g., Derenne & Baron, 2002).

A second molecular account of pausing is based on the run of responses or amount of work that precedes reinforcement (Shull, 1979, pp. 217–218). This "work-time" interpretation holds that the previously experienced run of responses regulates the length of the postreinforcement pause. Work time affects the PRP by altering the value of the next scheduled reinforcement. In other words, the more effort or time expended for the previous reinforcer, the lower the value of the next reinforcer and the longer it takes for the animal to initiate responding (i.e., pause length). Interestingly, Skinner made a similar interpretation in 1938 when he stated that pausing on fixed-ratio schedules occurred because "the preceding run which occurs under reinforcement at a fixed ratio places the [reflex] reserve in a state of strain which acts with the temporal discrimination of reinforcement to produce a pause of some length" (p. 298). Skinner's use of the strained reserve seems equivalent to the more current emphasis on work time. Overall, this view suggests that the harder one works for reinforcement, the less valuable the next reinforcement and therefore the longer it takes to start working again.

Neither the induced behavior nor the work-time accounts of pausing are sufficient to handle all that is known about patterning on schedules of reinforcement. A schedule of reinforcement is a procedure for combining a large number of different conditions that regulate behavior. Some of the controlling factors arise from the animal's behavior, and others are set by the experimenter. This means that it is exceedingly difficult to unravel the exact processes that produce characteristic schedule performance. Nonetheless, the current interpretations of pausing point to some of the more relevant factors that play a role in the regulation of behavior on fixed schedules.

The Dynamics of Schedule Performance

There are reasons for detailed research on the postreinforcement pause and interresponse time. The hope is to analyze schedule effects in terms of a few basic processes. This area of research, called **behavioral dynamics**, is an important endeavor, because the environment of people and other animals can be arranged in an infinite number of ways. If performance on schedules can be reduced to a small number of fundamental principles, then reasonable interpretations may be made about any particular arrangement of the environment. Also, it should be possible to predict behavior more precisely from both the knowledge of the operating contingencies and the axioms that govern reinforcement schedules.

Behavioral dynamics is at the leading edge of behavior analysis, and, like most scientific research, it requires a high level of mathematical sophistication. Both linear and nonlinear calculi are used to model the behavioral impact of schedules of reinforcement. In the 1990s, an issue of the *Journal of the Experimental Analysis of Behavior* was devoted to this important subject and included topics like chaos theory and performance on fixed-interval schedules, dynamics of behavioral structure, behavioral momentum, resistance to behavior change, and feedback functions for variable-interval schedules (see Baum, 1992; Galbicka, 1992; Gibbon & Church, 1992; Harper & McLean, 1992; Hoyert, 1992; Killeen, 1992; Marr, 1992; McDowell, Bass, & Kessel, 1992; Nevin, 1992; Palya, 1992; Rachlin, 1992; Shimp, 1992; Zeiler, 1992). In this same issue, Dr. Peter Killeen, a professor at Arizona State University, builds on his previous work and suggests that "behavior may be treated as basic physics," with responses viewed as movement through behavioral space (Killeen, 1974, 1975, 1985, 1992). Although these issues are beyond the scope of this book, the student of behavior analysis should be aware that the physics of schedule performance is an advanced area of the science of behavior.

Schedule Performance in Transition

We have described typical performances generated by different schedules of reinforcement. The patterns of response on these schedules take a relatively long time to develop. Once behavior has stabilized, showing little change from day to day, the organism's behavior is said to have reached a **steady state**. As we have pointed out, the pause-and-run pattern that develops on FR schedules is a steady-state performance and is only observed after an animal has considerable exposure to the contingencies. Similarly, the steady-state performance generated on other intermittent schedules takes time to evolve. When an organism is initially placed on any schedule of reinforcement, typically behavior patterns are not consistent or regular. This early performance on a schedule is called a **transition state**. Transition states are the periods between initial steady-state performance and the next steady state (see Sidman, 1960, for steady-state and transitional-state analysis).

Behavior analysts rarely study transitions, but one might argue that when behavior is in transition is exactly when most learning is taking place. One problem with an experimental analysis of behavior in transitions is clearly defining what constitutes the boundary between steady-state performances. How operant performance is characterized as stable has been a point of serious consideration for many decades (e.g., Cumming & Schoenfeld, 1960; McLean & Blampied, 1995). Most often, stability is determined by some combination of inspection of cumulative records, or other rate indicators, and number of sessions. Until the "boundary problem" of transition to steady states is solved, the experimental analysis of behavior in transition is likely to remain a less investigated area of learning. There are, however, interesting patterns of behavior in transition that can be addressed here.

Consider how you might get an animal to press a lever 100 times for each small presentation of food (FR 100). First, you shape the animal to press the bar on continuous reinforcement (see chap. 4). After some arbitrary steady-state performance is established on CRF, you are faced with the problem of how to program the steps from CRF to FR 100. Notice that in this transition there is a large shift in the ratio of reinforcement to bar pressing. This problem has been studied with the use of a progressive-ratio schedule (Findley, 1958). Stafford and Branch (1998) employed this schedule in an investigation that looked at step size and criteria for stability. If you simply move from CRF to the large FR value, the

animal will probably show what is called **ratio strain**, in the sense that it pauses longer and longer after reinforcement. This occurs, for one reason, because the time between successive reinforcements contributes to the postreinforcement pause. The pause gets longer as the interreinforcement interval (IRI) increases. Because the PRP makes up part of the interval between reinforcements and is controlled by it, the animal eventually stops responding. Thus, there is a negative-feedback loop between the increasing PRP length and the time between reinforcements.

Large and sudden increases in schedule values may also produce extinction. For this reason, a slow progression to higher schedule values is typically programmed. Even when a small change in the fixed ratio is made, an animal is momentarily exposed to a period of extinction. Recall that during the early phase of extinction, behavior becomes more variable and a burst of responses is likely to occur. This eruption of responses may actually be used to support the transition to a higher ratio requirement. In other words, when continuous reinforcement (FR 1) is changed to FR 5, the animal makes several rapid responses, a burst, and the fifth response is reinforced. Following several reinforced sequences of five responses, the ratio requirement may be raised again. The transition to the next FR requirement also produces an extinction burst and enables the animal to contact the next scheduled value. Notice that this issue does not occur with interval schedules. If pausing occurs on either VI or FI, the time will run out, the next response will be reinforced, and responding will be strengthened. For this reason, these schedules are said to be self-perpetuating; they will maintain at least a minimum of responding.

Extinction bursts and increased behavioral variability allow for adaptation to changing environmental contingencies. When an organism changes its behavior on the basis of life experience, this is called **ontogenetic selection**. In this ontogenetic form of adaptation, the topography and frequency of behavior increase when reinforcement is withheld. These behavioral changes during extinction allow for the selection of behavior by new contingencies of reinforcement. Thus, a wild rat that has been exploiting a compost heap may find that the home owner has covered it. In this case, the rat emits various operants that may eventually uncover the food. The animal may dig under the cover, gnaw a hole in the sheathing, or search for some other means of entry. A similar effect occurs when food in the compost heap is depleted and the animal emits behavior that results in getting to a new food patch. In the laboratory, this behavior is measured as an increase in the topography and frequency of bar pressing as the schedules of reinforcement change.

Transitions from one reinforcement schedule to another play an important role in human development. Developmental psychologists have described periods of life in which major changes in behavior typically occur. One of the most important life stages in Western society is the transition from childhood to adolescence. Although this phase involves many biological and behavioral processes, one of the most basic changes involves schedules of reinforcement.

When a youngster reaches puberty, parents, teachers, peers, and others require more behavior and more skillful performance than they did during childhood. A young child's reinforcement schedules are usually simple, regular, and immediate. In childhood, food is given when the child says "Mom, I'm hungry" after playing a game of tag, or it is scheduled at regular times throughout the day. On the other hand, a teenager is told to fix his or her own food and clean up the mess. Notice that the schedule requirement for getting food has significantly increased. The teenager may search through the refrigerator, open packages and cans, sometimes cook, get out plates, eat the food, and clean up. Of course, any part of this sequence may or may not occur depending on the disciplinary practices of the parents. Although most adolescents adapt to this transition state, others may show signs of ratio strain and extinction. Poor eating habits by teenagers may reflect the change from regular to intermittent reinforcement.

Many other behavioral changes may occur during the transition from childhood to adolescence. Ferster, Culbertson, and Boren (1975) have noted the transition to intermittent reinforcement that occurs in adolescence.

> With adolescence, the picture may change quite drastically and sometimes even suddenly. Now money becomes a reinforcer on a fixed-ratio schedule instead of continuous reinforcement as before. The adolescent may have to take a job demanding a substantial amount of work for the money which heretofore he received as a free allowance. Furthermore, he now needs more money than when he was younger in order to interact with people he deals with. A car or a motorcycle takes the place of the bicycle. Even the price of services such as movies and buses is higher. Money, particularly for boys, frequently becomes a necessary condition for dealing with the opposite sex. The amount of work required in school increases. Instead of simple arithmetic problems, the adolescent may now have to write a long term paper, cover more subjects, or puzzle through a difficult algebra problem which will require much trial and error. (pp. 416–417)

There are other periods of life in which our culture demands large shifts in schedules of reinforcement. A current problem involves a rapidly aging population and the difficulties generated by forced retirement. In terms of schedules, retirement is a large and rapid change in the contingencies of reinforcement. Retired people face significant alterations in social, monetary, and work-related consequences. For example, a person who has enjoyed his or her academic career as a professor is no longer reinforced for research and teaching by the university community. Social consequences for these activities may have included approval by colleagues, academic advancement, interest of students, and intellectual discussions. Upon retirement, these social reinforcers are reduced in frequency or completely eliminated. It is not surprising, therefore, that retirement is an unhappy time of life for many people. Although retirement is commonly viewed as a problem of old age, a behavior analysis points to the abrupt change in rates and sources of reinforcement (Skinner & Vaughn, 1983).

Transitions in the schedules of reinforcement also occur with major life events. Significant life events that produce shifts in schedules of reinforcement include going to school, making a living, getting married, having children, divorcing, and experiencing the death of a loved one. The authors are familiar with the shift in contingencies of reinforcement that happens following a divorce. A person's sexual behavior may have to adjust to new requirements. This adjustment involves finding new partners and meeting the contingencies set by these individuals. Some people who go through a divorce may not be able to meet the new contingencies of reinforcement. Feelings of loneliness and depression often accompany marital breakdown. These feelings may be generated by ratio strain and extinction that result from a change in the contingencies of reinforcement. In contrast, there are people who readily adapt to this life crisis. Presumably, behavioral variability and an initial flurry of responding produced by extinction allow such persons to contact the new schedules of sexual reinforcement.

ON THE APPLIED SIDE: SCHEDULES OF REINFORCEMENT OF ABSTINENCE FROM CIGARETTE SMOKING

The use of drugs is operant behavior maintained in part by the reinforcing effects of the drug. One implication of this analysis is that reinforcement of an incompatible response (i.e., abstinence) can reduce the probability of taking drugs. The effectiveness of an abstinence

contingency depends on both the magnitude and the schedule of reinforcement for nondrug use (e.g., Higgins, Bickel, & Hughes, 1994).

In an investigation of cigarette smoking, Roll, Higgins, and Badger (1996) assessed the effectiveness of three different schedules of reinforcement for promoting and sustaining drug abstinence. These researchers conducted an experimental analysis of cigarette smoking because (a) cigarettes can function as reinforcers, (b) smoking can be reduced by reinforcement of alternative responses, and (c) it is relatively more convenient to study cigarette smoking than illicit drugs. Furthermore, cigarette smokers usually relapse within several days following abstinence. This suggests that reinforcement factors regulating abstinence exert their effects shortly after the person stops smoking, and it is possible to study these factors in a short-duration experiment.

Sixty adults, who smoked between 10 and 50 cigarettes a day, took part in the experiment. The smokers were not currently trying to give up cigarettes. Participants were randomly assigned to one of three groups: progressive reinforcement, fixed rate of reinforcement, and a control group. They were told to begin abstaining from cigarettes on Friday evening so that they could pass a carbon monoxide (CO) test for abstinence on Monday morning. Each person in the study went at least 2 days without smoking before reinforcement for abstinence began. On Monday through Friday, participants agreed to take three daily CO tests. These tests could detect prior smoking.

Twenty participants were randomly assigned to the progressive reinforcement group. The progressive schedule involved increasing the magnitude of reinforcement for remaining drug free. Participants earned $3.00 for passing the first carbon monoxide test for abstinence. Each subsequent consecutive CO sample that indicated abstinence increased the amount of money participants received by $0.50. The third consecutive CO test passed earned a bonus of $10.00. That is, passing the first CO test yielded $3.00; passing the second, $3.50; the third, $14.00 ($4.00 and bonus of $10.00); the fourth, $4.50; and so on. In addition, a substantial response cost was added for failing a CO test. If the person failed the test, the payment for that test was withheld, and the value of payment for the next test was reset to $3.00. Three consecutive CO tests indicating abstinence following a reset returned the payment schedule to the value at which the reset occurred (p. 497), supporting efforts to achieve abstinence.

Participants in the fixed reinforcement group (N = 20) were paid $9.80 for passing each CO test. There were no bonus points for consecutive abstinences, and there were no resets. The total amount of money available for the progressive and the fixed groups was the same. Smokers in both the progressive and the fixed groups were informed in advance of the schedule of payment and the criterion for reinforcement. The schedule of payment for the control group was the same as the average payment obtained by the first 10 participants assigned to the progressive condition. For these people, the payment was given no matter what their CO levels were. The control group was, however, asked to try and cut their cigarette consumption, reduce CO levels, and maintain abstinence.

Smokers in the progressive and fixed reinforcement groups passed more than 80% of the abstinence tests, whereas the control group only passed about 40% of the tests. The effects of the schedule of reinforcement are shown in Fig. 5.17A. The figure indicates the percentage of participants who passed three consecutive tests for abstinence and then resumed smoking over the 5 days of the experiment. Only 22% of those on the progressive schedule resumed smoking compared to 60 and 82% in the fixed and control groups. Thus, the progressive schedule of reinforcement was superior at preventing the resumption of smoking (after a period of abstinence).

Figure 5.17B shows the percentage of smokers who gave up cigarettes throughout the experiment. Again, a strong effect of schedule of reinforcement is apparent. Fifty percent
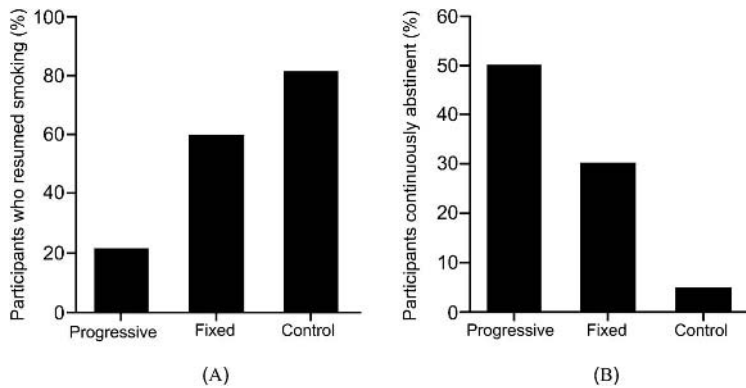
FIG. 5.17.   *Percentage of participants in each group who obtained three consecutive abstinences but then resumed smoking (A). Percentage of smokers in each group who were abstinent on all trials during the entire experiment (B).*

of those on the progressive reinforcement schedule remained abstinent for the 5 days of the experiment. This compares with 30 and 5% of the fixed and control participants.

Overall, these results indicate that a progressive reinforcement schedule, combined with an escalating response cost, is an effective short-term intervention for abstinence from smoking. Further research is necessary to see whether a progressive schedule maintains abstinence after the schedule is withdrawn. Long-term follow-up studies of progressive and other schedules are necessary to assess the lasting effects of reinforcement schedules on abstinence. What is clear, at this point, is that schedules of reinforcement may be an important component of stop-smoking programs.

KEY WORDS

Assumption of generality
Behavioral dynamics
Break and run
Continuous reinforcement
   (CRF)
Fixed interval (FI)
Fixed ratio (FR)
Intermittent reinforcement
Interreinforcement interval
   (IRI)
Interresponse time (IRT)
Interval schedules

Mechner notation
Molar accounts of
   schedule performance
Molecular accounts of
   schedule performance
Ontogenetic selection
Partial reinforcement
   effect
Preratio pause
Postreinforcement pause
   (PRP)
Progressive ratio schedule

Ratio schedules
Ratio strain
Run of responses
Scalloping
Schedule of reinforcement
Steady-state performance
Transition-state
   performance
Variable-interval (VI)
   schedule
Variable-ratio (VR)
   schedule

ON THE WEB

http://www.users.csbsju.edu/~tcreed/pb/schedules.html This Web site has a discussion of the
   basic schedules of reinforcement and their characteristic effects as well as illustrations of

cumulative records of performance. The claim that the period following reinforcement on FR schedules is aversive is contentious at the present time.

http://www.pigeon.psy.tufts.edu/eam/eam2.htm This module demonstrates basic schedules of reinforcement as employed in a variety of operant and discrimination procedures involving animals and humans.

http://www.fiu.edu/orgs/psych/eab_3002/interact/schedule.htm See the characteristic effects of FR schedules of reinforcement on a rat's lever pressing for food in an operant chamber.

http://members.aol.com/standardcharter/conjugate.html This is a Web site by John Eshleman that addresses conjugate schedules of reinforcement as defined by Ogden Lindsley. With conjugate schedules, the intensity of a continuously available reinforcer varies with the rate of response.

http://www.wadsworth.com/psychology_d/special_features/sniffy/contents.htm Go to this Web address to find out about Sniffy the virtual rat and how to purchase the software. You can put Sniffy on all kinds of contingencies of reinforcement and see how Sniffy performs on various schedules of reinforcement.

STUDY QUESTIONS

1. Define a schedule of reinforcement. Compare humans and other organisms on similar schedules of reinforcement. (118)
2. **FOCUS ON**: Discuss the behavior analysis approach to science. In your answer, refer to the use of highly controlled settings, discouragement of speculation about the organism, study of behavior for its own sake, biological status as context, search for principles of behavior, accumulation of research, and integration of research by behavioral theory. (119–120)
3. According to Reynolds (1966b), why is the study of schedules of reinforcement central to understanding behavior regulation? Why are the early studies of schedule performance still important? (120)
4. Describe how orderly patterns of response develop on schedules of reinforcement. Use the terms contingency of reinforcement and steady-state performance in your answer. (120–121)
5. What happens when a hungry rat presses a lever for food and obtains a pellet for every 10 responses? (121)
6. Be able to discuss schedules of reinforcement in everyday life. How does a bird's foraging relate to schedules of reinforcement? Refer to the Cheney, Bonem, and Bonem (1985) experiment in your answer. (121–122)
7. What role does intermittent reinforcement play in the regulation of human interaction? (122)
8. Based on Azrin (1959), how does punishment affect behavior maintained on a fixed-ratio schedule of reinforcement? (122)
9. Why did Azrin's findings (Azrin, 1959; Azrin & Holz, 1961) on schedule effects and punishment lack generality? Refer to behavior reinforced after a fixed amount of time in your answer. (122–123)
10. What does Mechner notation describe? Write the notation for nine event symbols. Do the same for time and number symbols. What does $R \rightarrow S^r$ mean? What about $R_a \rightarrow R_b$? Write in Mechner notation: (a) A and B occur at the same time, and B produces C; (b) A and B occur at the same time, A produces C, and B prevents C; (c) A and B occur at the same time, and B repeatedly produces C. (123–124)

11. Define CRF and discuss resistance to extinction on this schedule. Compare CRF to intermittent reinforcement in terms of resistance to extinction. Refer to an experiment by Hearst (1961) in your answer. (124–125)

12. **FOCUS ON**: What researcher proposed the model of behavioral momentum? Explain behavioral momentum, using Nevin (1974) in your answer. Discuss the partial reinforcement effect (PRE) and how it is consistent with a behavioral momentum account. Give an example of behavioral momentum and its application, using a study by Dube and McIlvane (2000). (126–127)

13. Discuss response stereotypy on CRF using a classic study by Antonitis (1951). Indicate how reinforcement rate is related to response variability, referring to the experimental evidence with pigeons. Give an interpretation of the findings based on the textbook. How would you produce a performance that is variable in form and resistant to extinction? (127–128)

14. Define ratio and interval schedules. Name the four basic schedules of reinforcement. Write the Mechner notation for a FR 25 schedule of reinforcement. Describe the characteristic effects of fixed-ratio (FR) schedules, using run of responses and postreinforcement pause (PRP) in your answer. Discuss the preratio pause as a more accurate descriptor of pausing than the postreinforcement pause on FR schedules. (128–130 and relevant figures)

15. Discuss FR schedules and building a sun deck. Analyze piece-rate work in factories as schedule performance. Why do management and workers often disagree about piece-rate contingencies? (130–131)

16. What is a variable-ratio (VR) schedule of reinforcement? Write the Mechner notation for a VR 10 schedule. Compare FR and VR schedules in terms of behavioral effects. Give examples of VR schedules in everyday life. (131–132 and relevant figures).

17. Define a fixed-interval (FI) schedule. Give the Mechner notation for FI 90 s. Describe the characteristic effects of FI schedules. Outline a hypothetical experiment with humans responding for money on an FI schedule. What pattern of behavior is likely to occur at steady state? What happens to FI performance if mediating behavior times out the interval? (133–134)

18. **ADVANCED ISSUE**: Distinguish between molar and molecular accounts of schedule performance. Provide an IRT molecular analysis of differences in rate of response on interval and ratio schedules of reinforcement. Give a molar account of the rate differences on interval and ratio schedules. Analyze the PRP on fixed schedules using an IRT molecular perspective. Give a molar analysis of pausing on these schedules. (138–144)

20. Distinguish steady-state performance and performance during transition from one schedule to another (transition state). Why do behavior analysts study steady-state performance more than transition-state behavior. Discuss ratio strain and the transition from CRF to FR 100 schedule. Show how a slow progression to higher FR values can make use of the extinction burst to support the transition. What exactly is meant by ontogenetic selection? (144–145)

21. Relate transitions between schedules of reinforcement to important human behavior, referring to transitions from childhood to adolescence, work to retirement, and major life events like marriage and divorce. (145–146)

22. Outline the experiment by Roll, Higgins, and Badger (1996) concerned with abstinence from cigarette smoking and schedule of reinforcement. What schedule of reinforcement for abstinence was most effective? Why was this schedule the most effective? (146–148)

BRIEF QUIZ

1. Schedules of reinforcement were first described by
   (a) Charles Ferster
   (b) Francis Mechner
   (c) B. F. Skinner
   (d) Fergus Lowe
2. Infrequent reinforcement generates responding that is persistent and is called the
   (a) postreinforcement pause
   (b) partial reinforcement effect
   (c) molar maximizing
   (d) intermittent resistance
3. Mechner notation describes
   (a) stimulus effects
   (b) dependent variables
   (c) response contingencies
   (d) independent variables
4. Resurgence happens when
   (a) behavior is put on extinction
   (b) reinforcement magnitude is doubled
   (c) high-probability behavior persists
   (d) response variability declines
5. Schedules that generate predictable stair-step patterns are
   (a) fixed interval
   (b) fixed ratio
   (c) variable ratio
   (d) random ratio
6. Variable-ratio schedules generate
   (a) postreinforcement pauses
   (b) locked rates
   (c) break-and-run performance
   (d) high rates of response
7. Schedules combining time and responses are called
   (a) partial reinforcement schedules
   (b) complex schedules
   (c) interval schedules
   (d) fixed-time schedules
8. The shape of the response pattern generated by a FI is called a
   (a) scallop
   (b) ogive
   (c) break and pause
   (d) accelerating dynamic
9. Human performance on FI varies from animal data due to
   (a) intelligence differences
   (b) self-instruction
   (c) contingency effects
   (d) alternate strategies

10. Behavior is said to be in transition when it is between
    (a) a rock and a hard place
    (b) stable states
    (c) one schedule and another
    (d) a response run

Answers to brief quiz (*page*): c (118); b(126); d(123); a(128); b(130); d(131); c(129 Fig. 5.3); a(133); b(136); b(144)

CHAPTER 6
Aversive Control of Behavior

IN THIS CHAPTER

1. Discover the difference between positive and negative punishment.
2. Find out about negative reinforcement as the basis of escape and avoidance.
3. Learn about reduction in shock frequency as a determinant of avoidance.
4. Investigate the phenomenon of learned helplessness induced by inescapable electric shock.
5. Inquire about the difference between respondent and operant aggression.
6. Learn about the use of coercion in our society and its negative side effects.

Aversive stimuli are those events that organisms evade, avoid, or escape from. Stings, attacks, foul odors, bright light, and very loud noises are examples of events that organisms are prepared to evade on the basis of phylogeny. Escaping or avoiding these **primary aversive stimuli** had survival value, presumably because those animals that emitted this behavior survived and reproduced. In other words, organisms do not learn that these stimuli are aversive; they are biologically prepared to avoid or escape such events.

Other stimuli become aversive because they are associated with primary aversive events during an animal's lifetime. For people, **conditioned aversive stimuli** (S^{ave}) include threats, public criticism, a failing grade, a frown, and verbal disapproval. To affect behavior, these events usually depend on a history of punishment. A 1-week-old infant is not affected by a reprimand such as "Don't do that!" However, by the time the child is 2 years old, the command may stop the toddler from tearing pages out of your favorite book. Animals also learn responses to conditioned stimuli as aversive events. People commonly shout "No!" when pets misbehave, and this auditory stimulus eventually reduces the probability of the response it follows (e.g., chewing on your new chair). A wolf may snap at a yellow-jacket wasp, but following a sting or two the animal will avoid yellow-and-black striped insects.

There are good reasons for not using aversive contingencies in the regulation of behavior, and these reasons are discussed later in this chapter. Nonetheless, a large amount of human (and animal) behavior is regulated by contingent aversive stimuli, and for this reason the analysis is necessary. Azrin and Holz (1966), pioneers in the analysis of punishment, stated:

> We have seen that several methods other than punishment are available for eliminating behavior. For whatever the reasons, we may wish to use methods other than punishment. To what extent is this objective practicable? At the institutional level, it would seem to be quite possible to eliminate the use of physical punishment. Conceivably, administrative regulations could be altered such that public punishment in the form of flogging, spankings, or other physical abuse would be excluded. At the level of individual behavior, it seems somewhat more difficult but still not impossible to eliminate the use of physical punishment. *One type of punishment, however, seems to be virtually impossible to eliminate, and that is the punishing contingencies that are arranged by the physical world.* Whenever we interact with the physical world, there are many punishing contingencies awaiting us. A good example of this would be any behavior that moves

us through space such as walking, running, or reaching. It is only necessary to shut one's eyes while running to realize the extent to which punishing contingencies surround our movement. The degree to which these punishing contingencies are actually applied can be seen in the initial efforts of the young child in learning to walk and to run. So powerful are these potential punishing contingencies that they exist even when we sleep. The response of rolling off a bed is punished immediately and severely by collision with the floor below. Elimination of punishing contingencies by the physical world would appear to require elimination of all behavior that involves interaction with the physical world. (p. 438, emphasis added)

This passage makes it clear that, at least in the physical world, punishment is a fact of life. In fact, Sidman (2001) points out that we use coercion almost exclusively to control each other's behavior, yet we do precious little research on it and on how to best minimize untoward side effects.

Contingencies of Punishment

When a behavioral contingency results in a *decrease* in rate of response, the contingency is called **punishment**. Any event or stimulus that decreases the rate of operant behavior is called a **punisher**. Figure 6.1 makes it clear that it is the relationship between the consequence and its effects on behavior that defines the contingency. At this point, we discuss contingencies of punishment; negative reinforcement is addressed later in this chapter.

Positive Punishment

Positive punishment occurs when a stimulus is *presented* following an operant and the operant decreases in rate of response. The contingency, positive punishment, is shown in cell 2 of Fig. 6.1. When a parent spanks a child for running into the street and the child stops doing it, this is positive punishment (see Gershoff, 2002, on corporal punishment by parents; also, Park, 2002, on the difficulty of isolating the effects of parental punishment from a "package" of disciplinary tactics). Of course, spanking is a punishing consequence, only if it decreases the probability of running into the street. This is an important point, because in usual language people talk about punishment without considering its effects on behavior. For example, you may shout and argue with another person when he or she expresses a particular political position. Your shouting is positive punishment, only if the other individual stops (or decreases) talking about politics. In fact, the person may increase his or her rate of political conversation (as often happens in arguments). In this case, you have by definition reinforced rather than punished the person for arguing with you. Thus,

Stimulus Following Behavior	Effect on Behavior	
	Increase	Decrease
On/Presented		2 Positive Punishment
Off/Removed	3 Negative Reinforcement	4 Negative Punishment

FIG. 6.1. *Aversive contingencies of reinforcement and punishment (adapted from Fig. 4.2 in chap. 4). When a stimulus or event follows operant behavior, then the behavior increases or decreases in frequency. It is this relationship between behavior and consequence that defines the contingency.*

positive punishment is defined as a decline in operant behavior because of the presentation of a stimulus that follows it. By definition, punishment always works.

Negative Punishment

Negative punishment is portrayed in cell 4 of Fig. 6.1. When a stimulus is *removed* contingent on a response and this removal results in a decrease in rate of behavior, the contingency is called **negative punishment** (or omission). In other words, if the organism responds, the stimulus is taken away and behavior decreases. A hungry bird is given continuous access to food, but if it pecks the key, food is removed. A child is watching TV, but if the child runs around, the TV is turned off. In these cases, positive reinforcement (i.e., provision of food, or the TV is turned on) is removed contingent on behavior and the behavior decreases.

   Negative punishment is often confused with extinction. *Extinction occurs when a previously reinforced response no longer produces reinforcement.* In this case, a response has produced reinforcement; extinction for that response is in effect when the response → reinforcer contingency is discontinued. A pigeon may peck a key for food, but when extinction is programmed, pecking no longer produces the food reinforcer. Similarly, a child may be allowed to watch a favorite television show after completing homework assignments. When the TV is broken, the contingency is no longer in effect, and doing homework is on extinction.

   In Figure 6.2, ongoing reinforcement could be eating a meal with the family, and responses $R_2 \ldots R_N$ may involve talking to a sister, passing food around the table, turning on a compact disk player, and so on. Licking your plate is represented by R_1 and results in your father telling you to leave the table for a period of time (negative punishment). Forcing you to leave your supper reduces your tendency to engage in this nasty habit when you next have a meal with your family. (In applied behavior analysis this procedure is called time out.)

Relativity of Punishment and the Premack Principle

In chapter 4, we discussed the principle of reinforcement and the Premack (1959, 1962) principle. The principle states that the opportunity to engage in a higher frequency behavior will reinforce a lower frequency response. That is, *reinforcement is relative, not absolute.* Premack (1971) extended this principle to punishment. Consider a rat that can run in an activity wheel and drink water from a tube. The wheel apparatus is modified so that a break can be activated, locking the wheel and preventing the rat from running. In addition, a motor is installed that permits the wheel to rotate at a set speed, forcing the rat to run.
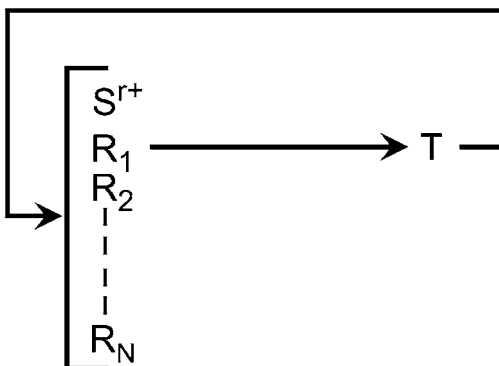
FIG. 6.2. *Negative punishment occurs when operant responses R_2 through R_N do not affect ongoing reinforcement (S^{r+}). If the response R_1 is emitted, however, reinforcement is removed for some period of time (T). After that time period has passed, reinforcement is reinstated.*

In this modified apparatus, withholding running while giving free access to water makes running the higher frequency behavior. On the other hand, depriving the rat of water while giving it access to running makes drinking the more probable behavior.

At this point, forced running (motorized wheel) is made the consequence of drinking. That is, the rat's drinking is followed by bouts of forced running. What do you think happens? The answer is that it depends on the relative frequency of running and drinking. When running is more probable than drinking (deprivation for running), bouts of forced running reinforce drinking (drinking increases). In contrast, when running is less probable than drinking (deprivation for water), bouts of forced running punish drinking (drinking decreases).

Notice that the same consequence (forced bouts of running) can function as either reinforcement or punishment for behavior, depending on the relative frequencies of the respective behaviors. More generally, Premack's analysis indicates that, like reinforcement, *punishment is relative, not absolute*. Even electric shock, usually viewed as an aversive stimulus or punisher, can function as reinforcement under appropriate conditions (e.g., when a fixed-interval schedule of shock is superimposed on a schedule of food reinforcement for lever pressing).

How To Make Punishment Most Effective

It is important to note that punishment neither teaches nor conditions new behavior. Contingencies of punishment eliminate or, more often, temporarily suppress the rate of operant behavior. In this section, we describe some of the conditions that increase the effectiveness of contingencies of punishment.

Experimental investigations of punishment are important. In the everyday world of people (and other animals), many consequences of behavior involve punishment. Parents scold and spank children, people fall off bicycles, individuals are forced to pay fines, and school kids are made to stand in a corner. All modern cultures use legal sanctions to control their citizens' conduct, and these contingencies are usually punitive. Experiments on punishment have shown how to make punishment most effective. Other research has suggested strong reasons for avoiding the use of punishment whenever possible (Sidman, 2001).

The study of punishment is complicated by the fact that punished responses are typically maintained on some schedule of reinforcement. In other words, a schedule of punishment is superimposed on a baseline schedule of positive reinforcement. This means that we are really investigating the effects of punishment on behavior maintained by some schedule of positive reinforcement, and results may reflect both of these variables. Nonetheless, there are reasonably clear findings that suggest how to make punishment most effective.

Abrupt Introduction of Punishment

Azrin, Holz, and Hake (1963) found that birds would continue to respond even when intense levels of electric shock (130 V) were delivered for key pecks. This effect occurred when the punisher was introduced at 60 V or less and gradually increased. On the other hand, animals that suddenly received moderate-intensity shocks, at 80 V, completely quit responding (see also Azrin, 1959; Miller, 1960). Importantly, the key-pecking behavior of the birds given sudden shock was irreversibly suppressed—they never pecked the key again.

Consider the following scenario: Mike has bought a new stereo system, and his friend Joe and Joe's 2-year-old daughter drop in for a visit. The child is eating a glob of peanut butter and makes a beeline for the new equipment. Nervously, Mike looks at his friend, who

says, "Emily, don't touch—that's Mike's new disk player." The child continues to fondle the knobs on Mike's $900 music system, and Joe says, "Please leave that alone!" Emily is still smearing peanut butter on Mike's investment, so Joe glowers at his child and loudly says, "I said stop that!" Emily does not stop and is now threatened with, "If you don't stop, Dad will give you a spanking!" Emily still plays with the stereo. In desperation, Joe gives Emily a light tap on the bottom, which she ignores. In this circumstance, presumed punishers are introduced at low intensity and gradually increased. Laboratory research suggests that this is a formula for creating a masochist. Of course, the best solution for the stereo problem would be to either wipe the child's hands off or place the equipment out of reach.

Intensity of Punishment

The preceding discussion should make it clear that if punishment is going to be used, it should be introduced at a moderate intensity on the first occasion. Generally, the higher the intensity of the punisher, the greater the response suppression. Low-intensity positive punishment may leave behavior relatively unaffected, whereas severe values of the punisher may permanently change behavior (Appel & Peterson, 1965; Azrin, 1960). Several experiments have shown that intense punishment can completely eliminate responding (Appel, 1961; Storms, Boroczi, & Broen, 1962). One interesting implication is that once complete suppression of responding occurs, behavior is unlikely to recover for some time when the punishment contingency is withdrawn. This is because the organism stops responding and the absence of the contingency is not contacted.

If organisms do respond after punishment is withdrawn, behavior eventually recovers to prepunishment levels. For this reason, Skinner (1953) and others have suggested that punishment only produces a temporary suppression of behavior:

> Recently, the suspicion has . . . arisen that punishment does not in fact do what it is supposed to do. An immediate effect in reducing a tendency to behave is clear enough, but this may be misleading. The reduction in strength may not be permanent. (p. 183)

This passage reflects Skinner's lifelong objection to the use of punishment for behavior regulation.

Nonetheless, research shows that high-intensity positive punishment can permanently eliminate responding. This elimination of responses does not seem to be affected by time away from the experimental situation (Azrin, 1959, 1960). For example, Masserman (1946) placed cats in a situation in which they had been punished 20 months earlier. The animals did not emit the punished response, even though the punishment contingency was discontinued. Thus, high-intensity punishment can reduce rate of response to absolute zero, and this appears to be an enduring effect.

Immediacy of Punishment

Punishment is most effective at reducing responses when it closely follows behavior (Azrin, 1956; Cohen, 1968). This effect can be missed easily, because punishment generates emotional behavior that may disrupt operant responses. In other words, when first introduced, *positive punishment elicits reflexive behavior that prevents the occurrence of operant behavior*. Watch a child (or adult) who has just been chastised severely. You will probably see the person sit quietly, possibly cry, look away from others, and so on. In common language, we may say that the child is pouting, but in fact, what is happening is that reflexive emotional behavior is disrupting all operant responses. If the child was punished immediately for making rude noises (the target behavior), those noises and many other operants

would decrease in frequency. However, in the long run, making noises would be relatively unaffected if punishment did not closely follow that response.

Estes (1944) punished some rats immediately after they made a response, whereas another group received *delayed* punishment. Both groups of animals showed a similar reduction in bar pressing. This finding was replicated 11 years later by Hunt and Brady (1955) and suggests that positive punishment reduces operant responses because it elicits competing respondent behavior. Later research by Azrin (1956) found that after the first hour of exposure to positive punishment, immediate versus delayed punishment makes a large difference. Responses that were punished after a time delay recovered substantially, but when the punisher was delivered immediately, responses were often completely eliminated. Thus, it appears that the introduction of punishment generates reflexive responses that may at first disrupt operant behavior. However, the contingency is eventually contacted and, in the long run, makes a large difference. To make punishment most effective, it should be delivered immediately after the response.

Schedule of Punishment

In general, positive punishment is most effective when it is delivered continuously for each response (Zimmerman & Ferster, 1963) rather than intermittently (Filby & Appel, 1966). Azrin, Holz, and Hake (1963) trained pigeons to peck a key on a VI 3-min schedule of food reinforcement. Once responding was stable, they shocked the bird when it pecked the key. Shocks were presented after 100, 200, 300, 500, or 1,000 key pecks. Rate of response substantially declined even when punishment was delivered after 1,000 responses. As rate of punishment increased, the number of responses per hour declined. In other words, as more and more responses were punished, operant rate decreased. Continuous punishment (FR 1) produced the greatest response suppression. This effect is similar to increasing the intensity of the punisher—to maximize suppression of responses, deliver the punisher as frequently as possible and increase its intensity.

Rate of response patterns on various schedules of punishment (FR, FI, VI, and VR) are usually *opposite* to the patterns produced on similar schedules of positive reinforcement. For example, a FI schedule of punishment when superimposed on a VI schedule of reinforcement for key pecking by pigeons produces an *inverse scallop*. (Recall that FI reinforcement often yields a scalloping pattern.) That is, the occurrence of each punisher is followed by an immediately high rate of pecking that gradually declines as the time to the next punishment approaches (Azrin, 1956).

FOCUS ON ISSUES: USE OF PUNISHMENT IN TREATMENT

There are behaviorally deficient and psychotic people who, for a variety of reasons, engage in self-destructive behavior. This behavior may escalate to the point at which the person is hitting, scratching, biting, or gouging himself or herself most of the day. In some cases, self-destructive acts are so frequent and intense that the person is hospitalized. Occasionally physical injury is irreversible, as when a child bangs his or her head on a wall until brain damage occurs. Although positive reinforcement programs have been used to alleviate severe behavior problems, these contingencies are not always successful. Because of this, behavior therapists have resorted to punishment as a way of reducing self-destructive behavior.

One seemingly benign type of punishment used to suppress self-injurious behavior is water misting (Osborne, 2002). The literature indicates that contingent misting in the face reduces self-injurious behavior from 30 to 90%, depending upon alternative sources of reinforcement. However, the use of water misting as an effective—if not completely effective—punishment procedure has not been formally used for several years.

Misting and other techniques of positive punishment have been controversial (Feldman, 1990). Opponents of punishment argue that such procedures are morally wrong, and they advocate a total ban on its use (e.g., Guess, Helmstetter, Turnbull, & Knowlton, 1986; Sobsey, 1990). These researchers also suggest that punishment is not necessary, because many positive methods are available to treat severe behavior problems. They further propose that positive techniques are as effective as punishment for eliminating self-destructive responses. On the other side of the issue are therapists and parents of self-abusive children who advocate the individual's right to effective treatment (e.g., Matson & Taras, 1989; Van Houten et al., 1988). The proponents of effective treatment claim that a combination of positive reinforcement and punishment is the best way to manage severely self-injurious behavior.

One reason given for not using punishment in applied settings is that aversive techniques may generate emotional distress and aggression (LaVigna & Donnellan, 1986; Lohrman-O'Rourke, & Zirkel, 1998; Meyer & Evans, 1989). Opponents of positive punishment often support this view by pointing to research with animals concerning electric shock and pain-elicited aggression (see the section Side Effects of Aversive Procedures later in this chapter). Essentially, when animals are given noncontingent electric shock, they attack other animals or inanimate objects. A broader, but similar, position has been advanced by Murray Sidman (2001) in his book, *Coercion and Its Fallout*. Sidman argues that violence within and between nations is the product of coercive contingencies (punishment and negative reinforcement). In a treatment setting, these side effects imply that coercive therapy may produce as many problems as it alleviates. (nonetheless, Kushner, 1970, presents a review of the effective and justified use of electric shock with humans in a clinical context).

Solomon (1969) recognized that there must be certain conditions that lead to the side effects of punishment—under specified conditions punishment may have devastating effects, under other conditions punishment may not. Solomon (1969) stated:

> When punishments are asserted to be ineffective controllers of [operant] behavior, they are in contrast, often asserted to be devastating controllers of emotional reactions, leading to neurotic and psychotic symptoms, and to general pessimism, depressiveness, constriction of thinking, horrible psychosomatic diseases, and even death! This is somewhat of a paradox, I think. The convincing part of such generalizations is only their face validity. There are experiments, many of them carefully done, in which these neurotic outcomes were clearly observed. . . . The side effects are frightening, indeed, and should not be ignored! But there *must be* some rules, some principles, governing the appearance of such side effects, for they *do not* appear in all experiments involving the use of strong punishment or the elicitation of terror. (p. 89)

Solomon clearly believes that an in-depth scientific analysis of punishment will solve the value question of whether to use punishment in a given situation. Although we agree with Solomon's hopes, current research on punishment is not sufficient to answer value questions. That is, research evidence suggests that complex interactions may occur between the reinforcement schedule maintaining behavior and punishment (Epling & Pierce, 1990; Linscheid & Meinhold, 1990). Most of these interactions, however, have not been sufficiently studied and replicated to draw any firm conclusions.

One reason for the lack of modern research is that many people think that it is not right to expose animals to coercive procedures. On the basis of animal ethics, investigations of

punishment have almost been eliminated at the basic level. Until our society finds it more important to understand punishment, questions about the coercive control of behavior cannot be well informed by scientific analysis.

Motivation for the Response

Punishment is most effective when the motivation to respond is reduced (Dinsmoor, 1952). Azrin, Holz, and Hake (1963) trained pigeons to peck a key on a VI 3-min schedule of food reinforcement. After responding was stable, they introduced an intense 160-V shock for every 100th response. Birds were exposed to the schedule of reinforcement plus punishment at several levels of food deprivation. Recall that deprivation for food is an *establishing operation* that should increase pecking the key for food (and increase the reinforcement effectiveness of food). The animals were punished for responding at 60, 65, 70, 75, and 85% of free-feeding body weight. At 85% weight, punishment virtually stopped the birds' responding. However, at 60% weight, the pigeons maintained a high, stable rate of response. As shown in Fig. 6.3, rate of response was ordered by level of deprivation—the less the deprivation for food, the more effective punishment was. Thus, behavior that is punished may be completely suppressed when the motivation to respond is low. Interestingly, there is evidence that once complete suppression has occurred, the behavior does not recover even when motivation is increased (Masserman, 1946; Storms et al., 1962). For example, a rat may be punished when it responds for food and its behavior is completely eliminated. Next, the level of food deprivation is increased but responding remains at zero rate.

These findings may have practical implications. Punishment is sometimes used to reduce the frequency of human behavior. (See the preceding Focus on Issues.) As we have said, there are side effects of punitive regulation, suggesting that these techniques should be used with caution. Nonetheless, there are circumstances in which punishment may be a reasonable option for changing behavior. When people behave in ways that hurt themselves or others, punishment can be used to quickly suppress these operants. In the preceding discussion, we described children who severely hurt themselves by banging their heads, hitting themselves, chewing on their flesh, and so on. In some of these cases, positive punishment can be used to rapidly reduce self-injurious behavior.
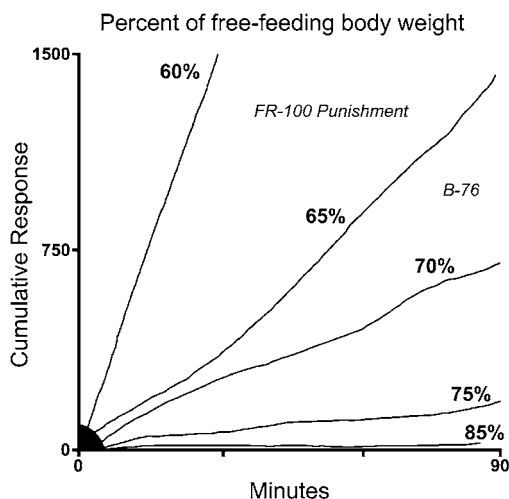
FIG. 6.3. *Level of food deprivation and punished responding maintained by a VI food reinforcement schedule. Adapted from "Fixed-Ratio Punishment" by N. H. Azrin, W. C. Holtz, and D. Hake, 1963,* Journal of the Experimental Analysis of Behavior, 6, *pp. 141–148.*

Some self-injurious behavior may be maintained by unintentional contingent attention from caretakers. Lovaas and Simmons (1969) treated three severely self-destructive children who were placed on extinction (adult attention was withdrawn) for hitting themselves. During extinction, one child (John) hit himself 9,000 times before stopping. The other child who was treated with extinction demonstrated similar behavior, emitting many self-injurious responses before extinction was complete. Lovaas and Simmons (1969) commented that:

> this procedure of withdrawing or making potential reinforcers unavailable has an undesirable attribute, in that it is not immediately effective and temporarily exposes the child to the danger of severe damage from his own self-destruction, which is particularly intense during the early stages of the extinction run. In some cases of severe self-destruction, it is ill-advised to place the child on extinction. Marilyn, . . . for example, could have inflicted serious self-injury or possibly even killed herself during an extinction run. (p. 155)

In contrast, when positive punishment was made contingent on this behavior, all three children hit themselves a few times and then quit. In cases like these, punishment seems warranted, but the animal research suggests a humane modification of the basic procedure.

The children treated by Lovaas and Simmons (1969) were apparently engaging in self-injurious behavior because of contingent social attention from adult caretakers. The motivation for attention might be reduced by having adults provide lots of noncontingent attention to a child before using a punishment procedure. This would be easy to implement: simply have staff hold, cuddle, and talk to the child for a few days before punishment is used to stop self-injurious responses. Once this is done, even mild punishment may eliminate the responses. Interestingly, the basic research also suggests that when motivation increases again, responding will not recover.

Response Alternatives

A straightforward way to make punishment more effective is to give a person or animal another way to obtain the same reinforcers that support target responses. Providing a response alternative is another way that moderate levels of punishment can be used effectively to suppress behavior. To use this procedure, it is essential to identify the consequences that are maintaining the behavior that is to be punished. After this is accomplished, motivation may be reduced, or the organism can be given another response opportunity to get the same reinforcer. Herman and Azrin (1964) had people lever press on a VI schedule of reinforcement. These individuals were punished with an annoying buzzing sound for each response, and this procedure slightly reduced their rate of response. When people were given another response opportunity that did not produce the buzzer, they quickly changed to that alternative, and punished responses were eliminated (see also Azrin & Holz, 1966, p. 405).

Pretend that there is a convenience store in the middle of the block directly behind your house. You often walk to the store, but if you turn left to go around the block you pass a chained pit bulldog that lunges and growls at you. On the other hand, if you turn right you do not pass the dog. It's obvious that most of us will choose the unpunished route to the store. If, however, turning right leads to a path that does not get you to the store, you may continue walking past the dog. In reality, of course, you could walk on the other side of the street or drive to the store—these are also unpunished alternative responses.

Contingencies of Negative Reinforcement

When an organism emits an alternative unpunished response, this may be viewed as escape or avoidance. If the response is made in the presence of the punishing stimulus, it is an **escape** response. The pit bulldog growls at you, and you cross to the other side of the street. When the operant prevents the punishing stimulus, it is an **avoidance** response. You turn right to go around the block and do not walk by the dog. In both cases, the removal, or prevention of an event, strengthens operant behavior. A contingency of negative reinforcement is presented in cell 3 of Fig. 6.1. **Negative reinforcement** occurs when an operant results in the removal (or prevention) of a stimulus and the operant increases in rate. Any event or stimulus that increases operant rate by its removal (or prevention) is called a **negative reinforcer**. Notice that the same event, delivery of electric shock, is a punisher in a punishment procedure and a negative reinforcer in a negative reinforcement procedure. When neither punishment nor negative reinforcement are well defined, we refer to the event as an aversive stimulus. In everyday life, the distinction between negative and positive reinforcement is occasionally uncertain (Michael, 1975). For example, do you open a window on a hot day to get a cool breeze or to escape the heat? Putting on glasses not only clarifies vision but also removes a blurry view of the world. Hineline (1984) has made a similar point:

> The addition of one event is the removal of another, and vice versa: Adding heat is removing cold; adding food is decreasing deprivation; adding a smile removes a frown. However, there is a fundamental asymmetry, for if a stimulus or situation is to be reducible or removable by some response, that response must occur in its presence. In contrast, positively reinforced responses necessarily occur in the absence of the stimuli upon which reinforcement is based. (pp. 496–497)

This difference between positive and negative reinforcement is reasonably easy to arrange in an operant laboratory, and experimental investigations of negative reinforcement are relatively clear cut (Khalili, Daley, & Cheney, 1969). When a response results in the removal or postponement of a stimulus and rate of response increases, negative reinforcement has occurred (see also Catania, 1973).

The distinction between escape and avoidance is somewhat artificial. Consider an experiment on escape, in which an animal makes a response that turns off a continuous electric shock. Hineline (1977) has suggested that in experiments like this:

> electric shock continuously delivered may not be continuously received. For example, if it is grid shock the animal may produce intermittency by jumping up and down. Nevertheless the escape procedure is treated as a clear case of negative reinforcement by removal of shock. The experimenter may even arrange an escape procedure by explicitly presenting intermittent pulses of shock several times per second, rather than presenting it continuously. But if shock is presented several times per second, why not just twice per second, or once per second, or even less frequently? At some point we tend to stop labeling it continuous shock, and call it a stream of shocks. Responses are reinforced by interruption of (escape from) a stream of shocks. But as the pulses of shocks are spaced out still further, to one every five, ten, or twenty seconds, we tend to characterize suspension of this situation not as removal of shock . . . but as reduction in shock frequency [avoidance]. (p. 369)

To make this clear, when an animal presses a lever to turn off a stream of shocks that are occurring every 0.2 s, we call this escape. If, however, the same animal makes a response that interrupts shocks that are scheduled every 20 s, then shocks are postponed and the procedure is usually called avoidance.
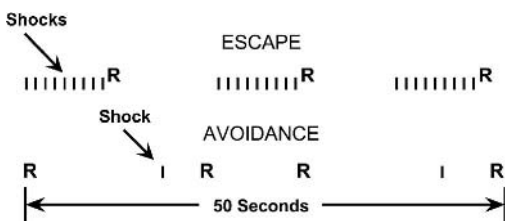
FIG. 6.4. *In the escape contingency, shocks (indicated by the vertical line) are scheduled once every second, and a response (R) delays the aversive stimulus for 10 s. The amount of time that a response delays shock onset is called the response–shock interval. During avoidance, shocks occur once every 10 s, and a response produces a 10-s delay. Notice that the only difference in the two procedures is the time between shock deliveries, called the shock–shock interval.*

The only difference between escape and avoidance, presented in Fig. 6.4, is the time between shocks, or the **shock–shock interval (S–S)**. In both procedures, time away from shock produced by responses, or the **response–shock interval (R–S)**, is 10 s. Thus, *escape and avoidance may represent endpoints on a continuum of negative reinforcement.* For this reason, escape and avoidance may be analyzed as behavior regulated by the same processes.

In this chapter, we make the traditional distinction between escape and avoidance. In avoidance, an organism evades some event; in escape, it removes the stimulus (or itself) from the situation. A person may escape a boring party by leaving it, or the party may be avoided by never going to it. In both cases, behavior is regulated by principles of negative reinforcement.

Escape

In escape learning, an operant response changes the situation from one in which a negative reinforcer is present to one in which it is absent, for some period of time. A pigeon could be exposed to continuous loud white noise, and when the bird pecks a key the noise is turned off. If pecking the key increases, then this defines the procedure as negative reinforcement. A person hangs up the telephone to cut off an obscene caller. Children may run home after school because a bully picked on them. A dog will readily jump across a barrier (leave the situation) to escape electric shock. Figure 6.5 is a diagram of a shuttle-box apparatus that is used to train escape responses in dogs. The figure also shows the notation for an escape contingency. Notice that there are many responses that may be emitted, but only R_1 removes the negative reinforcer.

In general, organisms acquire escape responses more readily than avoidance responses. This is easy to understand: Escape and avoidance behavior is strengthened by the removal or prevention of the aversive stimulus. In escape (but not avoidance), there is an *immediate change* from the presence of the negative reinforcer to its absence.

Another factor that affects how quickly an escape response is acquired is its compatibility with behavior elicited by the negative reinforcer. Evolution has ensured that organisms respond to many punishers, negative reinforcers, and aversive stimuli reflexively. In the everyday world, animals may only get one chance to save their lives in the presence of an aversive event. Running like crazy makes good sense (in many cases) when a predator appears. Those animals that "ponder over" the situation are likely to contribute calories to the predator, but not genes to the next generation. For this reason, species-specific stereotyped
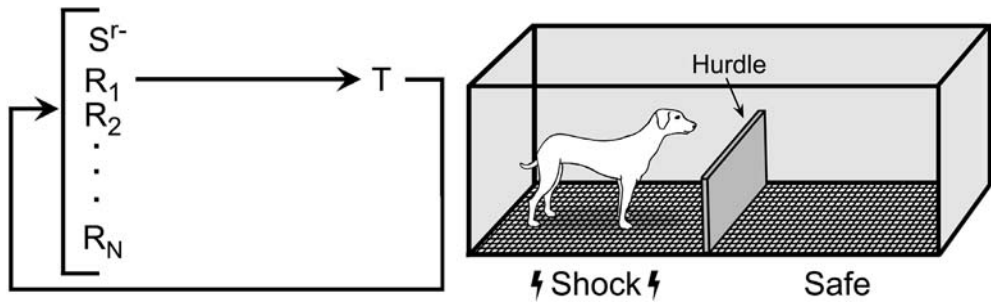
FIG. 6.5.   *(Left) An escape contingency: In the presence of a negative reinforcer (S^{r-}), an operant (R) produces a period of time (T) in which the aversive stimulus is absent. The increase in the operant is the process of negative reinforcement. (Right) A shuttle box that may be used to condition escape responses in dogs. The animal is placed in the left compartment at the start of a trial. Electric shock is turned on, and the dog can escape the aversive stimulus by jumping the hurdle and going to the safe area, on the right side of the box.*

responses often are elicited by aversive stimuli that function as negative reinforcers. For example, rats will typically run, freeze, or fight when they are shocked.

Conditioning lever pressing as an escape response is often difficult. When rats are presented with intense electric shock, they typically freeze. Depressing and then releasing a lever is not compatible with this species-typical response to shock. If the animal is simply required to press the lever and hold it down, the escape response is more readily acquired, because holding the lever down is compatible with freezing. In other words, negative reinforcement frequently elicits reflexive behavior that interferes with the acquisition of operant behavior supported by the removal of some event or stimulus. Khalili and Cheney (1969), however, developed a program of shock-off titration that reduces interference by reflexive behavior. With this procedure, they trained rats to lever press for shock removal on fixed-ratio (FR) schedules as high as 80 responses.

As stated earlier, holding a lever down is an escape response that is usually not difficult to condition. In general, training escape is easier when the *operant is similar to reflexive behavior* elicited by the aversive stimulus. A rat can be readily trained to run on a wheel to escape electric shocks, but conditioning the animal to stand up is much more difficult (Bolles, 1970). This occurs because running is a species-typical response to electric shock, but standing is not. Although respondent and operant conditioning interact in escape training, once behavior is established it comes under the control of the operant contingency. For example, if rats are trained to run on a wheel (or hold down a bar) to escape shock, they will stop running (or bar holding) if this response does not terminate the negative reinforcer.

Avoidance

When an operant prevents the occurrence of an aversive stimulus, the contingency is called avoidance. You typically walk the shortest distance to the university, but recently an acquaintance has joined you, at the halfway mark, and blabbed on and on about boring topics. Now you walk a longer distance than needed to the university because that path does not take you by the boring person's house. During their annual migration, young wildebeests stop to drink at a river infested with large crocodiles. The crocodiles wait each year for this gourmet lunch and "pig out" on rare wildebeest. Survivors of the crocodile picnic choose a different watering spot the next year.
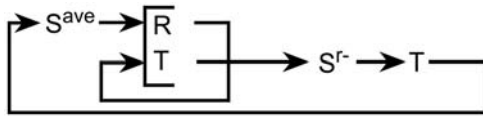
FIG. 6.6. *Discriminated avoidance occurs when a warning stimulus (S^{ave}) leads to a condition in which, after some time (T), a negative reinforcer (S^{r-}) is presented. If a response (R) is made, the negative reinforcer is delayed, and further responses continue to prevent the onset of the aversive stimulus. Once the negative reinforcer is presented, some amount of time passes, and the warning stimulus again comes on.*

Discriminated Avoidance

Avoidance may involve responding when a warning signal precedes an aversive stimulus. Because the organism only responds when the warning signal occurs, the procedure is called **discriminated avoidance**. A parent may say to a child, "Nathan, keep the noise down or else you will have to go to bed." An antelope may smell a lion and change the direction it is traveling. In these cases, the child is told what not to do and the antelope detects what direction to avoid. Pretend that you are all set to go to a party but are told that Dr. Hannibal Sloat will be attending. Dr. Sloat is an unusually obnoxious professor, and you have just flunked his human sexuality class. In this case, the warning that he will be at the bash may result in you avoiding the party. Figure 6.6 is a diagram of discriminated avoidance in an experimental situation. In the presence of a warning stimulus (S^{ave}), a response postpones for some time, T, the onset of a negative reinforcer (S^{r-}). If the response does not occur, the negative reinforcer is presented, and after some time, the warning stimulus comes on again.

In the operant laboratory, discriminated avoidance is typically acquired only after many hours of training. Rats will quickly learn to lever press for food but take a surprisingly long time to acquire lever pressing in order to avoid electric shock (Solomon & Brush, 1956). Pigeons are also slow at acquiring avoidance behavior when they are required to peck a key to avoid an aversive event. A major reason for this is that in the discriminated avoidance procedure, the warning stimulus (S^{ave}) is also a CS that elicits respondent behavior (like freezing) that interferes with operant behavior (Meyer, Cho, & Wesemann, 1960). As stated in the section on escape conditioning, other responses like running and jumping are elicited by shock and are acquired much more readily than bar pressing. For example, Macphail (1968) found that pigeons required 120 trials to learn to avoid shock by running down a straight alley. Rats require only 2 or 3 trials to learn to jump onto a platform (Baum, 1965, 1969).

In an interesting series of experiments, Modaresi (1990) found that lever pressing in rats, as an avoidance response, was acquired more readily (a) if the lever was high on the wall and (b) lever pressing not only avoided the shocks but also resulted in access to a platform to stand on. Additional experiments showed that these two aspects were in accord with the rats' species-specific behavior to the shock stimulus. That is, rats naturally stretch upward and seek a safe area when faced with painful aversive stimuli. Thus, to produce rapid acquisition of avoidance responses, choose behavior that is naturally elicited by the negative reinforcer.

Nondiscriminated Avoidance

In the laboratory, a rat may press a lever to avoid the delivery of an electric shock. Shocks are scheduled every 60 s, and each lever press prevents the shock and starts another
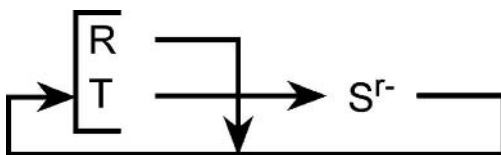
FIG. 6.7. *A Mechner diagram of nondiscriminated avoidance. A response (R) produces some time (T) in which negative reinforcers (S^{r-}) are not presented.*

1-min cycle (a postponement schedule of negative reinforcement). The shocks are simply programmed to occur on the basis of time, and there is *no warning signal* that they are about to be presented. When there are no warning stimuli present, the contingency is called **nondiscriminated avoidance**. There are people who compulsively wash their hands to get rid of unseen germs. In this case, hand washing is the operant, and the supposed absence of germs negatively reinforces the behavior. As demonstrated in later chapters, negative reinforcement appears to underlie many so-called abnormal behavior patterns. Figure 6.7 illustrates simple nondiscriminated avoidance in which the aversive event is presented without a warning signal.

This book was written on a computer, and an unexpected power failure can result in many hours of lost work. To prevent this aversive event, authors regularly emit the avoidance behavior of *hitting the save key*. This response saves the text to a disk or hard drive and is maintained because it prevents computer crashes from costing the author a day's work.

Murray Sidman (1953) was the first to investigate nondiscriminated avoidance, and the procedure is often called **Sidman avoidance** or free operant avoidance. Periodic shocks were given to a rat, unless the animal emitted an operant response. The time between shocks was (and still is) called the *shock–shock* (S–S) interval. When a response occurred, it delayed the onset of shock for some specified period of time called the *response–shock* (R–S) interval (see Fig. 6.4). Avoidance responding is more quickly acquired when the R–S interval is longer than the S–S interval (Leaf, 1965; Sidman, 1962). In other words, when the operant delays the negative reinforcer (R–S) for a period that exceeds the time between scheduled shocks (S–S), conditioning is enhanced (see Baron, 1991, p. 191).

FOCUS ON RESEARCH: AN ANALYSIS OF AVOIDANCE BEHAVIOR

Pretend that you live in a world in which evil professors have absolute authority over students. One day you walk into class and your professor says, "Class, from today until the end of term you are subjects in a shocking experiment." You notice the straps attached to your desk and the two large electrodes embedded in your chair. Although you protest vigorously, the teaching assistant straps you to the chair and says, "Press the button on your desk, if you want to." You look at the button and wish you had taken another course. A powerful (but your professor says harmless) electric shock is delivered every 20 s (S–S = 20 s). In desperation, you press your button and notice that the frequency of shock delivery declines (you get fewer shocks). Each press of the button delays shock for 30 s (R–S = 30 s), and after some experience you regularly press your button and avoid most or all of the shocks. Consider, however, what would happen if the S–S interval remained at 20 s but the R–S interval changed to 5 s. Pressing the button would increase the frequency of shocks, unless you maintained a high rate of response. This occurs because a response brings the next shock closer than not responding does (5 s versus 20 s). Animal research suggests that under these conditions avoidance responding is poorly maintained.

Shock Frequency and Avoidance Behavior

In the preceding example, avoidance behavior is weak, because reducing the frequency of aversive stimulation appears to be a major factor maintaining responses (Sidman, 1962). In a classic experiment, Herrnstein and Hineline (1966) exposed 18 rats to a random sequence of electric shocks. The animals could press a lever to reduce the frequency of shocks, but some responses were still followed by the aversive stimulus. That is, bar pressing reduced the number of shocks per second but did not completely eliminate them. Seventeen of the 18 rats in this experiment showed avoidance responding—they reliably pressed the lever.

This finding has generated a debate over the critical factors that regulate avoidance behavior. Essentially, the issue concerns molar versus molecular control of behavior in avoidance. From a **molecular perspective**, the moment-to-moment time between shocks (S–S) and the time from response to shock (R–S) represent the essential variables regulating avoidance responding (Dinsmoor, 1977, 2001a, 2001b). Nonetheless, the bulk of the evidence supports a **molar perspective** (Baum, 2001), suggesting that the molar variable, overall reduction in shock frequency (or sensitivity to rates of shock), can produce and maintain operant avoidance (Gardner & Lewis, 1976; Hineline, 1970; Lewis, Gardner, & Hutton, 1976; Mellitz, Hineline, Whitehouse, & Laurence, 1983).

Consider what happens when another person persistently nags at you to stop watching television and start working on your term paper. You may tell your friend, "Leave me alone, I'll get to it after the movie is over." This will likely reduce the frequency of nagging but not eliminate it. In fact, your reply sometimes may be followed by, "I can't understand how you can just sit there glued to the idiot box, when you have so much to do." Assuming that the nagging is aversive, how can your vocal operant ("leave me alone . . .") be maintained? The answer, of course, is that it has reduced the overall number of nagging episodes while you are engrossed in *Return of the Killer Tomatoes*.

Although reduction in shock frequency can establish and maintain avoidance behavior, Hineline (May, personal communication, 1989) has stated that "rather than trying to establish either the molar or molecular view as correct, the point [is] to discover what determines the scale of process. That is, in what circumstances is behavior sensitive to its more remote consequences, as contrasted with its more immediate ones?" (see also Hineline, 2001, for a more detailed assessment) Dr. Philip Hineline is a professor of psychology at Temple University in Philadelphia. He has been interested in negative reinforcement and the regulation of operant behavior over short- and long-time scales. In his work with Dr. Timothy Hackenberg, he has drawn these two interests together.

Long-Term Effects of Negative Reinforcement

Hackenberg and Hineline (1987) used a conditioned-suppression paradigm to show the interrelations between avoidance and behavior maintained by positive reinforcement. Conditioned suppression is a procedure in which a conditioned aversive stimulus (a tone that has signaled shock) is presented when an animal is responding for food reinforcement. The tone usually suppresses the operant behavior regulated by food. Hackenberg and Hineline (1987) introduced an interesting twist to show that a similar effect could be obtained when a period of avoidance either preceded or followed entire sessions of food reinforcement.

In their experiment, eight rats were trained to press a lever for food on a fixed-interval 3-min schedule (FI 3 min). After response rates were stable on the FI schedule, animals were exposed to 100 min of unsignaled shock avoidance. During this period, shocks occurred every 5 s (shock–shock interval = 5 s) unless the rat pressed a lever that postponed

the shocks for 20 s (response–shock interval = 20 s). These avoidance periods were presented to four rats just before the food reinforcement sessions. The other four animals were given the avoidance period immediately after they responded for food. The question was whether the avoidance periods would suppress responding during food reinforcement sessions.

Results indicated that operant responding for positive reinforcement was disrupted when avoidance periods either preceded or followed the food sessions. This suppression occurred, even though the rats responded at a level that was high enough to obtain most of the available food. This means that the avoidance periods had an effect on responding that was independent of any interference with the schedule of positive reinforcement. When avoidance periods came after food reinforcement sessions, there was more disruption of food-related operants than when avoidance periods preceded fixed-interval responding for food. In addition, when avoidance was discontinued, operant responses for food took longer to recover if the avoidance periods came after positive reinforcement sessions.

In everyday language, it seems that the rats were worried about their appointment with doom (since they had experienced previous appointments). This is not unlike a student who has difficulty studying because he or she is scheduled to have a wisdom tooth extracted a few hours later. People, and apparently rats, respond to long-term aversive consequences in their environment. This disruption of responding is severe when long-term aversive consequences are impending. Immediately delivered aversive events can also suppress operant behavior but, all things being equal, do not appear to affect responses as strongly as long-term aversive consequences. By implication, a child who receives reprimands from a teacher for talking out of turn will show little disruption of play and school work. In contrast, a student who is regularly harassed by a bully after school is over may show general disruption of school activities throughout the day.

Side Effects of Aversive Procedures

There are obvious ethical reasons for not using punishment contingencies to change behavior. In addition to ethical concerns, there are serious side effects that often arise when contingencies of punishment and negative reinforcement are employed. Skinner (1953, 1971) has consistently argued against the use of punishment techniques:

> The commonness technique of control in modern life is punishment. The pattern is familiar: if a man does not behave as you wish, knock him down; if a child misbehaves, spank him; if the people of a country misbehave, bomb them. Legal and police systems are based on such punishments as fines, flogging, incarceration, and hard labor. Religious control is exerted through penances, threats of excommunication, and consignment to hell-fire. Education has not wholly abandoned the birch rod. In everyday personal contact we control through censure, snubbing, disapproval, or banishment. In short, the degree to which we use punishment as a technique of control seems to be limited only by the degree to which we can gain the necessary power. All of this is done with the intention of reducing tendencies to behave in certain ways. Reinforcement builds up these tendencies; punishment is designed to tear them down.
>
>   The technique [punishment] has often been analyzed, and many familiar questions continue to be asked. Must punishment be closely contingent upon the behavior punished? Must the

individual know what he is being punished for? What forms of punishment are most effective and under what circumstances? This concern may be due to the realization that the technique has unfortunate by-products. In the long run, punishment, unlike reinforcement, works to the disadvantage of both the punished organism and the punishing agency. The aversive stimuli which are needed generate emotions, including predispositions to escape or retaliate, and disabling anxieties. For thousands of years men have asked whether the method could not be improved or whether some alternative practice would not be better. (Skinner, 1953, pp. 182–183)

Behavioral Persistence

As previously mentioned, punishment may under some circumstances produce a rapid decline in behavior. Consider that when positive punishment is used, it is almost always in a circumstance in which one person is attempting to reduce the aversive behavior of another. A teacher punishes a child who talks loudly out of turn in class; a wife shouts at her husband for making sexist comments at a party; a boss threatens to fire an employee who is insubordinate. In each of these examples, the responses of the teacher, wife, and boss are negatively reinforced by a reduction in talking out of turn, sexist jokes, and insubordinate comments. For this reason, individuals who effectively use punishment are more likely to use aversive regulation on future occasions. This is an important point: The "successful" use of punishment leads to further use of the technique, which produces the other side effects of aversive control.

Operant–Respondent Interactions and Persistence

Consider a person who has received a painful wasp sting. The sight and buzz of the insect precede the sting and (for some people) become powerful conditioned stimuli (CS) that elicit anxiety. The CS− that is established will likely generalize to similar sights and sounds (i.e., the sight of other flying insects, the buzz of a harmless fly). The CS− also has a dual function: In terms of Pavlovian conditioning, it elicits anxiety; in an operant sense, it functions as a conditioned aversive stimulus (S^{ave}) and will strengthen behavior that removes it (negative reinforcement). To extinguish the effects of the CS−, it must be presented in the absence of the unconditioned stimulus (respondent extinction). In ordinary circumstances, the CS− would rapidly extinguish, since buzzing sounds and flying insects (CS−) are rarely accompanied by pain (US). However, people who are afraid of wasps and bees avoid places in which they may be found and leave locations in which they encounter buzzing sounds and flying insects. That is, *avoidance behavior maintained by operant conditioning prevents respondent extinction.*

One way to place avoidance behavior on extinction is to expose the organism to aversive stimulation while preventing effective escape responses. A rat may be trained to press a lever to turn off electric shock, but during extinction bar presses have no effect. Extinction occurs most rapidly when it is clearly signaled—a buzzer could be turned on during extinction and turned off when responses prevented shock. However, in many everyday settings, escape and avoidance responses are resistant to extinction. This persistence occurs when the difference between the acquisition and the extinction setting is low. (Extinction is not clearly signaled.) When the difference between the extinction setting and the conditions under which the contingency is in effect is slight, extinction is not discriminated and avoidance responding continues. In everyday life, a particular dentist's office smells and looks similar to one in which pain was experienced; flying insects and buzzing sounds were accompanied by a sting; and so on.

The famous psychiatrist who survived the Nazi concentration camps, Bruno Bettelheim, provided a moving account of behavioral persistence and aversive control:

> Often an SS man would for a while enforce some nonsensical rule, originating in a whim of the moment. Usually it was quickly forgotten, but there were always some old prisoners who continued to observe it and tried to enforce it on others long after the SS had lost interest. Once, for example, an SS man was inspecting the prisoners' apparel and found that some of their shoes were dirty on the inside. He ordered all prisoners to wash their shoes inside and out with soap and water. Treated this way, the heavy shoes became hard as stone. The order was never repeated, and many prisoners did not even try to carry it out the first time, since the SS, as was often the case, gave the order, stood around for a few minutes and then left. Until he was gone, every prisoner busied himself with carrying out the order, after which they promptly quit. Nevertheless there were some old prisoners who not only continued to wash the insides of their shoes every day but cursed all who failed to do so as being negligent and dirty. These prisoners believed firmly that all rules set down by the SS were desirable standards of behavior, at least in the camp. (Scott, 1971, p. 206)

The prisoners were, of course, washing their shoes to escape the aversive consequences that the SS would administer if the prisoners did not obey the order. Some of the men became very persistent and continued washing their shoes even when the SS did not require them to do so. Generally, it was the older prisoners, who had more experience with the aversive contingencies of the SS that were likely to persist in washing their shoes. For these men, the concentration camp experience generated escape and avoidance behavior. The older prisoners in the concentration camp also accepted the rules of the SS and preached these standards to their fellow inmates. These responses are more complex than simple avoidance and may be analyzed as rule-governed behavior (Skinner, 1969; see also chap. 11).

Learned Helplessness

A similar persistence effect occurs when animals are exposed to inescapable aversive stimulation and then are given an opportunity to escape. In the phenomenon called **learned helplessness**, an animal is first exposed to inescapable and severe aversive stimulation. Eventually the animal gives up and stops attempting to avoid or escape the situation. Next, an escape response, which under ordinary circumstances would be acquired easily, is made available, but the animal does not make the response. In an early experiment, Seligman and Maier (1967) exposed dogs to intense, inescapable electric shock. Following this, they attempted to teach the animals to avoid signaled shocks by jumping across a shuttle-box barrier (see Fig. 6.5). The dogs failed to avoid the shocks, and even after the shocks came on (for 50 s) they would not escape by crossing the barrier to safety. The researchers suggested that the dogs had learned to give up and become helpless when presented with inescapable aversive stimulation. Of course, dogs that are not first exposed to inescapable shock learn quickly to escape and avoid shocks in a shuttle box.

Learned helplessness has been found in a large number of experiments and has been documented in other animals (Baker, 1976; Glazer & Weiss, 1976a, 1976b; Maier, 1970; Maier, Albin, & Testa, 1973; Maier & Seligman, 1976; Maier, Seligman, & Solomon, 1969; Overmier & Seligman, 1967; Seligman & Maier, 1967). For example, Jackson, Alexander, and Maier (1980) found that rats in a maze had difficulty learning to escape electric shocks after exposure to inescapable aversive stimuli.

Similar results have been reported for humans. Hiroto and Seligman (1975) exposed college students to a series of inescapable loud noises. Following this procedure, the students had to solve a number of anagram problems. Students who were exposed to inescapable noise

had more difficulty solving problems than students who did not get the loud noise. Most control subjects solved all the anagrams and reached solutions faster and faster. In contrast, students exposed to inescapable noise failed many problems and made slow improvements in performance.

The practical implication of these findings seems obvious. When people are exposed to inescapable "shocks," they may learn to give up and become helpless. A parent who spanks a child on the basis of his or her mood rather than for the child's misbehavior may create a socially withdrawn individual. The child has learned "No matter what I do, I get a spanking." A husband that frequently "blows up" for no apparent reason might produce a similar set of responses in his partner.

Helplessness and Depression

Seligman (1975) argued that the research on learned helplessness provides a model for clinical depression. For example, there is evidence that helplessness is involved in the relationship between alcohol dependence and depression (Sitharthan, Hough, Sitharthan, & Kavanagh, 2001). More generally, thousands of people each year are diagnosed as depressive. These individuals show insomnia, report feeling tired, often say that life is not worth living, have difficulty performing routine tasks, and may be suicidal. Clinical depression is severe, long lasting, and is not easily traced to a recent environmental experience.

Seligman (1975) has suggested that the behavior of helpless dogs may be relevant to the origin and treatment of clinical depression. Depression may arise when a person has a history of inescapable abuse. This could occur when a parent, spouse, or caretaker unreasonably and severely mistreats a child, partner, or elderly person. In other writings, Seligman and his co-workers have pointed out that, although animal experiments may shed light on human depression, there are differences (Abramson, Seligman, & Teasdale, 1978; Peterson & Seligman, 1984). For the most part, Seligman points to differences that occur because of human verbal behavior. That is, a person may talk about his or her problems and attribute them to either internal or external causes. When people say that their difficulties are caused by internal factors (e.g., "I am a failure"), these responses could function as discriminative stimuli for giving up (as in rule-governed behavior in chap. 11).

In terms of treatment, research on learned helplessness has practical importance. When helpless dogs are forced to make a response that escapes the electric shocks, they eventually begin to make the escape response on their own (i.e., a dog that fails to jump the barrier is forcibly guided across it). Based on this finding, Seligman has suggested that depressed individuals should be placed in situations in which they cannot fail. In this manner, the person may eventually learn to emit appropriate responses in the presence of aversive events.

Seligman has also suggested how to prevent learned helplessness and depression. A person who has already learned to escape from punitive control may be "immunized" from the effects of inescapable aversive events. Such an effect is suggested by experiments where animals initially learn to some response (e.g., wheel running) to escape electric shocks. That is, the animals first learn an effective escape response to negative reinforcement contingencies. Next, the animals are exposed to the typical learned helplessness procedures of inescapable shocks. Finally, the subjects are tested in a situation where a new response produces escape from shocks (e.g., switching sides in a shuttle box). The typical effect of pre-exposure to escape is that this experience blocks the learned helplessness usually brought on by inescapable aversive stimulation (Maier & Seligman, 1976; Williams & Lierle, 1986).

In addition to behavioral treatments (i.e., arranging for success or immunization), neuroscience research is currently underway using Seligman's procedures to induce learned helplessness in animals. The basic idea is to examine the possible interrelationships between brain chemistry and depression with the hope of finding neurochemical regulators of human depression. For example, dopamine (a neurotransmitter) seems to play a role in the depression caused by learned helplessness (Besson, Privat, Eschalier, & Fialip, 1999; Takamori, Yoshida, & Okuyama, 2001). Drugs that target the dopaminergic systems eventually may be helpful in the treatment of clinical depression, especially when combined with behavioral treatments focused on overcoming and preventing learned helplessness.

Aggression

Respondent Aggression

When two organisms are placed in the same setting and painful stimuli are delivered, the organisms may attack one another (Ulrich, Wolff, & Azrin, 1964). The fighting generated by this circumstance is called **respondent aggression** (or pain-elicited aggression) because it follows the presentation of aversive events. Attack occurs even though neither individual is responsible for the delivery of the painful stimuli. Ulrich and Azrin (1962) placed two rats in an operant chamber and noted that the animals showed no signs of aggression. However, when the rats were shocked, they turned and attacked each other. Elicited aggression has been documented in several species including humans (Azrin, Hutchinson, & Hake, 1963; Hutchinson, 1977), and it has been found with painful stimuli other than electric shock (Azrin, Hake, & Hutchinson, 1965). Most people recognize that they are more prone to aggression when exposed to painful stimuli. When feeling good you may never shout at your boyfriend, but you may do so if you have a severe toothache. It is probably good advice to stay clear of your boss when he or she has a headache, and so on.

O'Kelly and Steckle (1939) first described pain-elicited aggression. In these early experiments, rats were placed in a small enclosure and electric shock occurred periodically, no matter what the animals did (a procedure similar to the one that induces learned helplessness, but two rats are placed in the chamber). When the rats were periodically shocked, they began to fight. Twenty-three years later, Ulrich and Azrin (1962) systematically investigated the fighting behavior of rats to inescapable and intermittent aversive stimulation. These researchers began by testing whether two rats would fight when simply placed in a small operant chamber. They noted that the animals did not usually attack one another when placed in a confined space. However, when random shocks were given, the animals would immediately stand up and vigorously strike and bite one another (see Fig. 6.8).

Shocks were delivered at increasing frequencies, and the number of attacks increased as more and more shocks were presented. In addition, Ulrich and Azrin (1962) found that the probability of attack for any single shock increased as the number of shocks went up. When the animals got one shock every 10 min, attack followed approximately 50% of the shocks. When the animals received 38 shocks a minute, fighting followed 85% of the shocks.

Further experiments conducted by Ulrich and Azrin (1962) examined the effects of shock intensity on aggressive behavior. As shock intensity increased in milliamperes (mA), from 0.5 to 2.0 mA, the number of aggressive episodes went up. When shock intensity exceeded 2.0 mA, fighting decreased because the high-intensity shocks elicited running, jumping, and so on—responses that were incompatible with fighting.

An important question is whether such fighting occurs when animals are able to escape, or avoid, the electric shock. The floor of the operant chamber was made of metal rods,
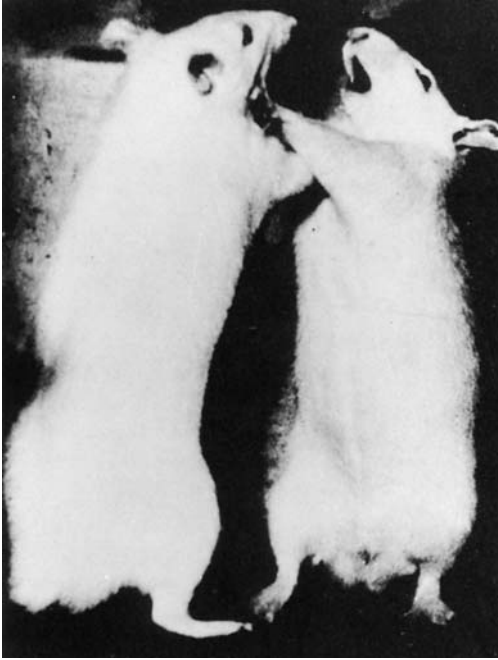
FIG. 6.8.   *Two rats in the attack position induced by electric shock.* Note: *From "Reflexive Fighting in Response to Aversive Stimulation," by R. E. Ulrich and N. H. Azrin, 1962,* Journal of the Experimental Analysis of Behavior, 5, *pp. 511–520, reprinted with permission. Copyright 1962, the Society for the Experimental Analysis of Behavior, Inc.*

and some of these were electrically charged positive, and others were charged with negative voltage. Animals could evade the shocks by standing on two positive or two negative rods. The rats readily learned this response, and since they did not get shocked, they did not fight. That is, allowing the animals to escape the shocks effectively eliminated the aggression.

Ulrich and Azrin (1962) varied the size of the operant chamber in another experiment. When there was little floor space (0.25 sq ft), almost all shocks resulted in fighting. As floor space increased to 2.25 sq ft, the chances of attack for any one shock decreased. It seems that the size of the chamber regulated pain-elicited fighting through the changing proximity of the opponents. In other words, the closer the animals were to each other, the greater the chances of attack attributable to shock.

To determine whether these findings occurred in other species, the researchers placed different animals in the shock box. Hamsters also fought when shocked, and these attacks occurred at shock intensities that did not elicit aggression in rats. One possibility is that hamsters have less padding or more pain receptors on their feet, making them more susceptible to low levels of shock. In contrast, mature guinea pigs would not fight when shocked. This passive response even occurred when a guinea pig was placed in the shock box with a rat. The rat attacked the guinea pig when it was shocked, but the guinea pig "reacted only by withdrawing from the rat's biting attacks following the shock delivery" (Ulrich & Azrin, 1962, p. 517). These findings suggest that there are species differences in the tendency to fight when exposed to painful stimulation.

There are other limitations on pain-elicited aggression. Ulrich and Azrin (1962) found that rats fought when exposed to intense heat or shock, but not to intense noise or cold temperature. Apparently there are specific forms of painful stimulation that elicit attack in a given species. Presumably, the type and intensity of painful stimulation that triggers attack is not the same for different kinds of animals.

Painful stimulation also produces attack-like responses in both humans and monkeys (Azrin et al., 1966; Azrin, Hutchinson, & Sallery, 1964; Hutchinson, 1977). In one experiment, squirrel monkeys were strapped into a small test chamber, and electric shock was delivered to the animals' tails (Azrin et al., 1964). As with rats, attack was elicited by electric shocks. The animals attacked other monkeys, rats, mice, and inanimate objects such as a stuffed doll, round ball, and a rubber hose that they could bite. As shock intensity increased, so did the probability and duration of the attacks—a result that parallels the findings with rats.

In a review of the side effects of aversive control, Hutchinson (1977) described bite reactions by humans to aversive stimulation. Subjects were paid volunteers who were given inescapable loud noise at regular intervals. Because the noise was delivered on a predictable basis, the subjects came to discriminate the onset of the aversive stimulus. Unobtrusive measures indicated that humans would show aggressive responses (or more precisely bite on a rubber hose) following the presentation of loud noise. The humans' responses to noise parallel the elicited fighting found in monkeys and other animals. However, Hutchinson suggests that the human results should be interpreted with caution. The subjects were told that they would receive aversive stimulation, but the intensity would be tolerable. Also, he noted that subjects were paid to stay in the experiment, and most people would leave such a situation in everyday life.

Operant Aggression

When one person punishes another's behavior, the punished individual may retaliate. This is not difficult to understand; one way to escape aversive stimulation is to eliminate or neutralize the person who is delivering it (Azrin & Holz, 1966). This strategy is called **operant aggression**, and it is shaped and maintained by negative reinforcement (i.e., removal of the aversive event). When two people have a fistfight, the winner of the combat is reinforced by the absence or reduction of punches from the other person. Unfortunately, this analysis suggests that physical aggression will increase in frequency for those individuals who successfully use counteraggression to stop the delivery of aversive stimuli.

Consider a situation in which a husband and wife argue and the husband loses his temper and strikes his spouse. Because men are typically larger and stronger than women, this probably ends the argument, and the husband is negatively reinforced (by withdrawal of the wife's arguing) for physical abuse. Although this does not completely explain spouse abuse, it does suggest that negative reinforcement plays a large role in many cases.

Investigating Human Aggression

Although human aggression is easily recognized, it is difficult to study in the laboratory. This is because aggressive behavior is a dangerous form of human conduct. For this reason, researchers have developed procedures that protect the victim from harm. In the laboratory situation, participants are led to believe that they have an opportunity to hurt another person when in reality they do not (e.g., Baron, Russell, & Arms, 1985; Gustafson, 1989; Zillmann, 1988). In a typical experiment, participants are told that they can deliver an aversive stimulus (e.g., loud noise, electric shock, etc.) to another person by pressing a button on a response panel. The other person is, in fact, an accomplice or confederate of the researcher and acts the role of victim but does not receive the aversive stimulus.

There has been a debate about the reality or external validity of these procedures. However, evidence suggests that these methods constitute a reasonable analog of human

aggression in everyday life. Participants in aggression experiments are convinced that their actions harmed the confederate (Berkowitz & Donnerstein, 1982). When the accomplice provokes (e.g., with insults) the subjects, they deliver greater amounts of painful stimulation than when they are not provoked (Baron & Richardson, 1993). Finally, people who are known to be violent usually select and deliver stronger levels of aversive stimulation than those without such a history (Gully & Dengerink, 1983; Wolfe & Baron, 1971).

Aggression Breeds Aggression

Operant and respondent principles suggest that the presentation of an aversive stimulus may elicit or set the occasion for aggressive behavior. Provocation by others is a common form of aversive stimulation that occurs in a variety of social settings. Consider a situation in which you have worked extremely hard on a term paper and you feel it is the best paper you have ever written. Your professor calls you to his or her office and says, "Your paper is rubbish. It lacks clarity, scholarship, organization, and is riddled with grammatical mistakes. Only an idiot could write and submit such trash!" You probably protest the unfair treatment, but to no avail. You storm out of the office mumbling a few choice words, and once down the hall you kick the elevator door. Later in the term you are asked to fill out a teaching evaluation and, in retaliation, you score the professor as one of the worst teachers you have known. In this example, the professor's insulting remarks generated aggressive responses that ranged from kicking doors to counterattack by negative evaluation. Generally, aggression breeds aggression (Patterson, 1976). Skinner (1953) described how aggression breeds aggression in his account of a game played by sailors during the 18th century.

> Sailors would amuse themselves by tying several boys or younger men in a ring to a mast by their left hands, their right hands remaining free. Each boy was given a stick or whip and told to strike the boy in front of him whenever he felt himself being struck by the boy behind. The game was begun by striking one boy lightly. This boy then struck the boy ahead of him, who in turn struck the boy next ahead, and so on. Even though it was clearly in the interest of the group that all blows be gentle, the inevitable result was a furious lashing. The unstable elements in this interlocking system are easy to identify. We cannot assume that each boy gave precisely the kind of blow he received because this is not an easy comparison to make. It is probable that he underestimated the strength of the blows he gave. The slightest tendency to give a little harder than he received would produce the ultimate effect. Moreover, repeated blows probably generate an emotional disposition in which one naturally strikes harder. A comparable instability is seen when two individuals engage in a casual conversation which leads to a vituperative quarrel. The aggressive effect of a remark is likely to be underestimated by the man who makes it, and repeated effects generate further aggression. The principle is particularly dangerous when the conversation consists of an exchange of notes between governments. (p. 309)

Skinner's analysis is confirmed by controlled experiments showing that both physical and verbal provocation produces aggression. In terms of physical provocation, experiments show that people respond to attacks with escalating counterattacks (Borden, Bowen, & Taylor, 1971; O'Leary & Dengerink, 1973; Taylor & Pisano, 1971). In these experiments, participants tried to beat their opponents on a reaction-time game in which the loser received an electric shock. In fact, there were no actual opponents, but participants received shocks that were programmed by the researchers. In this game, subjects were made to lose on a number of trials, and the shocks from the fictitious opponent increased in magnitude. Faced with increasing physical provocation, subjects retaliated by escalating the intensity of the shocks they gave when the "opponent" lost.

Recent experiments on provocation and aggressive behavior further support and refine Skinner's (1953) analysis of aggression. In one study, people matched their level of aggression

to the level of provocation (Juujaevari, Kooistra, Kaartinen, & Pulkkinen, 2001). Also, people retaliated more when they were provoked and subsequently presented with a minor annoyance than when they were only provoked or received no provocation. The minor annoyance became a "trigger" for retaliation when preceded by provocation; by itself it had no effect on aggressive behavior (Pedersen, Gonzales, & Miller, 2000).

Verbal insults also evoke and set the occasion for strong counterattacks. Wilson and Rogers (1975) suggest that verbal provocation can lead to physical retaliation, and they have noted incidents that began with verbal taunts escalating into violent fistfights. In a laboratory study of verbal insults, Geen (1968) found that subjects who were exposed to unprovoked, nasty comments from a confederate would retaliate with physical aggression. The subjects in this study were allowed to deliver shocks to the insulting confederate. (In fact, no shocks were actually given.) Compared to personal frustration (a confederate prevents them from competing an assigned task) and task frustration (the task did not have a solution), verbal insults produced the highest level of aggression toward the confederate.

In a more recent set of experiments, insults increased aggressive behavior more in people who came from a "culture of honor" (the southern United States) than from those who did not (the northern United States). For those who valued honor, insults diminished the person's reputation, and retaliation was behavior that had previously restored status and respect (Cohen, Nisbett, Bowdle, & Schwarz, 1996). Generally, aggression (both verbal and physical) breeds aggression, and aggressive episodes escalate toward greater levels of violence, especially in cultures that propagate dignity and honor (see Skinner, 1971, on other problems of freedom and dignity).

The dictum that aggression breeds aggression also can be extended to problems of violence in schools and other social situations. One common form of group behavior involves social exclusion of others based on their characteristics and behavior. For example, a student who shows high accomplishments in academic subjects may be excluded from the "in group" whose members call him a "nerd." Can this kind of group behavior instigate aggression in those who receive it? A recent experiment investigated this question in the laboratory (Twinge, Baumeister, Tice, & Stucke, 2001). Human participants were exposed to social exclusion by telling them that other participants had rejected them as part of the group. Social exclusion caused participants to behave more aggressively in various contexts.

When insulted by another person (target), excluded people retaliated by "blasting" the target with higher levels of aversive noise. In another experiment, the target received the same aggressive treatment, even though he or she had not insulted the excluded people. This suggests that it is social exclusion itself that instigated the aggressive behavior. A further experiment showed that the effects of social exclusion on aggression could be mitigated if the target provided social praise to the excluded person. That is, provision of social rewards prevented the retaliation induced by exclusion from the group. The researcher indicated that these responses were specific to social exclusion as opposed to other kinds of misfortunes. One implication is that school children who are excluded or rejected by their classmates may show aggressive behavior directed toward group members—another instance of aggression breeds aggression.

Social Disruption

When punishment is used to decrease behavior, the attempt is usually made to stop a particular response. The hope is that other unpunished behavior is not affected. Two factors

work against this: The person who delivers punishment and the setting in which punishment occurs can both become conditioned aversive stimuli (S^{ave}). Because of this conditioning, individuals will attempt to escape from or avoid the punishing person or setting. Azrin and Holz (1966) have called this negative side effect of punishment **social disruption**:

> It is in the area of social disruption that punishment does appear to be capable of producing behavioral changes that are far-reaching in terms of producing an incapacity for an effective life. . . . For example, a teacher may punish a child for talking in class, in which case it is desired that the unauthorized vocalization of the child be eliminated but his other behaviors remain intact. We have seen previously, however, that one side effect of the punishment process was that it reinforced tendencies on the part of the individual to *escape from the punishment situation itself*. In terms of the example we are using, this means that punishment of the vocalization would not only be expected to decrease the vocalization, but also increase the likelihood of the child leaving the classroom situation. Behavior such as tardiness, truancy, and dropping out of school would be strengthened. The end result would be termination of the social relationship, which would make any further social control of the individual's behavior impossible. This side effect of punishment appears to be one of the most undesirable aspects of having punishment delivered by one individual against another individual since the socialization process must necessarily depend upon continued interaction with other individuals. (pp. 439–440, emphasis ours)

It is also worth recalling the general suppressive effects of aversive stimuli. A teacher, parent, or employer (social agent) who frequently uses aversive techniques *becomes a conditioned punishing stimulus*. Once this occurs, the mere presence of the social agent can disrupt all ongoing operant behavior. This means that positive behavior falls to low levels when this person is present.

ON THE APPLIED SIDE: COERCION AND ITS FALLOUT

The social disruptive effects of aversive control have been addressed by Murray Sidman (Fig. 6.9), a prominent researcher in behavior analysis. He is known for his work on unsignaled avoidance and other aspects of negative reinforcement and punishment. (See nondiscriminated avoidance in this chapter.) Dr. Sidman has published over 100 scientific

FIG. 6.9. *Murray Sidman. Reprinted with permission.*

articles and is the author of the book *Tactics of Scientific Research*, a definitive account of single-subject research and methodology (Sidman, 1960). In a more recent book, *Coercion and Its Fallout*, Sidman (2001) provides a behavior analysis of coercion and its frequent use in North American society. **Coercion** is defined as the "use of punishment and the threat of punishment to get others to act as we would like, and to our practice of rewarding people just by letting them escape from our punishments and threats." (p. 1) That is, coercion involves the basic contingencies of punishment and negative reinforcement. An interesting part of this book concerns escape and "dropping out" of the family, community, and society.

One kind of escape contingency is dropping out—a major social problem of our time. People drop out of education, family, personal and community responsibility, citizenship, society, and even life. Sidman (2001, p. 101) points out that the common element in all of these forms of conduct is negative reinforcement. Once involved in an aversive system, people can get out by removing themselves from the coercive situation, and this strengthens the behavior of dropping out. Sidman notes that society is the loser when people cease to participate; dropping out is nonproductive, since dropouts no longer contribute to their own or society's welfare.

An unfortunate, but common, example is the school dropout. Day after day, students are sent to schools where coercion is a predominant way of teaching. That is, often the teacher's job is to "get students to learn" by punishing them when they fail. The pupil who is slow to answer or who errs on obvious questions is subjected to ridicule. Written work is filled with negative comments, and classmates observe the low grades on assignments as papers are returned from front to rear. Report cards emphasize failing grades in red ink; poor students are seated at the back of the room as examples of what happens to failures. Students who cannot deal with the normal workload are required to do extra work at school and home, making those who fail social outcasts who are deprived of play and other activities. Children who fail eventually conclude that learning and pleasure are not compatible—the more learning the less the pleasure.

As the aversive control escalates, escape is inevitable. Students show increasingly severe forms of dropping out. Tardiness, feigned illness, "playing hooky," and never showing up for school are common responses to the escalation of coercion in schools. Sidman summarizes the problem as follows:

> The current discipline and dropout crises are the inevitable outcome of a history of educational coercion. One may long for the days when pupils feared their teachers, spoke to them with respect, accepted extra work as punishment, submitted to being kept after school, and even resigned themselves to being beaten. But through the years, all these forms of coercive control were sowing the seeds of the system's destruction. Wherever and whenever coercion is practiced, the end result is loss of support of the system on the part of those who suffered from it. In every coercive environment, the coerced eventually find ways to turn upon the coercers. An adversarial relationship had developed between pupils and teachers, and the former victims, now parents, no longer support the system against their children. (Sidman, 2001, p. 107)

As Sidman goes on to note, not all teachers (or school systems) use coercion, or negative reinforcement, as a way to induce students to learn. Some teachers and educators are familiar with and use positive reinforcement effectively. A teacher who does use positive reinforcement looks to reward small steps of success rather than punish instances of failure. Schools who adopt positive reinforcement methods are likely to promote both the enjoyment of learning as well as high academic performance (Cameron & Pierce, 2002). Positive reinforcement turns dropping out into "tuning in."

KEY WORDS

Aversive stimulus	Molecular perspective	Punisher
Avoidance	Negative punishment	Punishment
Coercion	Negative reinforcer	Relativity of punishment
Conditioned aversive	Negative reinforcement	Respondent aggression
stimulus	Nondiscriminated	Response–shock
Discriminated avoidance	avoidance	interval
Escape	Operant aggression	Shock–shock interval
Learned helplessness	Positive punishment	Sidman avoidance
Molar perspective	Primary aversive stimulus	Social disruption

ON THE WEB

http://www.psych.upenn.edu/~fresco/helplessness.html This list provides a forum for learned helplessness research and theory. Faculty, graduate students, and undergraduate researchers are especially invited.

http://www.psychology.uiowa.edu/Faculty/wasserman/Glossary/punishment.html A Web page that helps you learn the differences between positive and negative punishment. There is more to learn at this site, so browse about.

http://www.teachervision.com/lesson-plans/lesson-10155.html A site devoted to the Art of Teaching by the Council for Exceptional Children. The Web page concerns the control of aggressive behavior in children based on behavior management.

STUDY QUESTIONS

1. Define and give an example of primary and conditioned aversive stimuli. (153) According to Azrin and Holz (1966), why is punishment a fact of life? (153)
2. What is meant by the terms punishment and punisher? (154) Discuss positive punishment and extend the analysis to a child who is spanked for hitting a friend. (154–155)
3. Outline the procedure of negative punishment. (155) Give an example of negative punishment involving a child who is watching television. (155) Distinguish between negative punishment and extinction. (155)
4. Discuss punishment and the Premack principle, indicating how punishment is relative not absolute. In your analysis, refer to the relativity of wheel running as punishment for drinking. (155–156)
5. Does punishment teach new behavior? (156) Why is it important to study the contingencies of punishment? (156) What complicates the study of punishment? (Hint: How is behavior usually maintained before it is punished?) (156)
5. Outline the effects of gradual and sudden punishment. (156) Give an example of graduated punishment involving a messy kid playing with Mike's new disk player. (156–157)
6. How does the intensity of positive punishment relate to response suppression? (157) Why have Skinner and others argued that punishment only produces temporary suppression of behavior? (157) What does the research indicate? (157)

 7. Discuss immediacy of positive punishment and how reflexive behavior may disrupt operant responding. In your answer refer to the Estes (1944) experiment. (157) What is the most effective schedule of positive punishment? Why? (158)

 8. **FOCUS ON**: Outline the issues about use of aversive procedures in behavior therapy. (158–159) What are two possible side effects in the use of positive punishment? (159) Discuss Solomon's recommendation to solve disputes about punishment. (159) Why hasn't it worked? (159) What could account for the lack of modern research on punishment? (159–160)

 9. How effective is punishment at different levels of food deprivation? Be sure to refer to Azrin, Holtz, and Hake (1963). (160) Discuss the practical implications of the motivation–punishment relationship by pointing to the modification of self-destructive behavior (Lovaas & Simmons, 1969). (160–161)

10. Outline how response alternatives make punishment more effective. (161) Give an everyday example of response alternatives and punishment. (161)

11. Distinguish between escape and avoidance. (162) Define negative reinforcement and negative reinforcer. (162) The distinction between positive and negative reinforcement is occasionally uncertain. Discuss. (162) Why is the distinction between escape and avoidance somewhat artificial? Use shock–shock interval and response–shock interval in your answer. (162–163)

12. Give some examples of escape conditioning. (163) Be able to write the Mechner notation for an escape contingency, as in Fig. 6.5. (164) Why are escape responses more easily acquired than avoidance behavior? (164) Discuss escape conditioning and the compatibility of reflexive and operant behavior. (164)

13. Define avoidance and give some common examples. (164) Outline discriminative avoidance and write the Mechner notation for this contingency, as in Fig. 6.6. (165) Discuss the rate of acquisition for discriminative avoidance and the controlling variables. (165) What did Modaressi (1990) find? (165)

14. Comment on nondiscriminative avoidance as compared to discriminative avoidance. (166) In a Sidman avoidance procedure, what determines how quickly the operant is acquired? (166)

15. **FOCUS ON**: Analyze the S–S and R–S intervals and the effectiveness of an avoidance contingency. (166) Discuss the relationship between shock frequency and avoidance, referring to the molar and molecular views. (167) What is Hineline's view on the molar versus molecular distinction? (167)

16. What happens when a period of avoidance precedes or follows a session of food reinforcement (Hackenberg & Hineline, 1987)? (167–168) Discuss the experiment in everyday language. (168)

17. Be able to outline Skinner's argument against aversive techniques. (168)

18. Discuss behavioral persistence as a side effect of punishment, referring to operant–respondent interactions. (169) How could you place avoidance behavior on extinction? (169) Provide an example of behavioral persistence in the Nazi concentration camps. (170)

19. What is learned helplessness? (170) How is this behavior acquired in animals (Seligman & Maier, 1967)? (170) Does learned helplessness occur in people? Give an example. (170–171) Explain how learned helplessness is a side effect of aversive control. (171)

20. Analyze the relationship between learned helplessness and depression, referring to relevant studies. (171) Discuss behavioral treatment (prevention) of depression based on learned helplessness. (171) What does neuroscience research say about

learned helplessness and depression? (171) Are behavioral treatments at odds with neuroscience interventions? (172)

21. Describe respondent (pain-elicited) aggression as a side effect of aversive control, indicating the appropriate studies. (172) As the frequency and intensity of shocks increase, what happens to aggression? (172)

22. What happens to respondent aggression if rats can escape or avoid the shocks? (172–173) How does the amount of space affect pain-elicited aggression? (173)

23. Describe the effects of random shocks on respondent aggression of other species. (173) Does the same kind of aversive stimulus lead to aggression in all animals? (173) What about humans? (174)

24. What is operant aggression? (174) Give an example. Within the aggressive episode, how is aggressive behavior maintained by negative reinforcement? (174)

25. Discuss the problems of investigating human aggression in the laboratory. (174–175)

26. Provide a behavior analysis of how aggression breeds aggression, referring to Skinner's account of the sailors' game during the 18th century. (175)

27. What have controlled experiments with humans shown about how aggression breeds aggression? (175–176) How do insults affect human aggression? (176) What does a "culture of honor" do to human aggression? (176) Describe an experiment on social exclusion and aggressive behavior. (176)

28. Discuss the side effect of punishment known as social disruption. (176) Why does this side effect occur? (176–177)

29. What is coercion? (177) Based on Sidman's (2001) analysis of coercion, why do children drop out of school? (177–178) Can anything be done to turn dropping out into "tuning in"? (178)

BRIEF QUIZ

1. In terms of aversive stimuli, attacks and foul odors are _____ , whereas threats and failing grades are _____.
   (a) potent; impotent
   (b) natural; secondary
   (c) primary; conditioned
   (d) primitive; cultured

2. If wheel running is a higher frequency operant, then wheel running will _____ drinking; if wheel running is a lower frequency operant, then wheel running will _____ drinking.
   (a) decrease; increase
   (b) reinforce; punish
   (c) determine; undermine
   (d) diminish; exacerbate

3. Regarding the side effects of punishment, Solomon's (1969) solution is to
   (a) cease investigations of punishment, especially in applied settings
   (b) investigate the role of negative reinforcement rather than that of punishment
   (c) provide informed help to those who are controlled by punishment
   (d) search for the rules or principles governing such side effects

4. The time between shocks or the _____ interval and the time away from shocks produced by responses or the _____ interval are two aspects of escape and avoidance.
   (a) temporal shock; response time

(b) shock–shock; response–shock
(c) shocking; responding
(d) aversive; postponement
5. The procedure of nondiscriminative avoidance is also called
(a) signaled avoidance
(b) sensory aversion
(c) Sidman avoidance
(d) Stevens aversion
6. In terms of operant–respondent interactions, persistence and avoidance
(a) operant avoidance prevents respondent extinction
(b) operant avoidance interacts with respondent aggression
(c) operant avoidance competes with respondent avoidance
(d) operant avoidance sets the occasion for respondent aversion
7. For learned helplessness, pre-exposure to escape _____ the helplessness brought on
by _____ aversive stimulation.
(a) enhances; noncontingent
(b) causes; excessive
(c) augments; expected
(d) blocks; inescapable
8. With regard to respondent aggression, Ulrich and Azrin (1962) found that the
probability of attack for any single shock
(a) decreased as the number of shocks went up
(b) remained constant as the number of shocks went up
(c) increased as the number of shocks went up
(d) increased then decreased as the number of shocks went up
9. Skinner (1953) reported a game played by sailors in the 18th century. The game
involved
(a) tying several boys in a ring
(b) each boy being told to hit another boy when he was hit
(c) a slight tap on one boy
(d) all of the above
10. In terms of dropping out, Sidman (2001) indicates that one basic element is
(a) escape due to negative reinforcement
(b) escape due to punishment
(c) escape due to contingencies of avoidance
(d) escape due to a history of inescapable shock

Answers to brief quiz (*page*): c(153); b(156); d(159); b(163); c(166); a(169); d(171);
c(172); d(175); a(178)

CHAPTER 7

Operant–Respondent Interrelationships and the Biological Context of Conditioning

IN THIS CHAPTER

1. Find out how operant and respondent contingencies interrelate in complex ways.
2. Explore the phenomena of sign tracking, autoshaping, and negative automaintance.
3. Investigate how researchers showed that operant contingencies could regulate behavior usually viewed as respondent.
4. Investigate the biological context of conditioning and the phenomenon known as taste-aversion learning.
5. Learn how adjunctive behavior is induced by interval- and fixed-time schedules of reinforcement.
6. Discover the interrelationships of eating and physical activity and how this relates to activity anorexia in both humans and other animals.

So far, we have considered operant and respondent behavior as separate domains. Respondent behavior is elicited by the events that precede it, and operants are strengthened (or weakened) by stimuli that follow them. Pretend that you are teaching a dog to sit and you are using food reinforcement. You might start by saying, "sit," and then push the animal into a sitting position and follow this posture with food. After training, you present the dog with the discriminative stimulus "sit," and it quickly sits. This sequence nicely fits the operant paradigm—the S^D "sit" sets the occasion for the response of sitting, and food reinforcement strengthens this behavior (Skinner, 1953).

In most circumstances, however, both operant and respondent conditioning occur. If you look closely at what the dog does, it should be apparent that the "sit" command also elicits respondent behavior. Specifically, the dog salivates just after you say "sit." This occurs because the "sit" command reliably preceded the presentation of food, and it becomes a conditioned stimulus that elicits respondent salivation. For these reasons, the stimulus "sit" is said to have a dual function: It is an S^D in the sense that it sets the occasion for operant responses, and it is a CS because it elicits respondent behavior.

Similar effects are seen when a warning stimulus (i.e., a tone) is turned on that signals imminent shock if a rat does not press a lever. The signal is a discriminative stimulus that increases the probability of bar pressing, but it is also a CS that elicits changes in heart rate, hormone levels, and so on (all of which can be called fear). Consider that you are out for a before-breakfast walk and you pass a doughnut and coffee shop. The aroma from the shop may be a CS that elicits salivation and an S^D that sets the occasion for entering the

store and ordering a doughnut. These examples should make it clear that in many settings respondent and operant conditioning are intertwined.

One reason for the interrelationship of operant and respondent conditioning is that whatever happens to an organism is applied to the whole neurophysiological system, not just to either one set of effectors or the other. That is, we analytically separate respondents (as smooth muscle and gland activity) from operants (striated skeletal muscle activity), but the contingencies are applied to the entire organism. When operant reinforcement occurs, it is contiguous with everything going on inside the individual. When a CS or US is presented, there will be all kinds of operant behavior ongoing as well. The separation of operant and respondent models is for analytical convenience and control, but the organism's interaction with the environment is more complicated than these basic distinctions.

Analysis of Operant–Respondent Contingencies

In some circumstances, the distinction between operant and respondent behavior becomes even more difficult. Experimental procedures (contingencies) can be arranged in which responses typically considered reflexive increase when followed by reinforcement. Other research has shown that behavior usually thought to be operant may be elicited by the stimuli that precede it. Many students (and more than a few psychologists) incorrectly label operant or respondent behavior in terms of its form or topography. That is, pecking a key is automatically called an operant, and salivation, no matter how it comes about, is labeled a reflex. Recall, though, that operants and respondents are defined by the experimental procedures that produce them, not by their topography. When a pigeon pecks a key for food, pecking is an operant. If another bird reliably strikes a key when it is lit up and does this because the light has been paired with food, the peck may be considered to be a respondent.

When biologically relevant stimuli, like food, are contingent on an organism's behavior, species-characteristic behavior is occasionally elicited. One class of species-characteristic responses that are occasionally elicited (when operant behavior is expected) is reflexive behavior. This intrusion of reflexive behavior occurs because *respondent procedures are sometimes embedded in operant contingencies of reinforcement.* These respondent procedures cause species-characteristic responses that may interfere with the regulation of behavior by operant contingencies.

At one time, this intrusion of respondent conditioning in operant situations was used to question the generality of operant principles and laws. The claim was that the biology of an organism overrode operant principles (Hinde & Stevenson-Hinde, 1973; Schwartz & Lacey, 1982; Stevenson-Hinde, 1983) and behavior drifted toward its biological roots.

Operant (and respondent) conditioning is, however, part of the biology of an organism. Conditioning arose on the basis of species history; organisms that changed their behavior as a result of life experience had an advantage over animals that did not change their behavior. Behavioral flexibility allowed for rapid adaptation to an altered environment. As a result, organisms that conditioned (or learned) were more likely to survive and produce offspring.

Both evolution and learning involve selection by consequences. Darwinian evolution has developed species characteristics through natural selection of the best fit. Operant conditioning selects response topographies, rates, and repertoires through the effects of consequences as well. A question is whether unconditioned responses (UR) in the respondent

model (US → UR) also are selected by consequences. In this regard, it is interesting to observe that the salivary glands are activated when food is placed in the mouth; as a result, the food can be tasted, ingested (or rejected), and digested. That is, there are notable physiological consequences following respondent behavior. If the pupil of the eye constricts when a bright light is shown, the result is an escape from retinal pain and avoiding retina damage. Respondents have come to exist and operate because they do something, and it is these consequences that maintain the operation of the reflex. One might predict that if the consequences of salivating (or blinking) did not result in improved performance, then neither response would continue; they would not add to the fitness of the organism.

Respondent Contingencies Predominate over Operant Regulation of Behavior

The Breland and Breland Demonstration

Marion and Keller Breland worked with B. F. Skinner as students and later established a successful animal training business. They conditioned a variety of animals for circus acts, arcade displays, and movies. In an important paper (Breland & Breland, 1961), they documented occasional instances in which species-specific behavior interfered with operant responses. For example, when training a raccoon to deposit coins in a box, they noted:

> The response concerned the manipulation of money by the raccoon (who has "hands" rather similar to those of primates). The contingency for reinforcement was picking up the coins and depositing them in a 5-inch metal box.
>
> Raccoons condition readily, have good appetites, and this one was quite tame and an eager subject. We anticipated no trouble. Conditioning him to pick up the first coin was simple. We started out by reinforcing him for picking up a single coin. Then the metal container was introduced, with the requirement that he drop the coin into the container. Here we ran into the first bit of difficulty: he seemed to have a great deal of trouble letting go of the coin. He would rub it up against the inside of the container, pull it back out, and clutch it firmly for several seconds. However, he would finally turn it loose and receive his food reinforcement. Then the final contingency: we put him on a ratio of 2, requiring that he pick up both coins and put them in the container.
>
> Now the raccoon really had problems (and so did we). Not only could he not let go of the coins, but he spent seconds, even minutes rubbing them together (in a most miserly fashion), and dipping them into the container. He carried on the behavior to such an extent that the practical demonstration we had in mind—a display featuring a raccoon putting money in a piggy bank—simply was not feasible. The rubbing behavior became worse and worse as time went on, in spite of non-reinforcement. (Breland & Breland, 1961, p. 682)

Breland and Breland documented similar instances of what they called instinctive drift in other species. **Instinctive drift** refers to species-characteristic behavior patterns that became progressively more invasive during training. The term instinctive drift is problematic because the concept suggests a conflict between nature (biology) and nurture (environment). Behavior is said to drift toward its biological roots. There is, however, no need to talk about behavior "drifting" toward some end. Behavior is appropriate to the operating contingencies. Recall that respondent procedures may be embedded in an operant contingency, and this seems to be the case for the Brelands' raccoon.

In the raccoon example, the coins were presented just before the animal was reinforced with food. For raccoons, food elicits rubbing and manipulating food items. Since

the coins preceded food delivery, they became CSs that elicited the respondent behavior of rubbing and manipulating (coins). This interpretation is supported by the observation that the behavior increased as training progressed. As more and more reinforced trials occurred, there were necessarily more pairings of coins and food. Each pairing increased the strength of the $CS_{(coin)} \rightarrow CR_{(rubbing)}$ relationship, and the behavior became more and more prominent.

Respondent processes also occur as by-products of operant procedures with rats and kids. Rats will hold on to marbles longer than you might expect when they receive food pellets for depositing the marble in a hole. Kids will manipulate tokens or coins prior to banking or exchanging them. The point is that what the Brelands found is not that unusual or challenging to an operant account of behavior.

Sign Tracking

Suppose that you have trained a dog to sit quietly on a mat, and you have reinforced the animal's behavior with food. Once this conditioning is accomplished (the dog sits quietly on the mat), you start a second training phase. During this phase, you turn on a buzzer that is on the dog's right side. A few seconds after the sound of the buzzer, a feeder delivers food to a dish that is placed 6 ft in front of the dog. Figure 7.1 is a diagram of this sort of arrangement.

When the buzzer goes off, the dog is free to engage in any behavior it is able to emit. From the perspective of operant conditioning, it is clear what should happen. When the buzzer goes off, the dog should stand up, walk over to the dish, and eat. This is because the sound of the buzzer is an S^D that sets the occasion for the operant going to the dish, and this response is reinforced by food. In other words, the three-part contingency, SD: $R \rightarrow S^r$, specifies this outcome, and there is little reason to expect any other result. A careful examination of this contingency, however, suggests that the sign could be either an S^D (operant) that sets the occasion for approaching and eating the reinforcer (food) or a CS^+ (respondent) that is paired with the US (food). In this latter case, the CS would be expected to elicit food-related conditioned responses.

Jenkins, Barrera, Ireland, and Woodside (1978) conducted an experiment very much like the one described here. Dogs were required to sit on a mat, and a light/tone stimulus
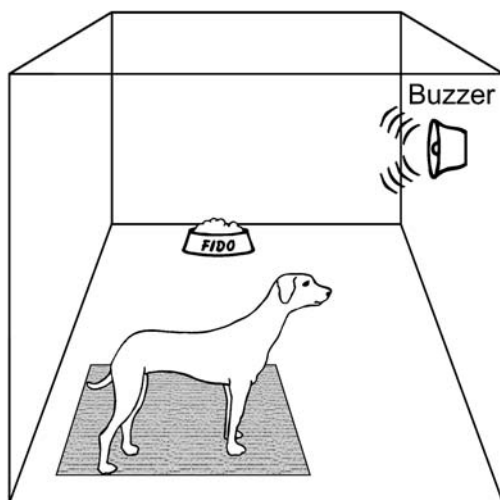
FIG. 7.1.   *Diagram of apparatus used in sign tracking. When the signal for food is given, the dog approaches the signal and makes "food-soliciting" responses rather than go directly to the food dish.*

compound was presented on either the left or the right side of the animal. When the stimulus was presented on one side, it signaled food, and on the other side it signaled extinction. As expected, when the extinction stimulus came on, the dogs did not approach the food tray and for the most part ignored the signal. However, when the food signal was presented, the animals approached the signal and made what was judged by the researchers to be "food-soliciting responses" to the stimulus. Some of the dogs physically contacted the signal source, and others seemed to beg at the stimulus by barking and prancing. This behavior is called **sign tracking** because it refers to approaching a sign (or stimulus) that signals a biologically relevant event (in this case, food).

The behavior of the dogs is not readily understood in terms of operant contingencies of reinforcement. As stated earlier, the animals should simply trot over to the food and eat it. Instead the dogs' behavior appears to be elicited by the signal that precedes food delivery. Importantly, the ordering of stimulus $\rightarrow$ behavior resembles the CS $\rightarrow$ CR arrangement that characterizes classical conditioning. Of course, S^D: R follows the same time line, but in this case, the response should be a direct approach to the food, not to the signal. Additionally, behavior in the presence of the stimulus appears to be food directed. When the tone/light comes on, the dog approaches it, barks, begs, prances, licks the signal source, and so on. Thus, the temporal arrangement of stimulus followed by response, and the form or topography of the animal's behavior, suggests respondent conditioning. Apparently, in this situation the unconditioned stimulus (US) features of the food are stronger (in the sense of regulating behavior) than the operant–reinforcement properties of the food. Because of this, the light/tone gains strength as a CS with each pairing of light/tone and food. A caution is that one cannot entirely dismiss the occurrence of operant behavior in this experiment. If the dog engages in a chain of responses that is followed by food you can expect the sequence to be maintained, and this seems to be the case in such experiments.

Autoshaping

Shaping is the usual way that a pigeon is taught to strike a response key. In the laboratory, closer and closer approximations to the final performance (key peck) are reinforced by a researcher operating the feeder with a hand switch. Once the bird makes the first independent peck at the key, electronic programming equipment activates a food hopper and the response is reinforced. The contingency between behavior and reinforcement, both during shaping and after the operant is established, is clearly operant (R $\rightarrow$ S^r). This method of differential reinforcement by successive approximation requires considerable patience and a fair amount of skill on the part of the experimenter.

Brown and Jenkins (1968) reported a way to automatically teach pigeons to peck a response key. In one experiment, they first taught birds to approach and eat grain whenever a food hopper was presented. After the birds were magazine trained, they turned on a key light 8 s before the grain was delivered. Next, the key light went out and the grain hopper was presented. After 10 to 20 pairings of this key light followed by food procedure, the birds started to orient and move toward the lighted disk. Eventually all 36 pigeons in the experiment began to strike the key, even though pecking did not produce food. Figure 6.2 shows the arrangement between key light and food presentation. Notice that the light onset precedes the presentation of food and appears to elicit the key peck.

The researchers called this effect **autoshaping**, an automatic way to teach pigeons to key peck. Brown and Jenkins offered several explanations for their results. In their view, the most likely explanation had to do with species characteristics of pigeons. They noted that pigeons have a tendency to peck at things they look at. The bird notices the onset of the light, orients toward it, and "the species-specific look-peck coupling eventually yields a
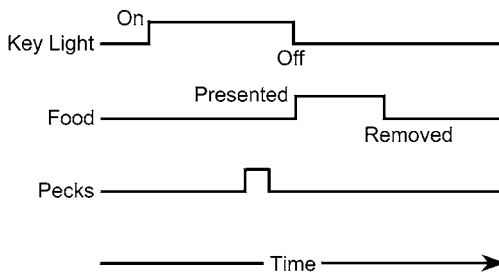
FIG. 7.2.   *Autoshaping procedures based on Brown and Jenkins (1968). Notice that the onset of the light precedes the presentation of food and appears to elicit the key peck.*

peck to the [key]" (Brown & Jenkins, 1968, p. 7). In their experiment, after the bird made the response, food was presented, and this contiguity could have accidentally reinforced the first peck.

Another possibility was that key pecking resulted from respondent conditioning. The researchers suggested that the lighted key had become a CS that evoked key pecks. This could occur because pigeons make unconditioned pecks (UR) when grain (US) is presented to them. In their experiment, the key light preceded grain presentation and may have elicited a conditioned peck (CR) to the lighted key (CS). Brown and Jenkins comment on this explanation and suggest that although it is possible, it "seem[s] unlikely because the peck appears to grow out of and depend upon the development of other motor responses in the vicinity of the key that do not themselves resemble a peck at grain" (1968, p. 7). In other words, the birds began to turn toward the key, stand close to it, make thrusting movements with their heads, and so on, all of which led to the eventual key peck. It does not seem likely that these are reflexive responses. They seem more like operant approximations that form a chain culminating in pecking.

Notice that reflexive behavior like salivation, eye blinks, startle, knee jerks, pupil dilation, and other reflexes do not depend on the conditioning of additional behavior. When you touch a hot stove, you rapidly and automatically pull your hand away. This response simply occurs when a hot object is contacted. A stove does not elicit approach to it, orientation toward it, movement of the hand and arm, and other responses. All of these additional responses seem to be operant, forming a chain or sequence behavior that avoids contact with the hot stove.

Autoshaping extends to other species and other types of reinforcement and responses. Chicks have been shown to make autoshaped responses when heat was the reinforcer (Wasserman, 1973). When food delivery is signaled for rats by lighting a lever or by inserting it into the operant chamber, the animals lick and chew on the bar (Peterson, Ackil, Frommer, & Hearst, 1972; Stiers & Silberberg, 1974). These animals also direct social behavior toward another rat that signals the delivery of food (Timberlake & Grant, 1975). Rachlin (1969) showed autoshaped key pecking in pigeons using electric shock as negative reinforcement. The major question that these and other experiments raise is: What is the nature of the behavior that is observed in autoshaping and sign-tracking experiments?

In general, research has shown that autoshaped behavior is at first respondent, but when the contingency is changed so that pecks are followed by food, the peck becomes operant. Pigeons reflexively peck (UR) at the sight of grain (US). Because the key light reliably precedes grain presentation, it acquires a conditioned stimulus function that elicits the CR of pecking the key. However, when pecking is followed by grain, it comes under the control of contingencies of reinforcement and it is an operant. To make this clear, autoshaping produces respondent behavior that can then be reinforced. Once behavior is reinforced, it is regulated by consequences that follow it, and it is considered to be operant.

ADVANCED ISSUE: THE NATURE OF AUTOSHAPED RESPONSES

Negative Automaintenance

When scientists are confronted with new and challenging data, they are typically loathe to accept the findings. This is because researchers have invested time, money, and effort in experiments that may depend on a particular view of the world. Consider a person who has made a career of investigating the operant behavior of pigeons, with rate of pecking a key as the major dependent variable. The suggestion that key pecking is actually respondent, rather than operant, behavior would not be well received by such a scientist. If key pecks are reflexive, then conclusions about operant behavior based on these responses are questionable. One possibility is to go to some effort to explain the data within the context of operant conditioning.

In fact, Brown and Jenkins (1968) suggested just this sort of explanation for their results. Recall that these experimenters pointed to the species-specific tendency of pigeons to peck at stimuli they look at. When the light is illuminated, there is a high probability that the bird looks and pecks. Some of these responses are followed by food, and pecks increase in frequency. Other investigators noted that when birds are magazine trained, they stand in the general area of the feeder, and the response key is typically at head height, just above the food tray. Anyone who has watched a pigeon knows that they have a high frequency of bobbing their heads. Since they are close to the key and are making pecking (or bobbing) motions, it is possible that a strike at the key is inadvertently followed by food delivery. From this perspective, key pecks are superstitious in the sense that they are accidentally reinforced. The superstitious explanation has an advantage because it does not require postulating a look-peck connection and it is entirely consistent with operant conditioning.

Although these explanations of pecking as an operant are plausible, the possibility remains that the autoshaped peck is respondent behavior. An ingenious experiment by Williams and Williams (1969) was designed to answer this question. In their experiment, pigeons were placed in an operant chamber, and key illumination was repeatedly followed by food. This is, of course, the same procedure that Brown and Jenkins (1968) used to show autoshaping. The twist in the Williams and Williams procedure was that if the bird pecked the key when it was lighted, food was not presented. This is called omission training, because if the pigeon pecks the key, the reinforcer is omitted, or if the response is omitted, the reinforcer is delivered.

The logic of this procedure is that if pecking is respondent, then it is elicited by the key light and the pigeon will reflexively strike the disk. If, on the other hand, pecking is operant, then striking the key prevents reinforcement and responses should not be maintained. Thus, the clear prediction is that, with the **omission procedure** in place, if the bird continues to peck the key, it is respondent behavior. Using this procedure, Williams and Williams (1969) found that pigeons frequently pecked the key, even though responses prevented reinforcement. This finding suggests that, for pigeons, the sight of grain is an unconditioned stimulus that elicits an unconditioned response peck at the food. When a key light stimulus precedes grain presentation, it becomes a CS that elicits a peck at the key (CR). Figure 7.3 shows this arrangement between stimulus events and responses. It is also the case that by not presenting the food (US) the key light (CS) is no longer paired and the response (CR) undergoes extinction.

US ─────────→ UR
(Sight of grain)   (Peck at grain)

CS ─────────→ CR
(Key light on)   (Peck at key)

Peck ─────→ No Food
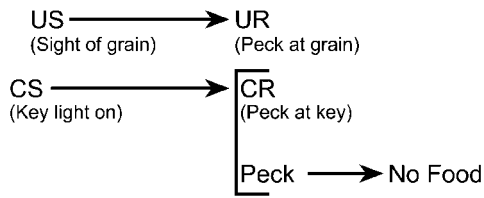
FIG. 7.3. *Omission procedures based on Williams and Williams (1969). The birds pecked the key even though these responses prevented reinforcement.*

In discussing their results, Williams and Williams state that "the stimulus-reinforcer pairing overrode opposing effects of . . . reinforcement indicate[ing] that the effect was a powerful one, and demonstrate[ing] that a high level of responding does not imply the operation of . . . [operant] reinforcement" (1969, p. 520). The puzzling aspect of this finding is that in most cases pecks to a key are regulated by reinforcement and are clearly operant. Many experiments have shown that key pecks increase or decrease in frequency depending on the consequences that follow behavior.

The Nature of the Autoshaped Response

Because of this apparent contradiction, several experiments were designed to investigate the nature of autoshaped pecking. Schwartz and Williams (1972a) preceded grain reinforcement for pigeons by turning on a red or white light on two separate keys. The birds responded by pecking the illuminated disk (i.e., they were autoshaped). On some trials, the birds were presented with both the red and the white keys. A peck on the red key prevented reinforcement, as in the omission procedure used by Williams and Williams (1969). However, pecks to the white key did not prevent reinforcement.

On these choice trials, the pigeons showed a definite preference for the white key that did not stop the delivery of grain. In other words, the birds more frequently pecked the key that was followed by the presentation of grain. Because this is a description of behavior regulated by an operant contingency (peck → food), autoshaped key pecks cannot be exclusively respondent. In concluding their paper, Schwartz and Williams wrote:

> A simple application of respondent principles cannot account for the phenomenon as originally described . . . and it cannot account for the rate and preference results of the present study. An indication of the way operant factors can modulate the performance of automaintained behavior has been given. . . . The analysis suggests that while automaintained behavior departs in important ways from the familiar patterns seen with arbitrary responses, the concepts and procedures developed from the operant framework are, nevertheless, influential in the automaintenance situation. (Schwartz & Williams, 1972a, p. 356)

Schwartz and Williams (1972b) went on to investigate the nature of key pecking by pigeons in several other experiments. The researchers precisely measured the contact duration of each peck that birds made to a response key. When the omission procedure was in effect, pigeons produced short duration pecks. If the birds were autoshaped but key pecks did not prevent the delivery of grain, peck durations were long. These same long-duration pecks occurred when the pigeons responded for food on a schedule of reinforcement. Generally, it appears that there are two types of key pecks: short-duration pecks elicited by the presentation of grain, and long-duration pecks that occur when the bird's behavior is brought under operant control.

Other evidence also suggests that both operant and respondent conditioning are involved in autoshaping. It is likely that the first autoshaped peck is a respondent that is evoked by light-food pairings. However, once pecking produces food, it comes under operant control. Even when the omission procedure is in effect, a similar process probably occurs. During omission training, a response to the key turns off the key light and food is not delivered. If the bird does not peck the key, the light is eventually turned off and food is presented. Because on these trials turning the light off is associated with reinforcement, a dark key becomes a conditioned reinforcer. Thus, the bird pecks the key and is reinforced when the light goes off. Hursh, Navarick, and Fantino (1974) provided evidence for this view. They showed that birds quit responding during omission training if the key light did not immediately go out when a response was made.

Contingencies of Sign Tracking, Autoshaping, and Instinctive Drift

In discussing their 1968 experiments on autoshaping, Brown and Jenkins report that:

> Experiments in progress show that location of the key near the food tray is not a critical feature [of autoshaping], although it no doubt hastens the process. Several birds have acquired the peck to a key located on the wall opposite the tray opening or on a side wall. (p. 7)

This description of autoshaped pecking by pigeons sounds similar to sign tracking by dogs. Both autoshaping and sign tracking involve species-characteristic behavior that is elicited by food presentation. Instinctive drift also appears to be reflexive behavior that is elicited by food. Birds peck at grain and make similar responses to the key light. That is, birds sample or taste items in the environment by the only means available to them, beak or bill contact. Dogs make food-soliciting responses to the signal that precedes food reinforcement. For example, this kind of behavior is clearly seen in pictures of wolf pups licking the mouth of an adult returning from a hunt. Raccoons rub and manipulate food items and make similar responses to coins that precede food delivery. And we have all seen humans rubbing dice together between their hands before throwing them. It is likely that autoshaping, sign tracking, and instinctive drift represent the same (or very similar) processes (for a discussion, see Hearst & Jenkins, 1974).

One proposed possibility is that all of these phenomena (instinctive drift, sign tracking, and autoshaping) are instances of **stimulus substitution**. That is, when a CS (e.g., light) is paired with a US (e.g., food), the conditioned stimulus is said to substitute for, or generalizes from, the unconditioned stimulus. This means that responses elicited by the CS (rubbing, barking and prancing, pecking) are similar to the ones caused by the US. Although this is a parsimonious account, there is evidence that it is wrong.

Recall from chapter 3 that the laws of the reflex (US → UR) do not hold for the CS → CR relationship, suggesting there is no universal substitution of the CS for the US. Also, in many experiments, the behavior evoked by the US is opposite in direction to the responses elicited by the conditioned stimulus. (see chap. 3 on Drug Use, Abuse, and Compledities of Respondent Conditioning.) Additionally, there are experiments conducted within the autoshaping paradigm that directly refute the stimulus substitution hypothesis.

In an experiment by Wasserman (1973), chicks were placed in a very cool enclosure. In this situation, a key light was occasionally turned on, and this was closely followed by the activation of a heat lamp. All the chicks began to peck the key light in an unusual way. The birds moved toward the key light and rubbed their beaks back and forth on it. This behavior is described as snuggling. These responses resemble the behavior that newborn chicks direct toward their mothers, when soliciting warmth. Chicks peck at their mothers'

feathers and rub their beaks from side to side, behavior that results in snuggling up to their mother.

At first glance, the "snuggling to the key light" seems to illustrate an instance of stimulus substitution. The chick behaves to the key light as it does toward its mother. The difficulty is that the chicks in Wasserman's (1973) experiment responded completely differently to the heat lamp than to the key light. In response to heat from the lamp, a chick extended its wings and stood motionless, behavior that it might direct toward intense sunlight. In this experiment, it is clear that the CS does not substitute for the US because these stimuli elicit completely different responses (also see Timberlake & Grant, 1975).

An alternative to stimulus substitution has been proposed by Timberlake (1983, 1993), who suggested that each US (food, water, sexual stimuli, heat lamp, and so on) controls a distinct set of species-specific responses, or a behavior system. That is, for each species there is a behavior system related to procurement of food, another related to obtaining water, still another for securing warmth, and so on. For example, the presentation of food to a raccoon activates the **behavior system** that consists of procurement and ingestion of food. One of these behaviors, rubbing and manipulating the item, is elicited. Other behaviors like bringing the food item to the mouth, salivation, chewing and swallowing of the food are not elicited. Timberlake goes on to propose that the particular responses elicited by the CS depend, in part, on the physical properties of the stimulus. Presumably, in the Wasserman experiment, properties of the key light (a visual stimulus raised above the floor) were more closely related to snuggling than to standing still and extending wings.

At the present time, it is not possible to predict which response in a behavior system will be elicited by a given CS. That is, a researcher can predict that the CS will elicit one or more of the responses controlled by the US but cannot specify which responses will occur. One possibility is that the salience of the US affects which responses are elicited by the CS. For example, as the intensity of the heat source increases (approximating a hot summer day) the chicks response to the CS key light may change from snuggling to behavior appropriate to standing in the sun (open wings and motionless).

Operant Contingencies Predominate over Respondent Regulation of Behavior

As has been noted, there are circumstances in which both operant and respondent conditioning occur. Moreover, responses that on the basis of topography are typically operant are occasionally regulated by respondent processes (and as such are respondents). There are also occasions in which behavior that, in form or topography, appears to be reflexive is regulated by the consequences that follow it.

Reinforcing Reflexive Behavior

In the 1960s, a number of researchers attempted to show that involuntary reflexive or autonomic responses could be operantly conditioned (Kimmel & Kimmel, 1963; Miller & Carmona, 1967; Shearn, 1962). Miller and Carmona (1967) deprived dogs of water and monitored their respondent level of salivation. The dogs were separated into two groups. One group was reinforced with water for increasing salivation, and the other group was reinforced for a decrease. Both groups of animals showed the expected change in amount of salivation. That is, the dogs that were reinforced for increasing saliva flow showed an increase, and the dogs reinforced for less saliva flow showed a decrease.

At first glance, this result seems to demonstrate the operant conditioning of salivation. However, Miller and Carmona (1967) noticed an associated change in the dogs' behavior that could have produced the alteration in salivation. Dogs that increased saliva flow appeared to be alert, and those that decreased it were described as drowsy. For this reason, the results are suspect—salivary conditioning may have been mediated by a change in the dogs' operant behavior. Perhaps drowsiness was operant behavior that resulted in decreased salivation, and being alert increased the reflex. In other words, the change in salivation could have been part of a larger, more general behavior pattern that was reinforced. Similar problems occurred with other experiments. For example, Shearn (1962) showed operant conditioning of heart rate, but this dependent variable can be affected by a change in pattern of breathing.

The Miller Experiments

It is difficult to rule out operant conditioning of other behavior as a mediator of reinforced reflexes. However, Miller and DiCara (1967) conducted a classic experiment in which this explanation was not possible. The researchers reasoned that operant behavior could not mediate conditioning if the subject had its skeletal muscles immobilized. To immobilize their subjects, which were white rats, they used the drug curare. This drug paralyzes the skeletal musculature and interrupts breathing.

There are a number of technical problems associated with experiments like this. Because breathing is affected by curare, the rats had to be given artificial respiration. Careful monitoring of the animals' physiological or autonomic responses was necessary to show any conditioning effects. When curarized, the rats could not swallow food or water, and this made it difficult to reinforce the animals' behavior. Miller and DiCara (1967) solved this last problem by using electrical stimulation of the rats' pleasure center, which is located in the brain, as reinforcement for visceral reflexes.

Before starting the experiment, the rats had electrodes permanently implanted in their hypothalamus. This was done in a way that allowed the experimenters to connect and disconnect the animals from the equipment that pulsed the pleasure center. To make certain that the stimulation was reinforcing, the rats were trained to press a bar in order to turn on a brief microvolt pulse. This procedure demonstrated that the pulse was, in fact, reinforcing, since the animals pressed a lever for the stimulation.

At this point, Miller and DiCara (1967) curarized the rats and reinforced half of them with electrical stimulation for decreasing their heart rate. The other animals were reinforced for an increase in heart rate. Figure 7.4 shows the results of this experiment. Both groups start out with heart rates in the range of 400 to 425 beats per minute. After 90 min of contingent reinforcement, the groups are widely divergent. The group that was reinforced for slow heart
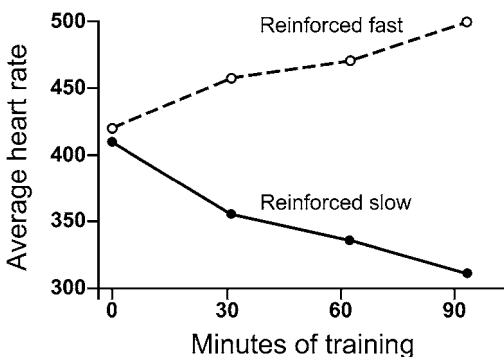
FIG. 7.4. *Effects of curare immobilization of skeletal muscles on conditioning of heart rate in the Miller and DiCara (1967) experiment. Half the rats received electrical brain stimulation for increasing heart rate; and the other half, for decreasing heart rate.*

rate is at about 310 beats per minute, and the fast-rate group is at approximately 500 beats per minute.

Miller and Banuazizi (1968) extended this finding. They inserted a pressure-sensitive balloon into the large intestine of rats, which allowed them to monitor intestinal contractions. At the same time, the researchers measured the animals' heart rate. As in the previous experiment, the rats were curarized and reinforced with electrical brain stimulation. Under different conditions, reinforcement was made contingent on increased or decreased intestinal contractions. Also, the rats were reinforced on some occasions for a decrease in heart rate and at other times for an increase.

The researchers showed that reinforcing intestinal contractions or relaxation changed them in the appropriate direction. The animals also showed either an increase or a decrease in heart rate when this response was made contingent on brain stimulation. Finally, Miller and Banuazizi (1968) demonstrated that a change in intestinal contractions did not affect heart rate, and conversely, changes in heart rate did not affect contractions.

Thus, contingent reinforcement modified behavior, usually considered to be reflexive, under conditions in which skeletal responses could not affect the outcome. Also, the effects were specific to the response that was reinforced, showing that brain stimulation was not generating general physiological changes that produced the outcomes of the experiment. It seems that responses that are usually elicited can be conditioned using an operant contingency of reinforcement. Greene and Sutor (1971) extended this conclusion to humans, showing that a galvanic skin response, or GSR, could be regulated by negative reinforcement (for more on operant autonomic conditioning, see DiCara, 1970; Engle, 1993; Jonas, 1973; Kimmel, 1974; Miller, 1969).

Although this conclusion is probably justified, the operant conditioning of autonomic responses like blood pressure, heart rate, and intestinal contraction has run into difficulties. Miller has even had problems replicating the results of his own experiments (Miller & Dworkin, 1974). The weight of the evidence does suggest that reflexive responses are, at least in some circumstances, affected by the consequences that follow them. However, this behavior is also subject to control by contiguity or pairing of stimuli. It is relatively easy to change heart rate by pairing a light (CS) with electric shock and then using the light to change heart rate. It should be evident that controlling heart rate with an operant contingency is no easy task. Thus, autonomic behavior may not be exclusively tied to respondent conditioning, but respondent conditioning is particularly effective with these responses.

FOCUS ON TEACHING: OPERANTS AND RESPONDENTS

Clearly, the fundamental distinction between operant and respondent conditioning is operational. The distinction is operational because conditioning is defined by the operations that produce it. Operant conditioning involves a contingency between behavior and its following consequences. Respondent conditioning entails the pairing of stimuli.

Autonomic responses are usually respondents and are best modified by respondent conditioning. If, however, they are changed by the consequences that follow them, they are operants. Similarly, skeletal responses are usually operant and they are most readily changed by contingencies of reinforcement, but when they are modified by the pairing of stimuli they are respondents. The whole organism is impacted by contingencies whether they be operant or respondent. How the use of one procedure or another and the dependent variables recorded contribute to the issue at hand depends on the research question.

The Biological Context of Conditioning

As we stated in chapter 1, the evolutionary history, ontogenetic history, and current phys-
iological status of an organism is the **context for conditioning**. Edward Morris (1992) has
described the way we use the term *context*:

> Context is a funny word. As a non-technical term, it can be vague and imprecise. As a technical
> term, it can also be vague and imprecise—and has been throughout the history of psychology.
> In what follows, I mean to use it technically and precisely. . . . First, the historical context—
> phylogenetic and ontogenetic, biological and behavioral—establishes the current structure and
> function of biology (anatomy and physiology) and behavior (form and function). Second, the
> form or structure of the current context, organismic or environmental, affects (or enables) what
> behavior can physically or formally occur. Third, the current context affects (actualizes) the
> functional relationships among stimuli and response (i.e., their "meaning" for one another).
> (p. 14)

Reinforcing events, responses, and stimuli may vary from species to species. A hungry
dog can be reinforced with meat for jumping a hurdle, and a pigeon will fly to a particular
location to get grain. These are obvious species differences, but there are more subtle effects
of the biological context. The rate of acquisition and level of behavior once established
may be influenced by an organism's physiology, as determined by species history. Moreover,
within a species, reinforcers, stimuli, and responses can be specific to particular situations.
Behavior that is observed with any one set of responses, stimuli, and reinforcers may
change when different sets are used. In addition, different species may show different
environment–behavior relationships when the same set of responses and events is inves-
tigated. However, within a particular set of events, the principles of behavior hold. Also,
principles of behavior like extinction, discrimination, spontaneous recovery, and so on
generalize across species. The behaviors of school children working at math problems for
teacher attention and those of pigeons pecking keys for food are regulated by contingencies
of reinforcement.
As early as 1938, Skinner recognized that a comprehensive understanding of the be-
havior of organisms required the study of more than "arbitrary" stimuli, responses, and
reinforcers (Skinner, 1938, pp. 10–11). However, by using simple stimuli, easy-to-execute
and record responses, and precise reinforcers, Skinner hoped to identify general princi-
ples of conditioning. By and large, this same strategy is used today in the modern operant
laboratory.
The biological context suggests that the needed element is a specification of how behavior
principles apply given the organism and the environmental situation. Also, it is worth
noting that in many instances, principles of behavior generalize across responses, reinforcers,
stimuli, and organisms. With regard to this generalization, human conduct is probably more
sensitive to environmental influence than the behavior of any other species. In this sense,
humans may be the organisms best described by general principles of behavior.

Taste Aversion Learning

In an experiment by Wilcoxon, Dragoin, and Kral (1971), quail and rats were given blue
salty water. After the animals drank the water, they were made sick. Following this, the
animals were given a choice between water that was not colored but tasted salty and plain
water that was colored blue. The rats avoided the salty-flavored water, and the quail would
not drink the colored solution. This finding is not difficult to understand—when feeding or

Type of water

	Bright-Noisy	Flavored
Shock	Bright-Noisy drinking followed by shock	Flavored drinking followed by shock
Poison	Bright-Noisy drinking followed by poison	Flavored drinking followed by poison

Type of aversive stimulus (row label, left side)

FIG. 7.5.   *Conditions used to show taste aversion conditioning by rats in an experiment by Garcia and Koelling (1966). Relation of cue to consequence in avoidance learning.* Note: *Based on a description of procedures from "Relation of Cue to Consequence in Avoidance Learning," by J. Garcia and R. A. Koelling, 1966,* Psychonomic Science, 4, *pp. 123–124.*

drinking, birds rely on visual cues; and rats are sensitive to taste and smell. In the natural habitat, drinking liquids that produce illness should be avoided, and this has obvious survival value. Because quail typically select food on the basis of what it looks like, they avoided the colored water. Rats, on the other hand, avoided the taste because it had been associated with sickness.

In the Wilcoxon et al. (1971) experiment, the taste and color of the water was a compound CS that was paired with the US illness. Both species showed **taste aversion learning**. That is, the animals came to avoid one or the other of the conditioned stimulus elements based on biological history. In other words, the biology of the organism dictated which cue became a CS, but the conditioning of the aversion, or CS–US pairing, was the same for both species. Of course, a bird that relied on taste for food selection would be expected to associate taste and illness. This phenomenon has been called **preparedness**—quail are more biologically prepared to discriminate critical stimulus features when sights are associated with illness, and rats respond best to a flavor–illness association. Other experiments have shown that within a species the set of stimuli, responses, and reinforcers may be affected by the biology of the organism.

Garcia and his colleagues conducted several important experiments that were concerned with the conditions that produce taste aversion in rats.[1] Garcia and Koelling (1966) had thirsty rats drink tasty (saccharin-flavored) water or unflavored water that was accompanied by flashing lights and gurgling noises (bright-noisy water). After the rats drank the water, one half of each group was immediately given an electric shock for drinking. The other animals were made ill by injecting them with lithium chloride or by irradiating them with X rays. Lithium chloride and high levels of X rays produce nausea roughly 20 min after administration. Figure 7.5 shows the four conditions of the experiment.

After aversion training, the rats were allowed to drink, and their water intake was measured. The major results of this experiment are shown in Fig. 7.6. Baseline measures of drinking were compared to fluid intake after shock, lithium or X rays were paired with either a visual or flavor stimulus (CS). Both shock and illness induced by lithium or X-ray exposure suppressed drinking. Those rats that received shock after drinking the bright-noisy water

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[1]It is worth noting that the rat is an ideal subject in these experiments for generalizing to humans. Like humans the rat is omnivorous—it eats both meats and vegetables. Rats live wherever humans do and are said to consume 20% of the world's human food supply.
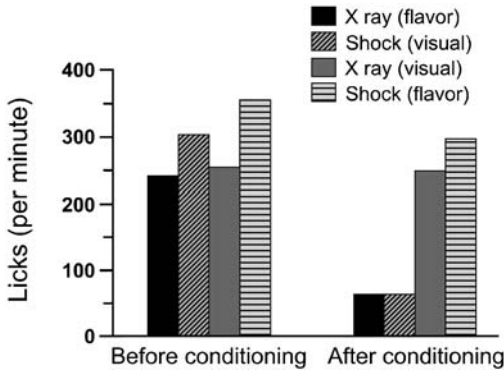
FIG. 7.6. *Major results of the taste-aversion experiment by Garcia and Koelling (1966). Relation of cue to consequence in avoidance learning.* Note: *Adapted from "Relation of Cue to Consequence in Avoidance Learning," by J. Garcia and R. A. Koelling, 1966,* Psychonomic Science, 4, *pp. 123–124.*

and the ones that were made sick after ingesting the flavored water substantially reduced their fluid intake. Water intake in the other two groups was virtually unaffected. The animals that were made sick after drinking the bright-noisy water and those that were shocked for ingesting the flavored water did not show a conditioned aversion.

These results are unusual for several reasons. During traditional respondent conditioning, the CS and US typically overlap or are separated by only a few seconds. In the Garcia and Koelling (1966) experiment, the taste CS was followed much later by the US, drug, or X ray. Also, it is often assumed that the choice of CS and US is irrelevant for respondent conditioning. (Pavlov advocated that the choice of CS was arbitrary; he said anything would do.) However, taste and grastrointestinal malaise produced aversion, but taste and shock did not condition. Therefore, it appears that for some stimuli the animal is prepared by nature to make a connection, and for others they may even be contraprepared (Seligman, 1970). Generally, for other kinds of classical conditioning many CS–US pairings are required, but aversion to taste conditioned after a single pairing of flavor-illness. In fact, the animal need not even be conscious in order for an aversion to be formed. (Provenza, Lynch, & Nolan 1994). Finally, it appears necessary for the animal to experience nausea in order for taste aversion to condition. Being poisoned, for example by strychnine, which inhibits spinal neurons, does not work (Cheney, Vander Wall, & Poehlmann, 1987).

These results can be understood by considering the biology of the rat. The animals are omnivorous, and as such, they eat a wide range of meat and vegetable foods. Rats eat 10 to 16 small meals each day and frequently ingest novel food items. The animals are sensitive to smell and taste but have relatively poor sight, and they cannot vomit. When contaminated, spoiled, rotten, or naturally toxic food is eaten, it typically has a distinctive smell and taste. For this reason, taste and smell but not visual cues are associated with illness. Conditioning after a long time period between CS and US occurs because there is usually a delay between ingestion of a toxic item and nausea. It would be unusual for a rat to eat and have this quickly followed by an aversive stimulus (flavor-shock); hence, there is little conditioning. The survival value of one-trial conditioning, or quickly avoiding food items that produce illness, is obvious—eat that food again and it may kill you.

Taste aversion learning has been replicated and extended in many different experiments (see Barker, Best, & Domjan, 1977; Rozin & Kalat, 1971). Revusky and Garcia (1970) showed that the interval between a flavor CS and an illness inducing US could be as much as 12 hr. Other findings suggest that a new novel taste is more easily conditioned than one that an animal has had experience with (Revusky & Bedarf, 1967). Novelty in setting (as well as taste) has been shown to increase avoidance of food when poison is

the unconditioned stimulus. For example, Mitchell, Kirschbaum, and Perry (1975) fed rats in the same container at a particular location for 25 days. Following this, the researchers changed the food cup and made the animals ill. After this experience, the rats avoided eating from the new container. Taste aversion learning also occurs in humans of course (Logue, 1979, 1985, 1988a). Dr. Alexandra Logue of the State University of New York, Stony Brook, has concluded:

> Conditioned food aversion learning in humans appears very similar to that in other species. As in other species, aversions can be acquired with long CS-US delays, the aversion most often forms to the taste of food, the CS usually precedes the US, aversions frequently generalized to foods that taste qualitatively similar, and aversions are more likely to be formed to less preferred, less familiar foods. Aversions are frequently strong. They can be acquired even though the subject is convinced that the food did not cause the subject's illness. (1985, p. 327)

Imagine that on a special occasion you spend an evening at your favorite restaurant. Stimuli at the restaurant include your date, waiters, waitresses, candles on the table, china, art on the wall, and so on. You order several courses, most of them familiar, and "just to try it out" you have pasta primavera for the first time. What you do not know is that a flu virus has invaded your body and is percolating away while you eat. Early in the morning, you wake up with a clammy feeling, rumbling stomach, and a hot acid taste in the back of your throat. You spew primavera sauce, wine, and several other ugly bits and pieces on the bathroom mirror.

The most salient stimulus at the restaurant was probably your date. Alas, is the relationship finished? Will you get sick at the next sight of your lost love? Is this what the experimental analysis of behavior has to do with romance novels? Of course, the answer to these questions is no. It is very likely that you will develop a strong aversion to pasta primavera. Interestingly, you may clearly be aware that your illness was caused by the flu, not by the new food. You may even understand taste aversion learning but, as one of the authors (Cheney) of this book can testify to, it makes no difference. The novel-taste CS, because of its single pairing (delayed by several hours even) with nausea, will likely be avoided in the future.

Taste aversion learning may help to explain anorexia in humans. In activity anorexia (Epling & Pierce, 1992, 1996a), food restriction increases physical activity, and mounting physical activity, reduces food intake (see On The Applied Side in this chapter). Bo Lett and Virginia Grant (Lett & Grant, 1996), two researchers, at Memorial University in Newfoundland, Canada, suggested that human anorexia induced by physical activity could involve taste aversion learning. Basically, it is known that physical activity like wheel running suppresses food intake in rats (e.g., Epling, Pierce, & Stefan, 1983; Routtenberg & Kuznesof, 1967). Lett and Grant proposed that suppression of eating could be due to a conditioned taste aversion (CTA) induced by wheel running. According to this view, a distinctive taste becomes a conditioned stimulus (CS) for reduced consumption when followed by the unconditioned stimulus (US)—nausea from wheel running. In support of this hypothesis, rats exposed to a flavored liquid that was paired with wheel running drank less of the liquid than control rats that remained in their home cages (Lett & Grant, 1996; see also, Heth, Inglis, Russell, & Pierce, 2001).

Further research by Sarah Salvy in Pierce's (author of textbook) laboratory at the University of Alberta indicates that CTA induced by wheel running involves respondent processes (Salvy, Pierce, Heth, & Russell, 2002), although operant components have not been ruled out. Currently, Salvy is conducting "bridging experiments" in which a distinctive food rather than a flavored liquid is followed by wheel running. In a recent study (unpublished), rats that ate food treats followed by bouts of wheel running consumed less of the food compared

to control rats receiving the food followed by access to a locked wheel. That is, CTA induced by wheel running appears to generalize to food stimuli. One possibility is that activity anorexia in humans is partly caused by taste aversion to food induced by increasing physical activity (e.g., intensive exercising or hyperactivity involving excessive walking or pacing).

Adjunctive Behavior

On time-based or interval schedules, organisms may emit behavior patterns that are not required by the contingency of reinforcement (Staddon & Simmelhag, 1971). If you received $5 for pressing a lever once every 10 min, you might start to pace, twiddle your thumbs, have a sip of soda, or scratch your head between payoffs on a regular basis. Staddon (1977) has noted that during the time between food reinforcers, animals engage in three distinct types of behavior. Immediately after food reinforcement, **interim behavior** like drinking water may occur; next an organism may engage in **facultative behavior** that is independent of the schedule of reinforcement (e.g., rats may groom themselves). Finally, as the time for reinforcement gets close, animals engage in food-related activities called **terminal behavior**, such as orienting toward the lever or food cup. The first of these categories, interim or **adjunctive behavior**,[2] is of most interest for the present discussion, because it is behavior that is not required by the schedule but is induced by reinforcement. Because the behavior is induced as a side effect of the reinforcement schedule, it is also referred to as **schedule-induced behavior**.

When a hungry animal is placed on a schedule of reinforcement, it may, if allowed to drink, ingest an excessive amount of water. Falk (1961, 1964, 1969) has suggested that this **polydipsia**, or excessive drinking, is adjunctive behavior induced by the time-based delivery of food. A rat that is working for food on an intermittent schedule may drink as much as half its body weight during a single session (Falk, 1961). This drinking occurs even though the animal is not water deprived. The rat may turn toward the lever, press for food, obtain and eat the food pellet, drink excessively, groom itself, and then repeat the sequence. Pressing the lever is required for reinforcement, and grooming may occur in the absence of food delivery, but polydipsia appears to be induced by the schedule. In general, adjunctive behavior refers to any excessive and persistent behavior pattern that occurs as a side effect of reinforcement delivery. The schedule may require a response for reinforcement, or it may simply be time based, as when food pellets are given every 30 s no matter what the animal is doing. Additionally, the schedule may deliver reinforcement on a fixed-time basis (e.g., every 60 s), or it may be constructed so that the time between reinforcers varies (e.g., 20 s, then 75, 85, 60 s, and so on).

Schedules of food reinforcement have been shown to generate such adjunctive behavior as attack against other animals (Flory, 1969; Hutchinson, Azrin, & Hunt, 1968; Pitts & Malagodi, 1996), licking at an airstream (Mendelson & Chillag, 1970), drinking water (Falk, 1961), chewing on wood blocks (Villareal, 1967), and preference for oral cocaine administration (Falk, D'Mello, & Lau, 2001; Falk & Lau, 1997). Adjunctive behavior has been observed in pigeons, monkeys, rats, and humans; reinforcers have included water, food, shock avoidance, access to a running wheel, money, and for male pigeons the sight of a female (see Falk, 1971, 1977; Staddon, 1977, for reviews). Muller, Crow, and Cheney (1979) induced locomotor activity in college students and retarded adolescents with fixed-interval (FI) and fixed-time (FT) token delivery. Stereotypic and self-injurious behavior of humans with developmental disabilities also have been viewed as adjuctive to the schedule

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[2]Induced behavior that immediately follows reinforcement has been called interim by Staddon (1977) and adjunctive by Falk (1961, 1964, 1969). The terms are interchangeable in this book.
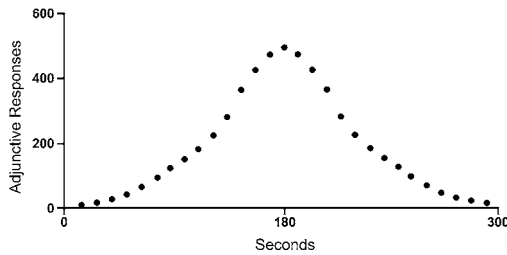
FIG. 7.7. *A bitonic relationship showing time between food pellets and amount of adjunctive water drinking.*

of reinforcement (Lerman, Iwata, Zarcone, & Ringdahl, 1994). Thus, adjunctive behavior occurs in different species, is generated by a variety of reinforcement procedures, and extends to a number of induced responses.

A variety of conditions affect adjunctive behavior, but the schedule of reinforcement delivery and the deprivation status of the organism appear to be the most important. As the time between reinforcement deliveries increases from 2 to 180 s, adjunctive behavior increases. After 180 s, adjunctive behavior drops off and reaches low levels at 300 s. For example, a rat may receive a food pellet every 10 s and drink a bit more than a normal amount of water between pellet deliveries. When the schedule is changed to 100 s, drinking increases; polydipsia goes up again if the schedule is stretched 180 seconds. As the time between pellets is further increased to 200, 250, and then 300 seconds, water consumption goes down. This increase, peak, and then drop in schedule-induced behavior is illustrated in Figure 7.7 and is called a bitonic function. The function has been observed in species other than the rat, and occurs for other adjunctive behavior (see Keehn & Jozsvai, 1989, for contrary evidence).

In addition to the reinforcement schedule, adjunctive behavior becomes more and more excessive as the level of deprivation increases. A rat that is at 80% of its normal body weight and is given food pellets every 20 s will drink more water than an animal that is at 90% weight and on the same schedule. Experiments have shown that food-schedule-induced drinking (Falk, 1969), airstream licking (Chillag & Mendelson, 1971), and attack (Dove, 1976) go up as an animal's body weight goes down. Thus, a variety of induced activities escalate when deprivation for food is increased and when food is the scheduled reinforcer.

Falk (1977) has noted that "on the surface" adjunctive behavior does not seem to make sense:

> [Adjunctive activities] are excessive and persistent. A behavioral phenomenon which encompasses many kinds of activities and is widespread over species and high in predictability ordinarily can be presumed to be a basic mechanism contributing to adaptation and survival. The puzzle of adjunctive behavior is that, while fulfilling the above criteria its adaptive significance has escaped analysis. Indeed, adjunctive activities have appeared not only curiously exaggerated and persistent, but also energetically quite costly. (p. 326)

Falk (1977) goes on to argue that, in fact, induced behavior does make biological sense.

The argument made by Falk is complex and beyond the scope of this book. Simply stated, adjunctive behavior may be related to what ethologists call displacement behavior. **Displacement behavior** is seen in the natural environment and is "characterized as irrelevant, incongruous, or out of context. . ... For example, two skylarks in combat might suddenly cease fighting and peck at the ground with feeding movements" (Falk, 1971, p. 584). The activity of the animal does not make sense given the situation, and the displaced responses do not appear to follow from immediately preceding behavior. Like adjunctive behavior, displacement activities arise when consummatory (i.e., eating, drinking, etc.) activities are

interrupted or prevented. In the laboratory, a hungry animal is interrupted from eating when small bits of food are intermittently delivered.

Adjunctive and displacement activities occur at high strength when biologically relevant behavior (i.e., eating or mating) is blocked. Recall that male pigeons engage in adjunctive behavior when reinforced with the sight of (but not access to) female members of the species. These activities may increase the chance that other possibilities in the environment are contacted. A bird that pecks at tree bark when prevented from eating may find a new food source. Armstrong (1950) has suggested that "a species which is able to modify its behavior to suit changed circumstances by means of displacements, rather than by the evolution of ad hoc modifications starting from scratch will have an advantage over other species" (Falk, 1971, p. 587). Falk, however, goes on to make the point that evolution has probably eliminated many animals that engage in nonfunctional displacement activities.

Adjunctive behavior is another example of activity that is best analyzed by considering the biological context. Responses that do not seem to make sense may ultimately prove adaptive. The conditions that generate and maintain adjunctive and displacement behavior are similar. Both types of responses may reflect a common evolutionary origin, and this suggests that principles of adjunctive behavior will be improved by analyzing the biological context.

ON THE APPLIED SIDE: ACTIVITY ANOREXIA AND THE INTERRELATIONS BETWEEN EATING AND PHYSICAL ACTIVITY

In 1967, Carl Cheney (who was then at Eastern Washington State University) ran across a paper (Routtenberg & Kuznesof, 1967) that reported self-starvation in laboratory rats. Cheney (author of this textbook) thought this was an unusual effect, since most animals are reluctant to kill themselves for any reason. Because of this, he decided to replicate the experiment, and he recruited Frank Epling (former author of this textbook), an undergraduate student at the time, to help run the research. The experiment was relatively simple. Cheney and Epling (1968) placed a few rats in running wheels and fed them for 1 hr each day. The researchers recorded the daily number of wheel turns, the weight of the rat, and the amount of food eaten. Surprisingly, the rats ran more and more, ate less and less, lost weight, and, if allowed to continue in the experiment, died of starvation. Importantly, the rats were not required to run, and they had plenty to eat, but they stopped eating and ran as much as 10 miles a day.

Twelve years later, Frank Epling (who was then an assistant professor of psychology at the University of Alberta) began to do collaborative research with David Pierce (author of this textbook), an assistant professor of sociology at the same university. They wondered if anorexic patients were hyperactive, like the animals in the self-starvation experiments. If they were, it might be possible to develop an animal model of anorexia. Clinical reports indicated that, indeed, many anorexic patients were excessively active. For this reason, Epling and Pierce began to investigate the relationship between wheel running and food intake (Epling & Pierce, 1988; Epling, Pierce, & Stefan, 1983; Pierce & Epling, 1991). The basic findings are that physical activity decreases food intake and that decreased food intake increases activity. Epling and Pierce call this feedback loop **activity anorexia** and argue that a similar cycle occurs in anorexic patients (see Epling & Pierce, 1992).

This analysis of eating and exercise suggests that these activities are interrelated. Depriving an animal of food should increase the reinforcing value of exercise. Rats that are

required to press a lever in order to run on a wheel should work harder for wheel access when they are deprived of food. Additionally, engaging in exercise should reduce the reinforcing value of food. Rats that are required to press a lever for food pellets should not work as hard for food following a day of exercise. Pierce, Epling, and Doug Boer, a graduate student, designed two experiments to test these ideas (Pierce, Epling, & Boer, 1986).

Reinforcement Value of Physical Activity

We asked whether food deprivation increased the reinforcing effectiveness of wheel running. If animals worked harder for an opportunity to exercise when deprived of food, this would show that running had increased in its capacity to support behavior. That is, depriving an animal of food should increase the reinforcing value of running. This is an interesting implication, because increased reinforcement effectiveness is usually achieved by withholding the reinforcing event. Thus, to increase the reinforcement value of water, a researcher typically withholds access to water, but (again) in this case food is withheld in order to increase the reinforcing value of wheel access.

We used nine young rats of both sexes to test the reinforcing effectiveness of wheel running as food deprivation changed. The animals were trained to press a lever to obtain 60 s of wheel running. When the rat pressed the lever, a brake was removed and the running wheel was free to turn. After 60 s, the brake was again activated, and the animal had to press the lever to obtain more wheel movement for running. The apparatus that we constructed for this experiment is shown in Fig. 7.8.

Once lever pressing for wheel running was stable, each animal was tested when it was food deprived (75% of normal weight) and when it was at free-feeding weight. Recall that the animals were expected to work harder for exercise when they were food deprived. To measure the reinforcing effectiveness of wheel running, the animals were required to press the lever more and more for each opportunity to run. Specifically, the rats were required to press 5 times to obtain 60 s of wheel running, then 10, 15, 20, 25, and so on. The point at which they gave up pressing for wheel running was used as an index of the reinforcing effectiveness of exercise.

The results of this experiment are shown in Fig. 7.9. All animals lever pressed for wheel running more when food deprived than when at normal weight. In other words, animals
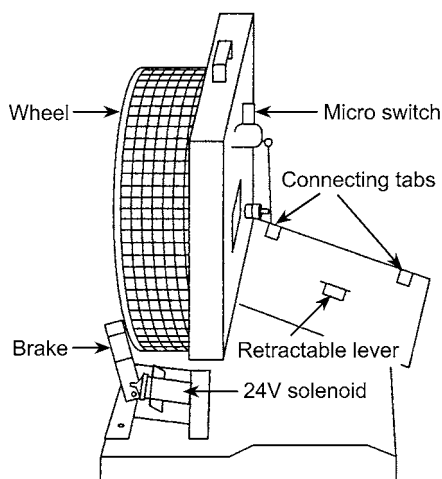
FIG. 7.8. *Wheel-running apparatus used in the Pierce, Epling, and Boer (1986) experiment on the reinforcing effectiveness of physical activity as a function of food deprivation.* Note: *From "Deprivation and Satiation: The Interrelations between Food and Wheel Running," by W. D. Pierce, W. F. Epling, and D. P. Boer, 1986,* Journal of the Eperimental Analysis of Behavior, 46, *pp. 199–210.*
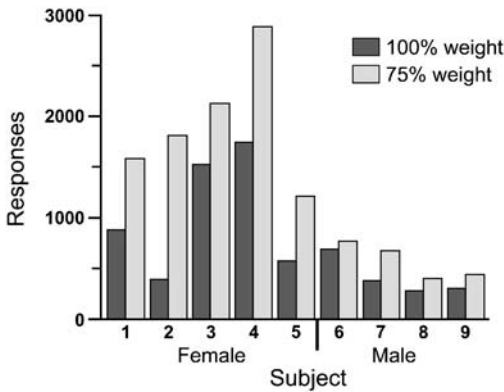
FIG. 7.9. *Number of bar presses for 60 s of wheel running as a function of food deprivation.* Note: *From "Deprivation and Satiation: The Interrelations between Food and Wheel Running," by W. D. Pierce, W. F. Epling, and D. P. Boer, 1986,* Journal of the Eperimental Analysis of Behavior, 46, *pp. 199–210.*

worked harder for exercise when they were hungry. Further evidence indicated that the reinforcing effectiveness went up and down when an animal's weight was made to increase and decrease. For example, one rat pressed the bar 1,567 times when food deprived, 881 times at normal weight, and 1,882 times when again food deprived. This indicated that the effect was reversible and was tied to the level of food deprivation.

Reinforcement Value of Food

In a second experiment, we investigated the effects of exercise on the reinforcing effectiveness of food. Four male rats were trained to press a lever for food pellets. When lever pressing occurred reliably, we tested the effects of exercise on each animal's willingness to work for food. In this case, we expected that a day of exercise would decrease the reinforcement effectiveness of food on the next day.

Test days were arranged to measure the reinforcing effects of food. One day before each test, animals were placed in their wheels without food. On some of the days before a test, the wheel was free to turn, and on other days it was not. Three of the four rats ran moderately in their activity wheels on exercise days. One lazy rat did not run when given the opportunity. This animal was subsequently forced to exercise on a motor-driven wheel. All animals were well rested (3 to 4 hr of rest) before each food test. This ensured that any effects were not caused by fatigue.

Reinforcement effectiveness or value of food was assessed by counting the number of lever presses for food as food became more and more difficult to obtain. For example, an animal had to press 5 times for the first food pellet, 10 for the next, then 15, 20, 25, and so on. As in the first experiment, the giving-up point was used to measure reinforcement effectiveness. Presumably, the more effective or valuable the reinforcer (i.e., food) the harder the animal would work for it.

Figure 7.10 shows that when test days were preceded by a day of exercise, the reinforcing effectiveness of food decreased sharply. Animals pressed the lever more than 200 times when they were not allowed to run, but no more than 38 times when running preceded test sessions. Food no longer supported lever presses following a day of moderate wheel running, even though a lengthy rest period preceded the test. Although wheel running was moderate, it represented a large change in physical activity since the animals were previously sedentary.

Prior to each test, the animals spent an entire day without food. Because of this, the reinforcing effectiveness of food should have increased. Exercise, however, seemed to override
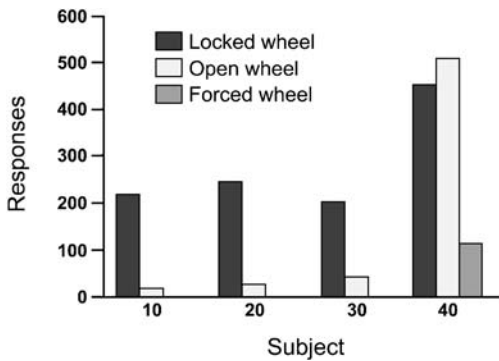
FIG. 7.10.   *Number of bar presses for food when rats were allowed to run on a wheel as compared to those when there was no physical activity.* Note: *From "Deprivation and Satiation: The Interrelations between Food and Wheel Running," by W. D. Pierce, W. F. Epling, and D. P. Boer, 1986,* Journal of the Eperimental Analysis of Behavior, 46, *pp. 199–210.*

the effects of food deprivation, since responding for food went down rather than up. Other evidence from these experiments suggested that the effects of exercise were similar to the effects when feeding the animal. This finding is important for understanding activity anorexia, since exercise appears to substitute for eating.

The rat that was forced to run also showed a sharp decline in lever pressing for food (see Fig. 7.10). Exercise was again moderate but substantial relative to the animal's sedentary history. Because the reinforcement effectiveness of food decreased with forced exercise, we concluded that both forced and voluntary physical activity produce a decline in the value of food reinforcement. This finding suggests that people who increase their physical activity because of occupational requirements (e.g., ballet dancers) may value food less.

The Biological Context of Eating and Activity

In our view, the motivational interrelations between eating and physical activity have a basis in natural selection. Natural selection favored those animals that increased locomotor activity in times of food scarcity. During a famine, organisms can either stay and conserve energy or become mobile and travel to another location. The particular strategy adopted by a species depends on natural selection. If travel led to reinstatement of food supply and remaining resulted in starvation, then those animals that traveled gained reproductive advantage.

A major problem for an evolutionary analysis of activity anorexia is accounting for the decreased appetite of animals who travel to a new food patch. The fact that increasing energy expenditure is accompanied by decreasing caloric intake seems to violate common sense. From a homeostatic (i.e., energy balance) perspective, food intake and energy expenditure should be positively related. In fact, this is the case if an animal has the time to adjust to a new level of activity and food supply is not greatly reduced.

When depletion of food is severe, however, travel should not stop when food is infrequently contacted. This is because stopping to eat may be negatively balanced against reaching a more abundant food patch. Frequent contact with food would signal a replenished food supply, and this should reduce the tendency to travel. Recall that a decline in the reinforcing value of food means that animals will not work hard for nourishment. When food is scarce, considerable effort may be required to obtain it. For this reason, animals ignore food and continue to travel. However, as food becomes more plentiful and the effort to acquire it decreases, the organism begins to eat. Food consumption lowers the reinforcement value of physical activity and travel stops. On this basis, animals that expend large amounts of energy on migration or trek become anorexic.

KEY WORDS

Activity anorexia
Adjunctive behavior
Autoshaping
Behavior system
Context for conditioning
Displacement behavior

Facultaive behavior
Instinctive drift
Interim behavior
Negative automaintenance
Omission procedure
   (training)

Polydipsia
Preparedness
Schedule-induced behavior
Sign tracking
Taste aversion learning
Terminal behavior

ON THE WEB

http://psych.rutgers.edu/program_areas/bbn/bbn_00.html Students who are interested in schedule-induced behavior or foraging models of behavior may be interested in this Web site for Biopsychology and Behavioral Neuroscience at Rutgers University. Click on the Faculty home pages for George Collier and John Falk.

http://www.jsu.edu/depart/psychology/sebac/fac-sch/spot-peck/spot-peck.html Go to this Web address to read an actual scientific article on "Stereotyped adjunctive pecking by caged pigeons" (Palya & Zacny, 1980) from *Animal Learning and Behavior*, 8, 293–303.

STUDY QUESTIONS

1. State what is meant by the dual function of a stimulus. Give an example of such a stimulus. (183)
2. Discuss a pigeon's key pecking as an operant and as a respondent. (184)
3. Outline the Brelands' effect of instinctive drift. How does this effect fit within a respondent conditioning view? (185)
4. What is sign tracking and how does it apparently challenge the operant, three-term contingency model (S^D: R S^r)? (186) Describe the Jenkins, Barrera, Ireland, and Woodside (1978) experiment and its findings. How do respondent relations help to explain these findings? (186–187)
5. Compare shaping by successive approximation to the autoshaping procedure of Brown and Jenkins (1968). Describe the research on autoshaping and the basic findings. (187–188)
6. **ADVANCED ISSUE**: How could accidental reinforcement account for autoshaping? (189) Show how Williams and Williams (1969) used omission training to test a reinforcement account of autoshaping. Be able to give a respondent analysis of this experiment. (189–190)
7. **ADVANCE ISSUE.** Describe the Schwartz and Williams (1972a,1972b) experiments and the relevance of these studies for the autoshaping controversy. What other evidence suggests that autoshaping involves both operant and respondent processes? (190–191)
8. What do sign tracking, autoshaping, and instinctive drift have in common? How can the dispute between operant and respondent accounts of biologically relevant behavior be resolved? (191–192)
9. Summarize the experiments on reinforcement of reflexive behavior. (192–193) Show how Miller and DiCara (1967) solved the problem of operant behavior mediating reinforcement of a reflex. State and discuss the findings. (193–194)

10. What does Morris (1992) mean by context? (195) How does the biological context establish and change operant (or respondent) relations (SD: R → S^r)? (195)

11. Be able to describe how organisms acquire food aversions based on biologically relevant visual and taste cues. Use respondent conditioning and the concept of preparedness in your answer. (195–196)

12. Describe the Garcia and Koelling (1966) experiment on taste aversion and its major findings. What is unusual about their results and how can we explain them? After a dinner date at which you became ill, why would you probably give up pasta primavera rather than your date? (196–198)

13. What three distinct types of behavior occur between food reinforcement on interval- or time-based schedules? Define the term polydipsia and explain how it occurs. (199)

14. Describe the adjunctive behavior that occurs for different reinforcers and species. (199)

15. What are the major conditions that regulate adjunctive behavior? How is the schedule of reinforcement related to the amount of adjunctive behavior? What about deprivation and adjunctive behavior? (200)

16. Discuss adjunctive responses as displacement behavior. Point to the adaptive value of such behavior. (200–201)

17. How are eating and exercise motivationally interrelated? (201–202) What is the relationship between food deprivation and the reinforcement value of running? (202–203) How does running affect the reinforcement value of eating? (203–204) What is the evolutionary analysis of these relations and activity anorexia? (204)

BRIEF QUIZ

1. In terms of operant contingencies and the intrusion of reflexive behavior
   (a) operant procedures elicit reflexive behavior directly by the contingencies of reinforcement
   (b) reflexive behavior is elicited by respondent procedures embedded in operant contingencies
   (c) respondent procedures cause species-characteristic responses
   (d) both b and c

2. What did Brown and Jenkins (1968) conclude about autoshaping in their pigeons?
   (a) the look–peck coupling is species specific and results in pecks to the illuminated key
   (b) following the key light with grain eventually caused the lighted key to elicit pecking
   (c) eventually an operant chain develops culminating in pecking
   (d) all of the above
   (e) none of the above

3. Regarding automaintenance (**Advance Issue**), Schwartz and Williams (1972) indicated
   (a) a simple application of respondent principles is a good account of this phenomenon
   (b) operant factors can modulate the performance of automaintained behavior
   (c) an understanding of automaintenance only involves species-specific behavior
   (d) none of the above

4. In terms of operant conditioning of reflexive behavior, the experiment by Miller and Carmona (1967)
   (a) showed conclusive results for operant conditioning of salivation
   (b) showed that salivation and heart rate were both susceptible to operant conditioning
   (c) showed that the increased flow of saliva was accompanied by the dogs being more alert
   (d) all of the above

5. What does the evidence suggest about the operant conditioning of reflexive behavior?
   (a) reflexes can be conditioned by operant procedures in some circumstances
   (b) reflexive behavior is hardly ever controlled by respondent procedures
   (c) reflexive behavior is generally controlled by operant procedures
   (d) only b and c

6. When a CS compound (color and taste) is associated with illness, different species show avoidance to the two parts of the compound. This phenomenon is called
   (a) species readiness
   (b) species set
   (c) species preparedness
   (d) species activation

7. What did Lett and Grant (1996) suggest in terms of activity anorexia?
   (a) activity anorexia could involve taste aversion induced by physical activity
   (b) activity anorexia probably explains taste aversion conditioning
   (c) activity anorexia is the first stage in taste aversion conditioning
   (d) both b and c

8. Excessive drinking is technically called
   (a) polyhydration
   (b) polydipsia
   (c) polyfluidity
   (d) polydistation

9. According to Falk (1977) schedule-induced or adjunctive behavior could be
   (a) fixed action patterns
   (b) distancing behavior
   (c) displacement behavior
   (d) finishing behavior

10. The basic finding for activity anorexia is that
    (a) decreased food intake increases physical activity
    (b) increased food intake increases physical activity
    (c) physical activity decreases food intake
    (d) both a and c

Answers to brief quiz (*page*): d(184); d(188); b(190); c(193); a(194); c(196); a(198); b(199); c(200); d(201–202)

CHAPTER 8
Stimulus Control

IN THIS CHAPTER

1. Learn about stimulus control of behavior and multiple schedules of reinforcement.
2. Solve the problem of the "bird-brained" pigeon and see what it means for teaching and learning.
3. Investigate the behavioral contrast and its determinants.
4. Find out about stimulus generalization, peak shift, errorless discrimination, and fading.
5. Investigate delayed matching to sample and an experimental analysis of remembering.

In the everyday world, human behavior is changed by signs, symbols, gestures, and spoken words. Behavior is also regulated by sounds, smells, sights, and other sensory stimuli that do not depend on social conditioning. When social or nonsocial events precede operant behavior and affect its occurrence, they are called controlling stimuli. A **controlling stimulus** (S) is said to alter the probability of an operant, in the sense that the response is more (or less) likely to occur when the stimulus is present.[1]

One kind of controlling stimulus that we discussed in chapter 4 is the S^D, or *discriminative stimulus*. An S^D is a controlling stimulus that sets the occasion for reinforcement of an operant. In a pigeon experiment, a red light may reliably signal the presentation of food for pecking a key. After some experience, the bird will immediately strike the key when it is illuminated with the red light. Thus, the discriminative stimulus sets the occasion for a high probability of response.

The discriminative stimuli that regulate human behavior may be as simple as those in the pigeon experiment or far more complex. A green traffic light and the word WALK set the occasion for pedestrians to cross a street. In a library, the call numbers posted above the stacks and on the books are discriminative stimuli for stopping, turning corners, and so on that result in finding a book. On the football field, a quarterback who is about to pass the ball must decide whether to pick the left or right receiver. Throwing the ball to a receiver is based on the degree of coverage (number and proximity of defensive players). In this example, the degree of coverage is a complex S^D that controls the direction, speed, and elevation of the quarterback's pass.

Another kind of controlling stimulus is called an S^Δ *(S-delta)*, or an *extinction stimulus*. An S^Δ is a stimulus that sets the occasion for nonreinforcement or extinction of an operant

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[1]In this chapter, we have invented a classification scheme for stimuli that precedes and sets the occasion for reinforcement, extinction, or punishment of operant behavior. We introduce the generic term controlling stimulus (S) to stand for all events that exert stimulus control over operant behavior. There are three kinds of controlling stimuli: S^D, S^Δ, and S^{ave}. Notice that in each case the controlling stimulus is modified to reflect its function based on the contingencies of reinforcement that have established it (i.e., reinforcement, extinction, or punishment). See chapter 6 for a discussion of the S^{ave} function of controlling stimuli.

(see chap. 4). A rat may press a lever on a VI schedule of food reinforcement. Every now and then, a tone comes on and a period of extinction is in effect. After some time, the rat will stop pressing the bar as soon as the tone is presented. Thus, the tone is defined as an S^Δ, because lever pressing has a low probability of occurrence in its presence.

Extinction stimuli that regulate human behavior also range from simple to complex. When your car is almost out of gas, a service station sign that says CLOSED is an S^Δ for turning into that station. A tennis opponent who usually wins the match may become an extinction stimulus for playing the game. In this case, you may play tennis with others but not with the person who always wins. Sometimes breakdown of communication between a married couple may be caused by stimuli that signal extinction for conversation. A wife may try to talk to her husband about a variety of issues, and he pretends to read the newspaper. The husband's behavior is an S^Δ for conversation if the wife reliably stops talking when he picks up the paper.

Differential Reinforcement and Discrimination

When an organism makes a response in one situation but not in another, we say that the animal shows a discrimination between the situations. The simplest way to train a **differential response** or **discrimination** is to reinforce an operant in one situation and withhold reinforcement in the other.

Figure 8.1 shows the development of a differential response to a single key that is alternately illuminated red and green for 5 min. The graph shows the cumulative number of responses over a 90-min session. Pecks to the red light by a pigeon are intermittently reinforced with food. Responses emitted in the presence of the green light are extinguished, never reinforced.

As you can see in this idealized experiment, the pigeon begins by emitting about the same number of responses to the red and green stimuli. After about 20 min, the cumulative response curves start to separate. This indicates that the bird is pecking more in the presence of red than in the presence of green. At about 60 min, the pigeon seldom responds when the key is green, and this is shown by the leveling off of the curve for this stimulus. Notice, however, that the cumulative curve for pecking the red key continues to rise. Because the bird pecks in the presence of red but does not respond when the key is green, we may say that the pigeon discriminates between these two stimuli. At this point, it is possible to label
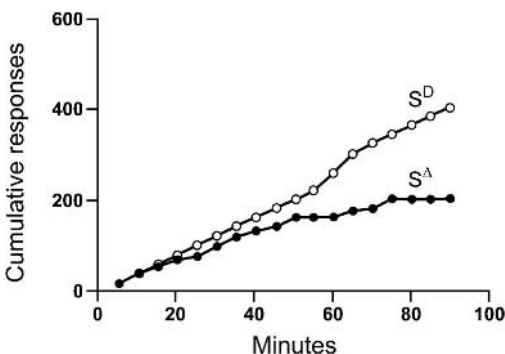
FIG. 8.1. *Development of a differential response in the presence of red and green stimuli. Cumulative number of responses over a 90-min session in which responses in the presence of red are reinforced and responses in the presence of green are on extinction.*

the red and green stimuli in terms of their functions. The red light is called a discriminative stimulus, or S^D, and the green color is an S^Δ, or extinction stimulus.

Suppose that the bird is returned to its home cage after 90 min of such differential reinforcement. On the next day, the pigeon is again placed in the operant chamber and the key is illuminated with the red light. During this test session, reinforcement is not given for pecking in the presence of either red or green. Because of its previous training, a high probability exists that the bird will strike the red key. Over a 60-s period, the bird may emit many responses when the S^D is present. After 60 s, the key light is changed from red to green. When the green light comes on, the probability of response declines and the bird makes few pecks to the green key. By continuing to alternate between red and green, the researcher can show the stimulus control exerted by the respective stimuli.

Stimulus control refers to a change in behavior that occurs when either an S^D or an S^Δ is presented. When an S^D is presented, the probability of response increases; when an S^Δ is presented, the probability of response decreases. The stimuli that commonly control human behavior occur across all sensory dimensions. Stopping when you hear a police siren, coming to dinner when you smell food, expressing gratitude following a pat on the back, elaborating an answer because the student looks puzzled, and adding salt to your soup because it tastes bland are instances of stimulus control in human behavior.

Stimulus Control and Multiple Schedules

Behavior analysts often use multiple schedules of reinforcement to study stimulus control in the laboratory. On a **multiple schedule**, two or more simple schedules are presented one after the other, and each schedule is accompanied by a distinctive stimulus. The idealized experiment that we have just discussed is one example of a multiple schedule. Pecking was reinforced when a red light appeared on the key, and a schedule of extinction was in effect when the green light was on. The schedules and the associated stimuli alternated back and forth every 5 min. As indicated, these procedures result in a differential response to the colors.

In an actual experiment, presenting the component schedules for a fixed amount of time or on an FI schedule (e.g., 5 min) would confound the results. Without a test procedure, the researcher may not be sure that the bird discriminates on the basis of color rather than on the basis of time. That is, time itself may have become a discriminative stimulus. For this reason, variable-interval schedules are often used for discrimination training (Guttman & Kalish, 1956).

Figure 8.2 is one example of a multiple variable-interval extinction schedule of reinforcement (MULT VI, EXT). The Mechner notation shows that in the presence of the red
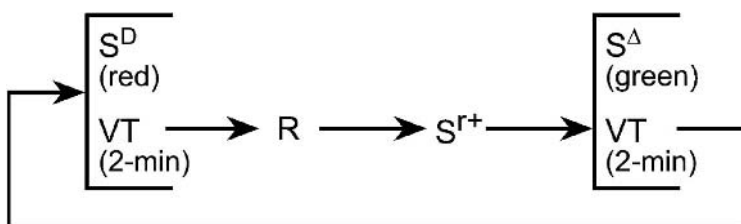
FIG. 8.2. *Mechner notation for a MULT VI 2-min, EXT 1-min schedule of reinforcement.*
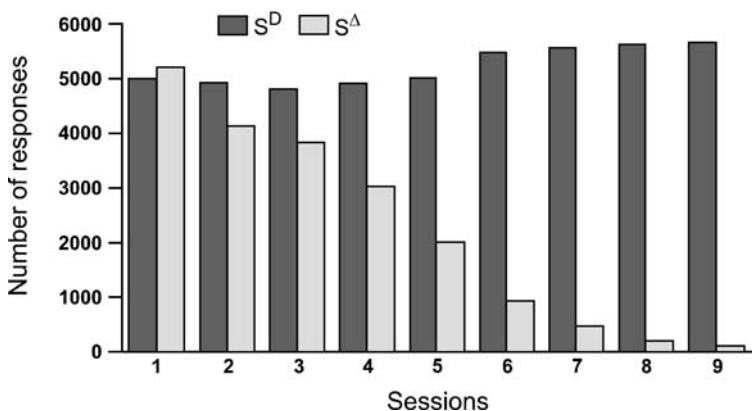
FIG. 8.3. *Idealized results for a MULT VI 2-min, EXT 1-min schedule of reinforcement. Relative to the red VI component, pecking declines over sessions to almost zero responses per minute in the green extinction phase.*

S^D, the first response after an average of 2 min produces reinforcement. Following reinforcement, the key light changes from red to the green S^Δ, and pecking the key no longer results in reinforcement. After an average of 2 min of extinction, the green light goes out and the red stimulus appears again. Pecking the key is now reinforced on the VI 2-min schedule, and the components continue to alternate in this fashion.

A likely result of this multiple schedule is shown in Fig. 8.3. The graph portrays the total number of responses during the red and green components for 1-hr daily sessions. Notice that the bird begins by pecking equally in the presence of both the red and the green stimuli. Over sessions, the number of pecks to the green extinction stimulus, or S^Δ, declines. By the last session, almost all responses occur in the presence of the red S^D, and almost none occur when the green light is on. At this point, pecking the key can be controlled easily by presenting either the red or the green stimulus. When red is presented, the bird will peck the key at a high rate, and if the color changes to green the pigeon will immediately stop. One way to measure the stimulus control exerted by the S^D and S^Δ at any moment is to use a **discrimination index (I_D)**. This index compares the rate of response in the S^D component to the sum of the rates in both S^D and S^Δ phases (Dinsmoor, 1951):

$$I_D = (S^D \text{ rate})/(S^D \text{ rate} + S^\Delta \text{ rate}).$$

Prior to discrimination training, the measure varies between 0.00 and 1.00. Using the I_D measure, when the rates of response are the same in both S^D and S^Δ components, the value of I_D is 0.50, indicating no discrimination. When all responses occur during the S^D phase, the S^Δ rate is zero, and I_D equals 1.00 in value. Thus, a discrimination index of 1.00 indicates a perfect discrimination and maximum stimulus control of behavior. Intermediate values of the index signify more or less control by the discriminative stimulus.

A study by Pierrel, Sherman, Blue, and Hegge (1970) illustrates the use of the discrimination index. The experiment concerned the effects of sound intensity on acquisition of a discrimination. The researchers were interested in sound-intensity relationships (measured in decibels) between S^D and S^Δ. The basic idea was that the more noticeable the difference in sound, the better the discrimination. For example, some people have doorbells for the front and back entrances to their houses. If the chimes are very close in sound intensity, a ring will be confusing and you may go to the wrong door. One way to correct this problem
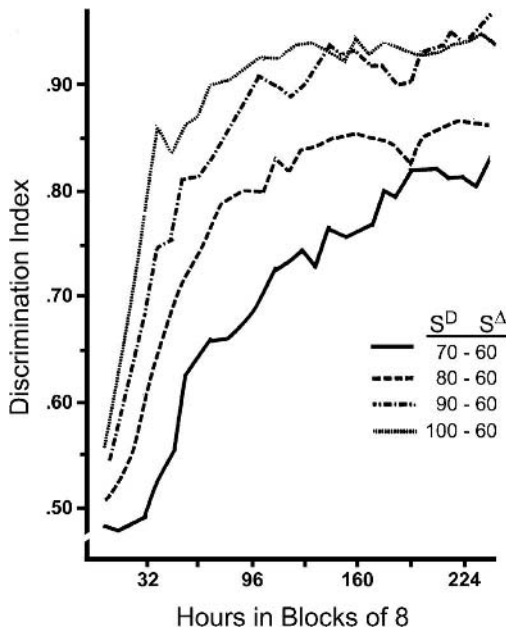
FIG. 8.4. *Discrimination Index (I_D) curves for different values of S^D and S^Δ. Each curve is a plot of the average I_D values based on a group of four animals, repeatedly exposed to 8-hr sessions of discrimination training (based on Fig. 1B from Pierrel, Sherman, Blue, & Hegge 1970; copyright 1970 by the Society for the Experimental Analysis of Behavior, Inc.). The labels for the x- and y-axes have been simplified to promote clarity.*

is to change the intensity of sound for one of the chimes (of course, another is to replace one chime with a buzzer).

In one of many experimental conditions, 16 rats were trained to respond on a MULT VI 2-min EXT schedule. The animals were separated into four equal groups, and for each group the auditory S^D for the VI component was varied, whereas the $S^Δ$ for the extinction phase was held constant. For each group, the $S^Δ$ was a 60-dB tone, but the S^D was different, a choice of 70, 80, 90, or 100 dB. Thus, the difference in decibels, or sound intensity, between S^D and $S^Δ$ increased over groups (70–60, 80–60, 90–60, and 100–60 dB). The rats lived in operant chambers for 15 days. Two 8-hr sessions of the multiple schedule were presented each day, with a 4-hr break between sessions.

Figure 8.4 shows the average acquisition curves for each experimental group. A mean discrimination index based on the four animals in each group was computed for each 8-hr session. As you can see, all groups begin with an I_D value of approximately 0.50, or no difference in responding between the S^D and $S^Δ$ components. As discrimination training continues, a differential response develops and the I_D value rises toward 1.00, or perfect discrimination. The accuracy of the discrimination, as indicated by the maximum value of I_D, is determined by the difference in sound intensity between S^D and $S^Δ$. In general, more rapid acquisition and more accurate discrimination occur when the difference between S^D and $S^Δ$ is increased.

FOCUS ON TEACHING: DISCRIMINATION AND THE "BIRD-BRAINED" PIGEON

Pretend that you are doing a class assignment that involves training a pigeon to discriminate between the red and the green components of a multiple schedule. The assignment counts for 30% of the course grade, and you must show the final performance of the bird to your

instructor. All students are given a pigeon, an operant chamber, and a microcomputer that allows you to control key color and the delivery of food from a hopper. Sessions are scheduled for 1 hr a day over a 2-week period that ends with the professor's evaluation of your project. The pigeon has been food deprived, magazine trained, and taught to peck at a white-illuminated key on a VI 60-s schedule.

You and the other students follow the Mechner notation for a MULT VI 60-s EXT 60-s schedule in which you signal the VI component with a red-key light and a minute of extinction by turning the key green. To create the VI schedule and the variable 60 s of extinction, you use operant-conditioning software to program your computer. The software program is set up to record the number of key pecks in both components of the multiple schedule. Your program starts a session with the key illuminated red, and the first response after an average of 60 s is reinforced with food (VI 60 s). After food is presented, the key color changes to green, and extinction is in effect for an average of 60 s.

Day after day, your bird pecks at a similar rate in both the red and the green components. You become more and more concerned, because other students have trained their birds to peck when the key is red and to stop when it is green. By the 11th session, you are in a panic because everyone else is finished, but your bird has not made much progress. You complain to your instructor that you were given a dumb or color-blind bird, and it is not fair to get a low mark because you tried your best. Your professor is a strict behavior analyst who replies, "The fault is with the program, not with the pigeon; go study your computer program in terms of Mechner notation." You spend the night pondering the program, and somewhat like Kohler's apes (Kohler, 1927) you "have an insight." Pecking in the extinction green-key component has been reinforced with the presentation of the red-key light.

You realize that the red color is always associated with food reinforcement, and this suggests that the stimulus has more than one function. It is obviously an S^D that sets the occasion for reinforced pecking. In addition, the stimulus itself is a conditioned reinforcer because of its association with food. Presumably, during the extinction component the bird sometimes pecked the green key, and on the basis of the computer program, the color changed to red. This change in color accidentally, or adventitiously, reinforced pecking in the extinction component. From the bird's point of view, pecking the key during extinction turns on the red light that allows food reinforcement. In fact, the pigeon's behavior is **superstitious** because pecking in the green component does not affect the presentation of red color.

Figure 8.5 shows how to solve the adventitious reinforcement problem in Mechner notation. The first part of the diagram presents the notation for a simple MULT VI 60-s EXT
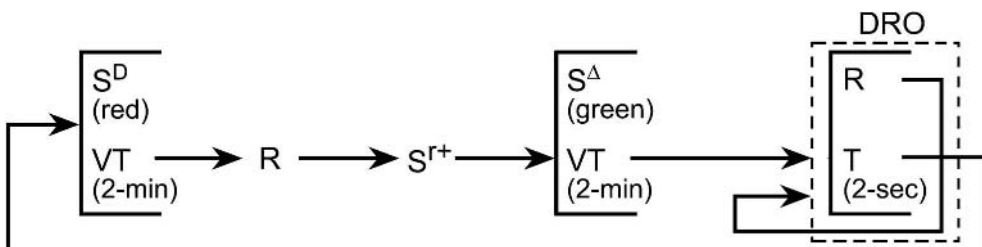
FIG. 8.5. *Mechner diagram of how to solve the adventitious reinforcement problem on a multiple schedule of reinforcement. The first part of the diagram presents the notation for a simple MULT VI 60-s, EXT 60-s schedule. Notice that when extinction ends, the DRO contingency requires an additional 2-s period before the red stimulus is presented. During this DRO time, each response or peck resets the 2-s interval. If the bird does anything other than strike the key for 2 s, the red stimulus will occur.*

60-s schedule. Enclosed within the dotted lines is an additional and critical contingency. This contingency prevents the onset of the red stimulus, if responding is occurring at the moment that the extinction phase (is supposed to) ends. That is, if the extinction period ends with the bird pecking the key, the onset of the red stimulus is delayed. The added contingency is called **differential reinforcement of other behavior**, or **DRO**. Notice that when extinction ends, the DRO contingency requires an additional 2-s period before the red stimulus is presented. During this DRO time, each response or peck resets the 2-s interval. If the bird does anything other than strike the key for 2-s, the red stimulus will occur.

With this insight, you rush to the laboratory and add DRO to your computer program. At the first opportunity, you place your "dumb or color-blind" pigeon in the operant chamber and initiate the program. As you watch the bird's performance on the cumulative recorder, the rate of response during the S^D and the S^Δ components begins to separate. After two more sessions, the discrimination index (I_D) is almost 0.90, indicating good discrimination between reinforcement and extinction phases. The instructor is impressed with your analytical skills, and you get the highest mark possible for the assignment (A+).

This analysis has implications for teaching and learning. When most people learn from instruction but a few do not, educators, psychologists, and parents often blame the poor student, confused client, or stubborn child. They see the failure to learn as a deficiency of the person rather than as a problem of contingencies of reinforcement (called blaming the victim, Shaver, 1985). The ones that fail to learn are said to be learning disabled, low in intelligence, dim-witted, and so on. Of course, some people and animals may have neurological and/or sensory impairment (e.g., color blindness, deafness, organic brain damage) that contributes to their poor performance. Nonetheless, defective contingencies of reinforcement also may contribute to, or exclusively produce, problems of discrimination and learning. In the case of the apparently dumb pigeon, the fault was caused entirely by adventitious reinforcement of responding during extinction. A small change in the contingencies of reinforcement (adding DRO) made a "bird-brained" pigeon smart.

Behavioral Contrast

Consider an experiment by Guttman (1977) in which rats were exposed to a two-component multiple schedule with a variable-interval 30-s reinforcement schedule in both components (MULT VI 30 s VI 30 s). One component was signaled by sound (white noise); and the other, by a light. The sound and light alternated every 3 min, and the rats made about the same number of responses in both components. Next, in the presence of the sound stimulus, the contingencies were changed from VI to extinction (MULT VI EXT). As you might expect, the rate of response declined in the extinction component. Surprisingly, the rate of response increased on the VI component signaled by the light. The increase occurred, even though the reinforcement contingencies for the VI component remained the same. Thus, changing the contingencies of reinforcement on one schedule affected reinforced behavior on another schedule.

This effect is called **behavioral contrast** (Reynolds, 1961a, 1961b, 1963). Contrast refers to a negative association between the response rates in the two components of a multiple schedule—as one goes up, the other goes down. There are two forms of contrast: positive and negative. **Positive contrast** occurs when the rate of response in an unchanged setting increases with a decline in behavior in another situation. **Negative contrast** occurs when the rate of response declines in an unaltered situation with increases in behavior in another setting.

There are many different accounts of why behavioral contrast occurs. These include the addition of autoshaped key pecks to responding in the unchanged component, fatigue or rest attributed to the amount of responding on the changed schedule, and compensating for response rate changes on the altered component (see de Villiers, 1977; McSweeney, Ettinger, & Norman, 1981; Schwartz & Gamzu, 1977, for a discussion). Although there is some dispute, one account suggests that behavioral contrast results from changes in relative rates of reinforcement. On a multiple VI schedule, the relative rate of reinforcement for the unchanged component increases when the number of reinforcers goes down on the other schedule. Of course, the relative rate of reinforcement for the unchanged component goes down when the number of reinforcers is increased on the other schedule.

For example, if an animal obtains 30 reinforcers each hour on the unchanged component and gets another 30 on the other schedule, then 50% of the reinforcement occurs on both components. If the schedule is changed to MULT VI EXT, then 100% of the reinforcements occur on the unaltered component. As the relative rate of reinforcement goes up on the unchanged component, so does the rate of response. Similarly, the response rate on the unaltered schedule will go down if the relative rate of reinforcement declines, because of an increase in reinforcement on the changed component. Relative rates of reinforcement provide an account of performance on multiple schedules that is consistent with a behavioral analysis of choice and preference (see chap. 9).

Although relative rates of reinforcement are important for an analysis of behavioral contrast, there is evidence that other conditions may also contribute to such effects. Research has shown that contrast may only occur in some species and may depend on the type of response required for reinforcement, although the data are inconsistent and sometimes contradictory (e.g., Beninger & Kendall, 1975; Hemmes, 1973; Pear & Wilkie, 1971; Westbrook, 1973).

McSweeney and her colleagues (Ettinger & McSweeney, 1981; McSweeney, Melville, & Higa, 1988) have examined how different kinds of responses and different types of reinforcement (e.g., food, water, alcohol, etc.) affect behavioral contrast. Her recent research on food and alcohol reinforcement suggests that the nature of the reinforcers on a multiple schedule may limit the impact of relative rates of reinforcement.

Changes in relative rates of reinforcement produced positive contrast (i.e., rate of response went up on the unchanged schedule) when food reinforcement was continued in one component and extinction for alcohol was introduced in the other. However, behavioral contrast did not occur when alcohol reinforcement was continued and responding for food was placed on extinction. One possibility is that alcohol is an economic substitute for food (as rice is for potatoes), but food is not a substitute for alcohol (I'll drink to that!). Anderson, Ferland, and Williams (1992) also reported a dramatic negative contrast result wherein rats stopped responding for food and switched exclusively to responding for electrical stimulation of the brain (ESB). Relative rates of reinforcement may produce contrast only when reinforcers are substitutable, based on reinforcement history or biology.

After hundreds of studies of behavioral contrast, it is clear that contrast effects may occur in pigeons, rats, and even in humans (Simon, Ayllon, & Milan, 1982). In addition, contrast has been shown with various schedules of reinforcement (both ratio and interval), different kinds of responses (e.g., lever pressing, key pecking, and treadle pressing), and different types of reinforcement (e.g., food, water, and alcohol) in the component schedules. This suggests that contrast is an important behavioral process that may have adaptive value. A bird that forages successively in two patches would be expected to increase searching for food in one patch if the other began to deplete (i.e., positive contrast). Similarly, negative contrast may occur when food in one of the patches becomes more abundant than that

in the other. In this case, the bird would decrease foraging in the less plentiful location (Cheney, DeWulf, & Bonem, 1993).

A problem with the research on behavioral contrast is that some of the findings are puzzling. Many experiments result in contrast, but others with apparently similar procedures do not, and it is not clear how this happens. Generally, there are several theories of behavioral contrast, but none of the accounts handle all the data (see Pear, 2001, pp. 154–158, for habituation, autoshaping, and following schedule theories of behavioral contrast).

FOCUS ON RESEARCH: SEARCHING FOR THE DETERMINANTS OF CONTRAST

Behavioral contrast is a topic that has interested many behavior analysts. Although contrast is not difficult to describe as a behavioral process, its analysis has been a puzzle for several decades. One of the more prominent researchers in this area is Dr. Ben Williams (Fig. 8.6), who at the time of this writing was a professor of psychology at the University of California, San Diego. After obtaining a Ph.D. at Harvard University, Dr. Williams pursued a career in basic research. His interests include concurrent schedules of reinforcement, delay of reinforcement, conditioned reinforcement, and stimulus control of operant and respondent behavior. He has been actively involved in an analysis of behavioral contrast for more than 20 years (see Williams, 1974).

In one of his programs of research on behavioral contrast, Williams investigated the sequencing of schedules and stimuli. That is, Williams (1976, 1979, 1981, 1990, 1992) began to investigate how contrast depends on the contingencies that either preceded or followed a target schedule. For example, in the schedule sequence A → B → C, the target schedule is component B, and response rates for this schedule may be influenced by the contingencies set by A or C.

Generally, Williams (1981) found that the schedule preceding the target component produced weak, variable, and transitory contrast effects. This transitory effect is shown in Fig. 8.7 (panel A), where the rate of response is high following reinforcement and drops off to precontrast levels. The schedule that followed the target component generated strong

FIG. 8.6.   *Dr. Ben Williams. Reprinted with permission.*
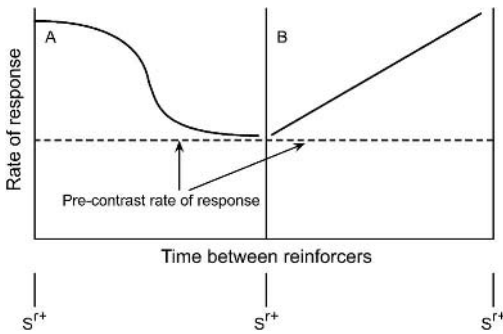
FIG. 8.7. *Two patterns of behavioral contrast. The drop-off pattern presented in panel A is often elicited by contingencies that precede the target schedule. The linear pattern presented in panel B is called anticipatory contrast and is a function of the contingencies that follow the target schedule.*

contrast effects that increased as training progressed (Fig. 8.7, panel B). Williams called this strong contrast effect **anticipatory contrast** to distinguish it from the weak elicited responding evoked by the preceding schedule (respondent contingencies).

Today, the causes of behavioral contrast still are not completely understood. What is clear from this research is that performance on a schedule of reinforcement is affected by the contingencies that precede and follow the current schedule. As in other areas of behavior analysis, performance on a schedule is a function of the operating contingencies and the context of reinforcement (Williams, 2002).

Generalization

An organism that responds in one situation but not in another is said to discriminate between the settings. An organism that behaves similarly in different situations is said to generalize across circumstances. **Generalization** is a common observation in everyday life. A child may call all adult males "daddy," label all small furry animals as dogs, and drink anything that looks like juice (one reason for child-proof caps on dangerous liquids). Some students call all university teachers "profs," even though professors are only the senior academics. Most of us have seen an old friend at a distance only to find out that the person was not who we expected. A rude person is one who tells vulgar jokes no matter who is listening. In these and many more examples, it appears that common properties of the different stimuli set the occasion for operant behavior.

The problem is that an observer cannot be sure of the stimulus properties that regulate a common response. That is, it is difficult to specify the geometry of dad's face, the physical characteristics that differentiate dogs from other animals, the common aspects of different audiences for the joke teller, and so on. In the operant laboratory, however, it is usually possible to specify the exact physical dimensions of stimuli in terms of wavelength, amplitude, size, mass, and other physical properties. On the basis of experiments that use well-defined stimuli, it is possible to account for everyday examples of generalization and discrimination.

Stimulus Generalization

Formally, stimulus generalization occurs when an operant that has been reinforced in the presence of a specific discriminative stimulus also is emitted in the presence of other stimuli. The process is called stimulus generalization, because the operant is emitted to new stimuli
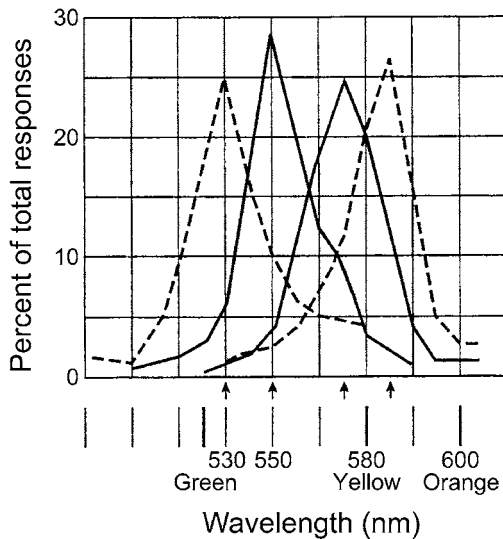
FIG. 8.8. *Stimulus generalization gradients of wavelength obtained from four groups of pigeons trained at different wavelengths.* Note: *Adapted from "Discriminability and Stimulus Generalization," by N. Guttman and H. I. Kalish, 1956,* Journal of Experimental Psychology, 51, *pp. 79–88. Copyright 1956 by Journal of Experimental Psychology.*

that presumably share common properties with the discriminative stimulus. Generalization and discrimination refer to differences in the precision of stimulus control. Discrimination refers to the precise control of an operant by a stimulus, and generalization involves less precise regulation of operant behavior.

Generalization Gradients

A classic study of generalization was conducted by Guttman and Kalish (1956). Pigeons were trained to peck a key on a VI 1-min schedule of reinforcement. The key was illuminated with a green light of 550 nm, which refers to a wavelength of light that is approximately in the middle of the color spectrum.[2] Once the rate of key pecking for food had stabilized in the presence of the green light, the researchers tested for stimulus generalization. To do this, the pigeons were exposed to 10 additional values of wavelength (variations in color) as well as to the original green light. All 11 colors were presented in a random order, and each wavelength was shown for 30 s. During these test trials, pecking the key was not reinforced (extinction). After the 11 wavelengths were presented (one block of trials), a new random series of the same colors was initiated. A total of 12 blocks of trials were given to the birds. Of course, as the test for generalization continued, key pecking decreased because of extinction, but the decline was equal over the range of stimuli because different wavelengths were presented randomly.

As shown in Figure 8.8, generalization gradients resulted from the experiment. A **generalization gradient** shows the relationship between probability of response and stimulus value. In the experiment by Guttman and Kalish (1956), probability of response is measured as the number of responses emitted by the pigeons, and the stimulus value is the wavelength of light. As you can see, a symmetrical curve with a peak at 550 nm (yellow-green training stimulus) describes stimulus generalization for pigeons trained at this wavelength. The more the new stimulus differed from the wavelength used in training, the fewer the number of responses. Importantly, these results were typical of the curves for individual birds. In

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[2]The visible color spectrum is seen when white light is projected through a prism. The spectrum ranges from violet (400 nm) on one end to red (700 nm) on the other.

addition, similar generalization gradients were found for three other groups of pigeons using 530, 580, and 600 nm as the training stimuli. Generally, probability of response is highest for a stimulus that has signaled reinforcement (S^D), less for stimuli that are similar but not identical to the S^D, and low for stimuli that substantially depart from the discriminative stimulus.

Peak Shift

Multiple schedules may also be used to study generalization gradients. Hanson (1959) reported an experiment with pigeons that was similar to the Guttman and Kalish (1956) study we just discussed. The procedural difference was that four groups of birds were exposed randomly to periods of VI reinforcement and extinction. For the experimental groups, the S^{Δ} period was either 555, 560, 570, or 590 nm, and the S^D phase was always 550 nm. A control group only received training on the VI schedule, with 550 nm of light on the response key. Notice that the S^D for all groups was a key light of 550 nm, replicating one of the stimulus values used by Guttman and Kalish.

Figure 8.9 shows the major results of Hanson's (1959) experiment. The control group that received only VI training produced a generalization gradient that replicates the findings of Guttman and Kalish. The peak of the distribution is at 550 nm and is symmetrical around this value (check this out). In contrast, the experimental groups uniformly showed a shift in the peak of the distribution from 550 to 540 nm, moving away from the stimulus value of the S^{Δ}, which was always greater than 550 nm. For this reason, **peak shift** refers to the change in the peak of a generalization gradient on the other side of S^D away from the
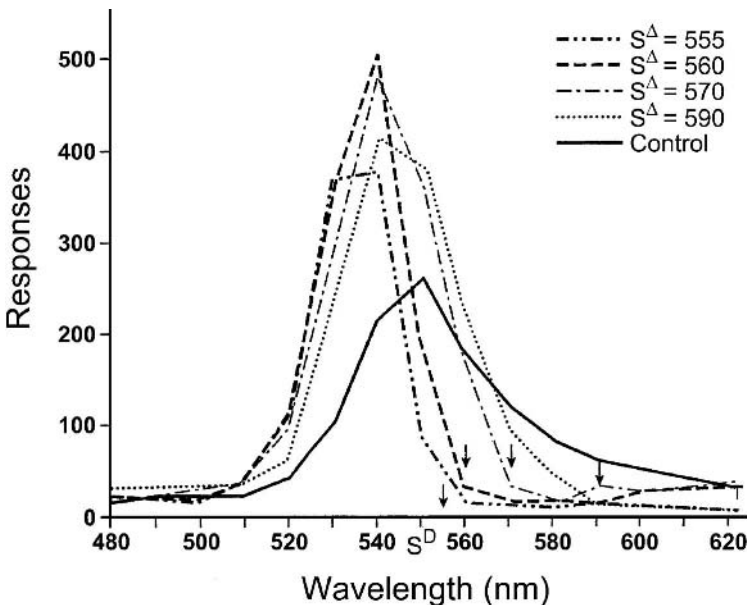
FIG. 8.9. *Peak shift of a generalization gradient shown by Hanson (1959). The control shows a peak of the distribution is at 550 nm and is symmetrical around this value (check this out). In contrast, the experimental groups uniformly showed a shift in the peak of the distribution from 550 to 540 nm, moving away from the stimulus value of the S^{Δ}, which was always greater than 550 nm.*

stimulus that signals extinction. Also, the number of responses made at the peak of each distribution is greater for the experimental groups when compared to the control subjects. This latter finding reflects *positive behavioral contrast*, which occurs on multiple schedules with S^D and S^Δ components. (See the foregoing section, Behavioral Contrast.)

Absolute and Relative Stimulus Control

Peak shift is an unusual effect from the point of view of absolute control by a stimulus. **Absolute stimulus control** means that the probability of response is highest in the presence of the stimulus value used in training. In fact, this occurs when reinforcement is the only procedure used to establish stimulus control. This is clearly seen in the results of the Guttman and Kalish (1956) study and in the control group of Hanson's (1959) experiment. In both studies, the peak of the generalization gradient is at the exact (or absolute) value of the stimulus presented during training (550 nm). However, when both S^D and S^Δ procedures are scheduled, the peak of the distribution shifts away from the absolute value of the training stimulus.

The shift in the peak of the generalization gradient may reflect relative, rather than absolute, stimulus control. **Relative stimulus control** means that an organism responds to differences among the values of two or more stimuli. For example, a pigeon may be trained to peck the "larger" of two triangles projected on a response key rather than to respond to the absolute size of the discriminative stimulus. Similarly, the birds in the peak-shift experiments may have come under the control of the relative value of the wavelengths. That is, the S^D was "greener" than the yellow-green S^Δ's used in discrimination training. Because of this, the birds pecked most at stimuli that were relatively "greener," shifting the peak to 540 nm.

There are other ways of showing relational control by stimuli. To study generalization gradients and peak shift, the researcher usually arranges the presentation of S^D and S^Δ so that one follows the other. This is called **successive discrimination**. An alternative procedure is labeled **simultaneous discrimination**—the S^D and S^Δ are presented at the same time and the organism responds to one or the other. For example, a pigeon may be presented with two keys, both illuminated with white lights, but one light is brighter than the other. The bird may be reinforced for pecking the "dimmer" of the two keys. Pecks to the other key are placed on extinction. After training, the pigeon will mostly peck the darker of the two keys. To test that the bird's performance is caused by the difference between the two stimuli, it is necessary to present new values of luminosity and observe whether the pigeon pecks the dimmer of two keys.

Gonzalez, Gentry, and Bitterman (1954) provide an example of complex simultaneous discrimination and relational stimulus control in the chimpanzee. The animals were presented with nine squares that were rank ordered in size from 1 (the smallest) to 9 (the largest). Discrimination training involved the simultaneous presentation of 1st-, 5th-, and 9th-ranked squares, and reinforcement was arranged for selecting the intermediate square (5th ranked). To rule out position of the square as an S^D, the researchers varied the position of the three squares from trial to trial.

After this training, the animals were allowed to choose from several new sets of three squares. A chimpanzee might be presented with a choice among squares that ranked 1, 3, and 5. If the animal selected square 3, it showed relational control by the intermediate stimulus. Similarly, choosing square 7 from the set 5, 7, and 9 shows the same kind of stimulus control. In contrast, the chimpanzee could have selected square 5, which would indicate absolute control by the stimulus. In fact, the animals typically chose the middle-sized square in most of the new sets. This finding indicates that relational properties of stimuli often control the operant behavior of organisms, especially if the S^D and S^Δ are presented at the same time.

Simultaneous discrimination tasks are often used in education. The television program *Sesame Street* teaches youngsters the relations of "same" and "different" by presenting several objects or pictures at the same time. The jingle "one of these things is just like the others" sets the occasion for the child to identify one of several items. After the child makes a covert response, something like "it's the blue ball," the matching item is shown. In this case, getting the correct answer is reinforcement for the discriminative response.

Malott and Malott (1970) taught pigeons a discrimination that was then used to demonstrate the concept of "sameness." In this study a split key was used that could be either red–red or violet–violet or one side of each color. After this same–different relationship discrimination was learned, the birds were tested with new colors such as blue–blue or yellow–yellow (same), or blue–yellow or yellow–blue (different). Three of four birds showed good same–different performance with the new stimuli.

Errorless Discrimination and Fading

When the S^D and S^Δ are alternately presented as in successive discrimination, the organism initially makes many errors. That is, the animal or person continues to respond in the presence of the S^Δ on the basis of generalization. As extinction and reinforcement progress, a differential response occurs to both S^D and S^Δ. A pigeon is taught to peck a green key for food. Once this behavior is well established, the color on the key is changed to blue and pecking is not reinforced. The blue and green colors are alternately presented, and the corresponding schedules of extinction or reinforcement are in effect. During the early sessions, the onset of extinction will often generate emotional behavior that interferes with ongoing operant behavior.

Extinction is an aversive procedure. Pigeons flap their wings in an aggressive manner and will work for an opportunity to attack another bird during the presentation of the S^Δ on a multiple schedule. Birds will peck a different key if pecking turns off the extinction stimulus, implying that the stimulus is aversive. There are other problems with successive discrimination procedures. Because emotional behavior is generated, discriminative responding takes a long time to develop. In addition, spontaneous recovery of S^Δ responding from session to session interferes with the acquisition of a discrimination. Finally, even after extensive training, birds and other organisms continue to make errors by responding in the presence of the signal for extinction.

Errorless Discrimination

These problems can be eliminated with a discrimination procedure described by Terrace (1963). The method is called **errorless discrimination**, because the trainer or teacher does not allow the organism to make mistakes by responding to the extinction stimulus. In his 1963 experiment, Terrace used early progressive training to reduce errors of discrimination. This training began when pigeons were conditioned to peck a red key for food reinforcement. The birds were started on continuous reinforcement and moved gradually to a variable-interval 1-min schedule. Early in this training, the key light was turned off for 5 s and extinction was in effect. Thus, a dark key was the S^Δ in this early phase. It is important to note that pigeons usually do not peck at a dark key, and Terrace made use of this fact.

As discrimination training continued, the dark key was gradually illuminated with a green light. The light became progressively brighter and remained on for longer and longer
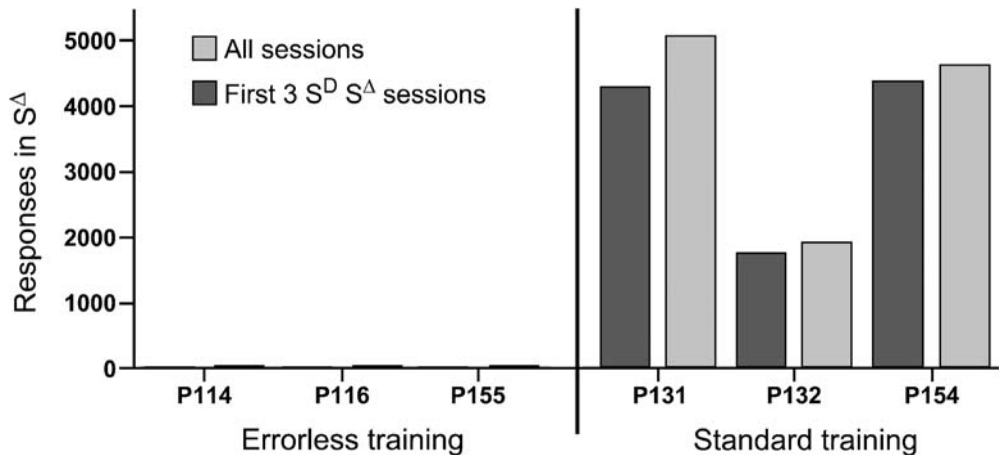
FIG. 8.10. *Results of errorless discrimination procedure used by Terrace* Note: *Adapted from Fig. 1 of "Discrimination Learning with and without 'Errors,'" by H. S. Terrace, 1963,* Journal of the Experimental Analysis of Behavior, 6, *pp. 1–27.*

intervals, until it stayed on the same amount of time as the red key light. At this point, the duration of the S^D (red) was increased to 3 min, and the S^Δ (green) was gradually increased from 5 s to 3 min.

Now the birds were responding on a MULT VI 1-min EXT 3-min schedule. On this schedule, the red key was presented for 3 min, and the pigeons pecked for food on a VI 1-min schedule for this period. After 3 min in the reinforcement component, the key color was changed from red to green and extinction was in effect for 3 min. With these new contingencies in effect, the pigeons had sufficient time in the S^Δ component to make numerous errors, but they did not respond in the presence of the red light.

When this early progressive training was compared to standard successive discrimination procedures, there were far fewer mistakes with the errorless technique. Figure 8.10 shows that the three pigeons trained with errorless discrimination procedures made about 25 pecks each to the extinction stimulus (errors). Another three birds had the S^Δ introduced later in the experiment, at full intensity and for 3 min (standard method); these pigeons made between 2,000 and 5,000 pecks to the S^Δ. Compared with the errorless group, most of the pecks to the S^Δ in the standard condition occurred during the first three sessions. Overall, errorless discrimination procedures result in faster acquisition of a discrimination and substantially less incorrect responding (see Roth, 2002, for a procedure to teach dolphins a discrimination involving auditory stimuli and the selecting of two-dimensional pictures).

Errorless training has other important effects. In a 1972 report, Terrace suggested that his procedures reduced the aversiveness of the S^Δ when compared to traditional discrimination methods. Because of this, Terrace claimed that errorless training eliminated the peak-shift effect and positive behavioral contrast. Animals are also less likely to show emotional behavior such as attack or aggressive wing flapping (see Rilling, 1977, for evidence against these assertions). For these reasons, errorless discrimination procedures may be useful in educational settings. Students will enjoy learning, learn very rapidly, and make few mistakes (Powers, Cheney, & Agostino, 1970; see Luciano, 1986, for training verbal behavior in language-delayed children).

Once a discrimination is established with errorless training, it may be difficult to re-verse the roles of S^D and S^Δ. Marsh and Johnson (1968) trained two groups of birds to

discriminate between red (S^D) and green (S^Δ) stimuli. One group received errorless train-ing, and the other got the standard discrimination procedure. After performance stabilized, the S^D and S^Δ were reversed so that the green stimulus now signaled reinforcement and the red indicated extinction. The birds trained by the errorless method continued responding in terms of their initial training—they would not respond to the S^Δ (the new S^D from the point of view of the researcher) even when explicitly reinforced for such behavior. Birds given standard discrimination training were not as persistent and quickly discriminated the change in contingencies.

These findings suggest that errorless procedures may be most useful in education when there is little chance of a change in the contingencies of reinforcement. For example, stu-dents may be best taught multiplication tables, standard word spellings, rules for extracting a square root, and other types of rote learning with the errorless method. In problem-solving situations where there are many alternative solutions or where the contingencies of re-inforcement change, the standard method of trial-and-error learning may produce more flexibility in responding.

Fading

Errorless discrimination involves two basic procedures: early introduction of the S^Δ and gradual transfer of stimulus control. It is the latter procedure, called fading, that has received the most attention by clinicians and educators. **Fading** involves transferring stimulus control from one value of a stimulus to another. This is done by gradually changing a controlling stimulus from an initial value to some designated criterion. When Terrace (1963) gradually changed the dark key toward the green color, this was fading. Cheney and Tam (1972) used fading to transfer control by a color discrimination to control by line angle tilt in pigeons; the procedure involved gradually increasing the intensity of the line segments projected on the key while decreasing the intensity of the colors. Control transferred from color to mirror-image line angles with some, but very few, errors.

A practical example of fading is given by Sherman (1965), who used the procedure to get a mute psychotic to say his first words. The patient was described by Sherman as:

> a 63-year-old man, diagnosed, in 1916, as dementia praecox, hebephrenic type. He had been in the hospital continuously for 47 years, with a history of mutism for 45 of those years. At the time of this study he was not receiving any medication or participating in psychotherapy. Periodically, when seen on the ward, . . . [he] could be observed walking around mumbling softly to himself. However, all of this mumbling appeared to be nonsensical vocal behavior. In his 45-year history of mutism [he] had not exhibited any recorded instance of appropriate verbal behavior. (1965, p. 157)

After many sessions of reinforcement and imitation training, Sherman succeeded in getting the patient to say "food"—his first distinct utterance in 45 years. At this point, Sherman used fading to bring this response under appropriate stimulus control—responding "food" to the question, "What is this?" The training was as follows:

> To obtain the word "food" from the subject when the experimenter asked "What is this?" a fading procedure was used. With the fading procedure, the experimenter continued to hold up a bite of food each time and to deliver instructions to the subject. The behavior of the subject—that is saying "food"—was maintained with reinforcement while the instructions to the subject were gradually changed in the following steps: (a) "Say food"; (b) "Say foo_____"; (c) "Say f_____"; (d) "What is this? Say f_____"; (e) "What is this? Say _____"; (f) "What is this?" (Sherman, 1965, p. 158)

This example shows that the patient initially replied "food" after the experimenter said "say food." The original verbal stimulus for the response "food" was gradually faded and replaced with a new stimulus of "What is this?"

In everyday life, fading is an important aspect of complex human behavior that often goes unrecognized because of its gradual nature. Children learn to identify many objects in the world by the step-by-step transfer of stimulus control. A parent may present a glass of milk to a 2-year-old and state, "Say milk." Eventually, the child says "milk" when a glass of milk is given. Once the response "milk" is established, stimulus control may be gradually transferred from "say milk" to questions such as "What is this?" by fading. In another example, a parent may initially stay at a day-care center in order to make the child comfortable in the new setting. Once the child starts to participate in activities, the parent sneaks out, and stimulus control for a variety of behavior is transferred to both the new situation and the teacher. A similar process occurs in adults. When you meet a stranger who is an acquaintance of an old friend, conversation proceeds normally as long as the old friend is present but becomes awkward if the friend leaves. Over time, the old friend can spend less and less time with you and the new person, because stimulus control of conversation is passed to the new acquaintance.

Complex Stimulus Control

To this point, we have discussed the control of behavior by relatively simple configurations of stimuli, as when a red color signals reinforcement and green signals no reinforcement. There are other procedures that allow for the investigation of performance regulated by more complex stimulus arrays.

Matching to Sample

Discrimination of Identity

One procedure that is often used to investigate identity discriminations is called **matching to sample**. In a simple identity procedure, a pigeon may be presented with three keys, as in Fig. 8.11. Panel A shows a triangle projected onto the center key. The triangle is the sample stimulus in the sense that it is an instance of a larger set of geometric forms. To ensure that the bird attends to the sample, it is required to peck the sample key. When this observing response happens, two side keys, which are called the comparison stimuli, are illuminated with a triangle on one and a square on the other. If the bird pecks the
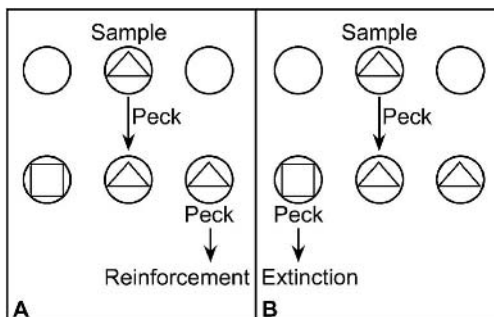
FIG. 8.11.   *Procedures used to train an identity discrimination by a pigeon. Panel A shows that a peck to the sample key (triangle) results in two shapes on the side keys. A peck to the side key that matches the sample is reinforced. Panel B shows a sequence that is not reinforced.*

comparison stimulus that corresponds to the sample (a match), this behavior is reinforced and leads to the presentation of a new sample. Panel B shows a nonreinforced sequence in which pecks to the noncorresponding stimulus result in extinction and the next trial. Over a number of trials, the comparison stimuli appear on either the left or the right keys with equal probability. After some training, pigeons will accurately match to sample even with new (never reinforced) samples and comparison stimuli (Blough, 1959, 1982). The evidence suggests that pigeons' behavior can be regulated by the identity or similarity among stimuli.

Delayed Matching to Sample and Remembering

A twist on the standard matching to sample task is called **delayed matching to sample (DMTS)**. This procedure was first described by Blough (1959) and involves adding a delay between the offset of the sample stimulus and the onset of the two comparison stimuli. For example, in Fig. 8.12 a pigeon is presented with a center key (sample) that is illuminated with
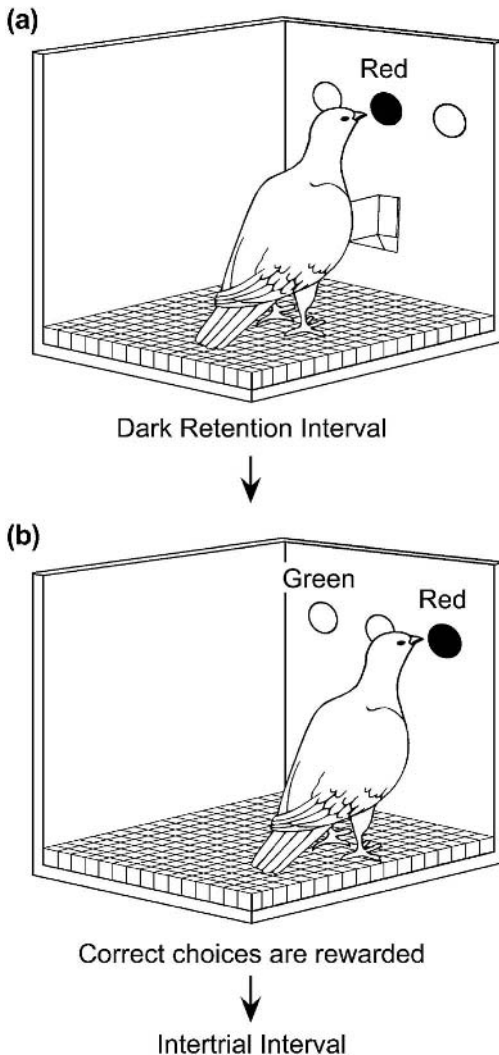
FIG. 8.12.   *Delayed matching to sample in a pigeon. The sequence begins (a) by the pigeon pecking a red or green sample on the center response key. The response to the sample is followed by the chamber being darkened during a retention interval. Next, the pigeon chooses (b) between red and green side keys; choices that match to the sample are reinforced with food; after a time interval another trial begins.*

a red light. The red sample turns off, and a few seconds later (e.g., 10 s) red and green comparison stimuli are presented on the side keys. A response to the stimulus that matches the sample is reinforced, and responses to the other stimulus are not. The basic finding is that the percentage of correct responses decreases as the delay increases (Blough, 1959; Grant, 1975).

Delayed matching to sample has been used to investigate behavior that is said to reflect cognition and memory. For example, the time between the offset of the sample stimulus and the onset of the comparison stimuli is usually called the **retention interval**. The idea is that during this interval the organism is covertly doing something that helps to retain the information about the sample. Thus, Grant (1981) found that pigeons would "forget" the sample if they were given a sign (a vertical line on the key) that indicated that the comparison stimuli would not appear on that trial. In terms of remembering the sample, Grant reported that the pigeons performed poorly if the forget cue was presented soon after the sample went off (see also Maki & Hegvik, 1980; Stonebraker, Rilling, & Kendrick, 1981). Performance was not as disrupted if the signal was given later in the interval. One interpretation is that the cue to forget interferes with covert rehearsal of the sample stimulus (Grant, 1981; Stonebraker & Rilling, 1981).

The cognitive metaphor of memory processes (encoding, storage, retrieval, rehearsal, etc.) is popular in psychology. Tulving (1983) explained that remembering an event involves mental encoding of the event and subsequent retrieval of the information from memory due to reactivation of the encoding operations. He proposed that encoding results in a memory trace or representation of the past event. The memory trace becomes manifest when combined with retrieval processes. Thus, memory research has emphasized how encoding produces mental representations that in turn aid in retrieval.

An explanation of remembering based on inferred mental processes is unacceptable to behavior analysts. Unless the mental processes have direct evidence, encoding, mental representations, and retrieval are inferences from remembering itself. When mental processes are inferred from remembering itself, they cannot be used to explain it—the explanation is said to be circular. Behavior analysts insist that a scientific analysis of remembering must refer to both contingencies of reinforcement and basic behavior principles.

Geoffrey White in the Department of Psychology at the University of Otago (Dunedin, New Zealand) has developed a behavioral approach to memory using basic operant principles. White (2002) indicates that a behavior analysis of memory points to actions or choices (e.g., choosing between the comparison stimuli) based on current contingencies and how those choices are in part regulated by the reinforcement history for similar choices in the past. In this regard, White (2002) explains:

> **Remembering** is not so much a matter of looking back into the past or forward into the future as it is of making choices at the time of remembering. The [behavioral] approach treats remembering as a process of discriminating the relevant events from alternative possibilities. By analogy with the discrimination of objects at a physical distance, objects or events can be discriminated at a temporal distance. . . . That is, the discrimination is not made at the time of encoding, or learning, but at the time of remembering. (pp. 141–142)

One aspect of White's behavioral approach to memory is that it challenges the well-known finding that remembering gets worse as the retention interval increases. If the discrimination of a past event is made at the time of remembering, White suggests that it is possible to train pigeons to be accurate at a specific delay. In this case, the remembering of a stimulus would be more accurate at a specific delay than with less delay or no delay. That is, remembering would not decline in accord with the retention interval.

Using the delayed matching to sample procedure of Fig. 8.12, Sargisson and White (2000) compared the performance of pigeons trained with 0-s delay and those trained with
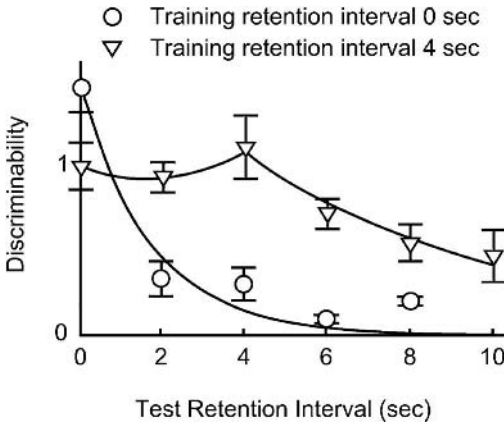
FIG. 8.13. *Selected data from Sargisson and White (2000) showing the accuracy of matching to sample in different groups of pigeons trained with either a 0-s retention interval or a 4-s retention interval; pigeons were tested with retention intervals that varied from 0 to 10 s. The discriminability measure is the log of the ratio of correct to error responses, and is not influenced by response bias. From "Psychophysics of Remembering the Discrimination Hypothesis," by K. G. White, 2002,* Current Directions in Psychological Science, 11, *141–145, reprinted with permission. Copyright 2001 by Blackwell Publishing, Ltd.*

one specific delay at the outset. Typically, birds are trained to match to sample with a 0-s delay, and subsequently the delay or retention interval is gradually lengthened. In the new procedure, pigeons were trained in matching to sample at one specific delay (e.g., 4 s) and then asked to remember the sample at different retention intervals.

Figure 8.13 shows the discriminability of the sample for birds trained with a 0-s delay (circles). Notice that the accuracy of the discrimination decreases with the retention interval, as would be predicted by cognitive theories of memory. For pigeons trained with a 4-s delay, however, their accuracy does not systematically decrease over the retention interval (triangles). Instead, these birds were most accurate at the training delay of 4 s, a finding that argues against the mental representation of the sample with a declining memory trace. Notice also that the birds were not trained to perform with less accuracy at brief delays. That is, the discrimination of the "to be remembered color" should have been easier at short delays (e.g., 0 s), because the sample color was observed very recently. The data show, however, that the pigeons were less accurate at delays of less than 4 s, again disconfirming a cognitive representational account. Overall, the results of the experiment support a behavioral view that remembering involves discriminative operant behavior specific to the time interval of retrieval (see White & Wixted, 1999, for a discrimination model of remembering).

FOCUS ON RESEARCH: CONCEPT FORMATION BY PIGEONS

Principles of stimulus control are involved in many instances of concept formation and abstract reasoning (Critchfield, Galizio, & Zentall, 2002). People usually assume that conceptual thinking is a defining feature of humans that separates them from other animals. Although this kind of behavior is common in humans, it occurs in a more limited way in other organisms. Herrnstein and Loveland (1964) designed an experiment to teach pigeons to identify humans from other objects (learning the concept—human).

Consider what it means to know that this is a human being and other objects are not. Humans come in a variety of sizes, shapes, colors, postures, and so on. Characteristics of the stimulus "human" are abstract and involve multiple stimulus dimensions rather than a single property such as wavelength of light. For example, human faces differ in terms of presence or absence of hair, geometric form, and several other factors. Defining characteristics of

faces include bilateral symmetry, two eyes, a nose, a mouth, and many additional features common to all people.

Although a precise physical description of humans is elusive, Herrnstein and Loveland (1964) asked whether pigeons could respond to the presence or absence of human beings in photographs. If a bird can do this, then its behavior is controlled by the abstract property of humanness. There is no concrete set of attributes that visually equals a human being, but there are relations among such attributes that define the stimulus class. The bird's task is to respond correctly to instances of the stimulus class and by doing so demonstrates concept formation. Herrnstein and Loveland (1964) described the experiment as follows:

> It is well known that animals can use one or a few distinguishing features to discriminate stimuli such as simple visual arrays differing in size, shape, or color. In the experiment described here, however, pigeons were trained to detect human beings in photographs, a class of visual stimuli so diverse that it precludes simple characterization.
>
> [After pigeons were trained to peck at a hinged switch in the presence of a translucent plate] . . . the plate was illuminated throughout each session with projections of 35-m color slides from a projector that housed 81 slides. . . . Over 1200 unselected slides obtained from private and commercial sources were available. Before each session, the projector was loaded with 80 or 81 different photographs of natural settings, including countryside, cities, expanses of water, lawn, meadow, and so on. For any one session, approximately half the photographs contained at least one human being; the remainder contained no human beings—in the experimenter's best judgment. In no other systematic way did the slides appear to differ. Many slides contained human beings partly obscured by intervening objects: trees, automobiles, window frames, and so on. The people were distributed throughout the pictures: in the center or to one side or the other, near the top or the bottom, close up or distant. Some slides contained a single person; others contained groups of various sizes. The people themselves varied in appearance: they were clothed, semi-nude, or nude; adults or children; men or women; sitting, standing or lying; black, white, or yellow. Lighting and coloration varied: some slides were dark, others light; some had either reddish or bluish tints, and so on.
>
> . . . Pictures containing people . . . meant an opportunity to feed . . . and pictures without people meant no such opportunity. . . . Each day the slides themselves and also the random sequence of positive (S^D) slides (that is, containing a person) and negative (S^Δ) slides (without people), were changed for each pigeon. Many slides were used again in later sessions, but never in the order with other slides in which they had appeared earlier. The pigeons had no opportunity, therefore, to learn groups of particular slides or sequences of positives and negatives in general. (pp. 549–550)

The results showed that the pigeons could discriminate between slides with people and ones without them. Within 10 sessions of this training, every bird was responding at a higher rate to slides with humans in them. Over several months, the performance of the birds steadily improved. After extensive training, the birds were given 80 (or 81) slides that they had never seen before. Pigeons pecked at a high rate to new slides with people and at lower rates to slides without them. Generally, this experiment shows that pigeons can differentially respond to the abstract stimulus class of human being.

Additional experiments on concept formation have been conducted with other stimulus classes and different organisms. Pigeons have discriminated trees (Herrnstein, 1979), geometric forms (Towe, 1954), letters of the alphabet (Blough, 1982), fish (Herrnstein & de Villiers, 1980), one person from another (Herrnstein, Loveland, & Cable, 1976), and aerial photographs of human-made objects (Lubow, 1974). Concept formation has also been reported for monkeys (Schrier & Brady, 1987), an African gray parrot (Pepperberg, 1981), and mynah birds (Turney, 1982).

Overall, this research suggests that animals differentially respond to abstract properties of stimulus classes. These stimulus classes are commonly called categories when humans

make similar discriminations. When people describe different categories, they are said to "understand the concept." People can easily identify a computer disk and an automobile as human-made objects. When a similar performance is shown by other animals, we are reluctant to attribute the discriminative behavior to the creature's understanding of the concept.

Rather than attribute understanding to complex performances by humans or animals, it is possible to provide an account based on both evolution and the current demands of the environment. Natural selection shapes sensory capacities of organisms that allow for discrimination along abstract dimensions. Birds obtain food, navigate, care for young, find mates, and so on, largely on the basis of visual stimuli. Many of these activities require subtle adjustments to a complex and changing visual world. It is not surprising, therefore, that these creatures are readily able to discriminate abstract properties of visual objects, especially when reinforcement contingencies favor such a discrimination.

Conditional Discrimination

In everyday life, stimuli that regulate behavior (S^D and S^Δ) often depend on the context. Consider a matching-to-sample experiment in which a bird has been trained to match to either triangles or squares based on the sample stimulus. To turn this experiment into a conditional-discrimination task, either a red or a green light illuminates the sample stimulus. The bird is required to match to the sample when the background light is green and to choose the noncorresponding stimulus when the light is red. That is, when a green triangle is the sample, the bird must peck the comparison triangle, but when a red triangle is presented, pecks to the circle are reinforced. Of course, if a green circle is the sample, pecks to the circle are reinforced, and when the sample turns red, pecking the triangle is the correct response. Conditional matching to sample involves simultaneous discrimination of three elements in a display. The animal must respond to geometric form depending on the background color of the sample. It also must respond to the correspondence or noncorrespondence of the comparison stimuli.

Conditional discrimination is a common aspect of human behavior. A person who is hurrying to an appointment on the 15th floor of an office building will ordinarily enter the first available elevator. This same person may wait for the next lift if the elevator is full. Thus, getting on the elevator (operant) when the doors open (S^D) is conditional on the number of people in the car. In another example, you will say "eight" when shown $3 + 5$ and "fifteen" if the relation is 3×5. Your response to the 3 and 5 is conditional on the $+$ and $\times$ symbols. In the chapter on verbal behavior (chap. 12), we see that conditional discrimination is also important for the emergence of symbolic behavior and communication. When people say that the spoken word cat, the written word CAT, and a picture of a cat are the same, their behavior is a result of such complex discrimination training.

ON THE APPLIED SIDE: THE PIGEON AS A QUALITY CONTROL INSPECTOR

In industrial settings, workers often are hired as quality control inspectors. Quality control usually is a monotonous job of checking samples of a product to identify any defects. The most important skills or attributes needed for such jobs are good visual acuity and color vision. Based on these visual requirements, Thom Verhave (1966) suggested to the
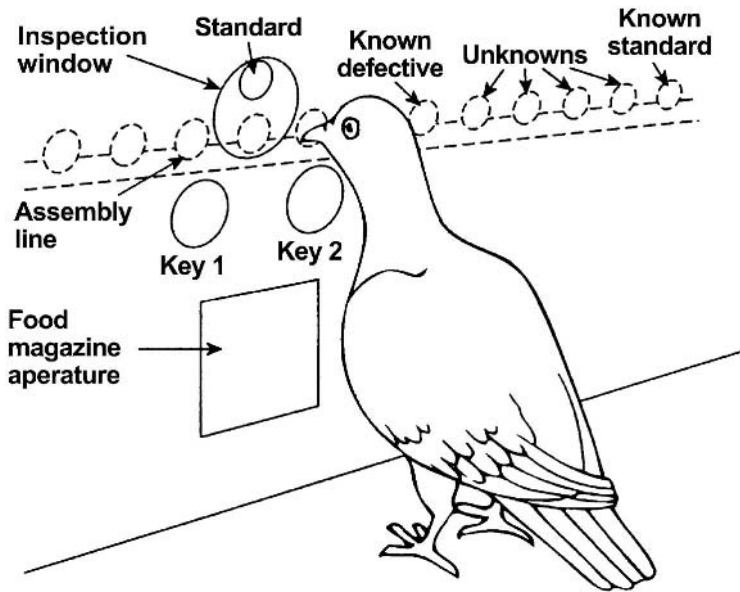
FIG. 8.14. *Drawing depicts Verhave's (1966) discrimination procedures as described in the text. Pigeons were trained to inspect a line of drug capsules, accepting those that met a fixed standard and rejecting defective ones.* From Behavior Principles, *p. 558, by C. B. Ferster, S. Culbertson, and M. C. P. Boren, 1975, Englewood Cliffs, NJ: Prentice-Hall, republished with permission. Copyright 1975, Pearson Education, Inc.

management of a drug company that the laboratory pigeon (Columba livia domestica) would be a cheap and efficient quality control inspector. Although skeptical, the director of research for the company gave Verhave the go-ahead to train pigeons as inspectors.

The procedures were similar to a matching to sample (identity matching) task. Pigeons were trained to inspect a line of drug capsules, accepting those that met a fixed standard and rejecting defective ones. In this procedure (Fig. 8.14), a bird compared a drug capsule to a standard sample (a perfect one) and pecked Key 1 if it matched or pecked Key 2 if there was a defect (a skag).

The standard capsule was fixed in position behind an inspection window. A line of capsules passed by the same window one at a time; some were perfect and others were defective. In order to initiate an inspection, the pigeon pecked at the inspection window activating a beam of light that illuminated the sample and the comparison capsules. During training, all capsules on the inspection line were precoded by an electrical switch as either perfect or skags. If a capsule on the line was precoded as perfect, then the pigeon's response to Key 1 (matching response) resulted in food, turned off the beam of light behind the inspection window, and moved a new capsule into place. If a capsule was precoded as a skag, then a response to Key 2 (nonmatching response) turned off the illumination, moved a new capsule into the inspection window, and resulted in presentation of the food hopper. All other responses were false alarms or misses that were not reinforced and resulted in a 30-s blackout. With these contingencies in effect, the birds were about 99% accurate in identifying perfect capsules and skags.

One practical problem that Verhave faced concerned the persistence of a pigeon's performance on a real-life inspection line. In everyday life, there is no experimenter to designate perfect capsules, skags, misses, and false alarms. Without this monitoring, differential

reinforcement for "hits versus misses" cannot be maintained, and a bird's performance will deteriorate over time to chance levels. A solution was to introduce capsules "known to be perfect or defective" occasionally onto the inspection line. Reinforcement or punishment were only in effect for "known" instances of matching (or nonmatching) to sample. With this procedure, sufficient differential reinforcement occurred to maintain stimulus control by the sample and comparison capsules.

In addition to Verhave (1966), there have been other attempts to use pigeons either for navigation of missiles (Skinner, 1960) or for running assembly lines (Cumming, 1966). More recently, Azar (2002) reports that the U.S. Navy in the 1970s and 1980s used pigeons to find people stranded at sea. Navy scientist Jim Simmons, Ph.D., trained pigeons by operant conditioning for search-and-rescue missions. The pigeons were trained to recognize objects floating in the water from an aircraft and were 93% accurate, compared with only 38% accuracy for human flight crews. When combined with human searchers, the pigeons' detection rate rose to almost perfect. Today with the threat of terrorism, there is talk of using pigeons to screen baggage at airport terminals, but history suggests that such a project will not work. In each pigeon project, the company's management (or military officers) were at first skeptical and amused by the claim that pigeons could perform such feats. Once it became clear that behavioral researchers could establish and maintain precise performance in pigeons, upper-level management no longer found this research either humorous or acceptable and immediately stopped all funding.

Analysis of the reinforcement contingencies related to upper management's rejection of pigeons in industry is informative. For example, although pigeons can be effective quality control inspectors, customers might complain about the lack of sanitary conditions. This could result in sales losses that would offset the benefits of having pigeons as low-cost employees. Other contingencies for managers may involve the complaints of union workers. Even though the quality control task is boring and monotonous, union workers could complain about the loss of jobs and use strikes to back their demands. Again, the benefits of pigeons as inspectors are offset by human labor disputes. Overall, although pigeons are excellent, low-cost employees, the social and economic contingencies of the human marketplace ensure that pigeons' pecking will not prevail.

KEY WORDS

Absolute stimulus control	Discrimination	Positive contrast
Anticipatory contrast	Discrimination Index (I_D)	Relative stimulus control
Behavioral contrast	Errorless discrimination	Remembering
Conditional discrimination	Generalization gradient	Retention interval
Controlling stimulus (S)	Matching to sample	Stimulus control
Delayed matching	Multiple schedule	Stimulus generalization
to sample	Negative contrast	Successive discrimination
Differential response	Peak shift	Superstitious behavior

ON THE WEB

http://www.polyxo.com/discretetrial/sd.html The Web site <polyxo.com> concerns teaching of children with autism, and the site has a focus on discriminative stimuli and teaching.

http://www.unc.edu/courses/psyc070d/dpat/ A slide show of the discriminative effects of drugs such as dopamine and opioids established by Charles Cook.

http://www.psych.ualberta.ca/∼msnyder/Academic/Psych_281/C10/Ch10page.html A site maintained by Mark Snyder and slide shows for various aspects of stimulus control and discrimination (e.g., generalization gradient, peak shift, errorless discrimination, etc.).

http://www2.vet.upenn.edu/labs/equinebehavior/cognition.htm The study of concept formation in the horse is the topic of this Web site; it is interesting that the researchers interpret the discriminative responses of the horses as evidence for animal cognition and mental representation. We suggest that mentalistic explanations of the horses' behavior are not necessary; an account in terms of the contingencies of reinforcement would be more appropriate.

STUDY QUESTIONS

1. Define a controlling stimulus. Discuss two kinds of controlling stimuli and provide examples of these in everyday life. (208)
2. In behavioral terms, what is discrimination? Describe the contingency of differential reinforcement. Discuss the effects of this procedure in an idealized experiment with pigeons pecking red and green keys. (209)
3. What is meant by stimulus control? Give an example in both laboratory and everyday settings. (210)
4. Define a multiple schedule of reinforcement and write the Mechner notation for a multiple VI, extinction (MULT VI, EXT) schedule. How can the mere alternation of the red and green components in a multiple schedule confound the results? What is the likely result of a bird responding on a multiple VI 2-min extinction (MULT VI 2-min EXT) schedule? (210)
5. Discuss the discrimination index and write a simple equation for it. How does the index vary, and what are the meanings of different values? (211)
6. Discuss a study by Pierrel, Sherman, Blue, and Hegge (1970) on differences in sound intensity, using the Discrimination Index. What do the results of this experiment mean? (211)
7. **FOCUS ON**: Summarize the problem faced by the student with a "bird-brained" pigeon. How did the student solve the problem using Mechner notation? In your answer, refer to adventitious reinforcement on multiple schedules, superstitious behavior, and a differential reinforcement of other behavior (DRO) contingency. Draw out the implications for teaching and learning. (213)
8. Define behavioral contrast and how it occurs on a MULT VI EXT schedule. Name two kinds of contrast and define them. Give a relative rate of reinforcement analysis of behavioral contrast. What other conditions affect contrast? How could contrast have adaptive value? (214)
9. **FOCUS ON**: In terms of the the research of Ben Williams, which component of an A → B → C sequence of schedules is the target? In relation to the target schedule, which schedule produces weak and fleeting contrast effects? Which schedule produces strong and durable contrast effects? Describe the transitory contrast effect elicited by the preceding schedule. Describe the more robust effect of anticipatory contrast. Where do we stand today in terms of behavioral contrast? (216)
10. What is stimulus generalization? Give several common examples. Discuss generalization gradients using a classic experiment by Guttman and Kalish (1956). Define a peak shift. Recount an experiment by Hanson (1959) on the peak-shift phenomenon. (217)

11. Define absolute and relative stimulus control. How is peak shift an instance of relative stimulus control? Compare successive and simultaneous discrimination. (219)

12. Use an experiment by Gonzalez, Gentry, and Bitterman (1954) to illustrate simultaneous discrimination. What were the results? Give an example of simultaneous discrimination on the television program *Sesame Street*. (220)

13. How does extinction interfere with establishing a discrimination? What is errorless discrimination? Discuss the Terrace (1963) experiment on errorless discrimination. Compare the effects of early progressive training to those of standard successive discrimination. (221)

14. What are some additional effects of errorless discrimination procedures? Discuss the importance of errorless training in educational settings. (223)

15. Describe two basic procedures that underlie errorless training. What is fading? Give a practical example of fading used by Sherman (1965). How is fading important in everyday life? (223)

16. What is identity discrimination? Describe delayed matching to sample in a pigeon experiment. How is this procedure used to investigate behavior said to reflect cognition and memory? Provide a behavior analysis (White, 2002) of remembering using delayed matching to sample (DMTS) in terms of both choice and discrimination. (224)

17. **FOCUS ON**: Summarize the Herrnstein and Loveland (1964) research on concept formation by pigeons. What were the results? How general is concept formation? Draw out the implications of this research area. (227)

18. Outline conditional discrimination using a pigeon and matching to sample procedure. How does conditional discrimination help explain complex human behavior? (229)

19. How did Verhave (1966) teach pigeons to be quality control inspectors? What did Verhave do to keep performance accurate on the inspection line when the match between the sample and the comparison capsules was unknown? What contingencies does management face that prevents the adoption of pigeons as quality control inspectors? (229)

BRIEF QUIZ

1. An S^{Δ} sets the occasion upon which a response is _____ reinforced.
   (a) sometimes
   (b) always
   (c) never
   (d) maybe

2. An S^D does not cause or elicit the appearance of a response the way a _____ does.
   (a) UR
   (b) US
   (c) CS
   (d) CR

3. In operant conditioning the antecedent stimulus paired with reinforcement is called an
   (a) S^{Δ}
   (b) S–R–S
   (c) S^D
   (d) CS

4. A two-component schedule in which both components have separate stimuli is called a
   (a) MIX
   (b) CONC
   (c) TAND
   (d) MULT

5. In order to keep the onset of S^D from reinforcing responses in S^Δ one needs add a _____ contingency.
   (a) EXT
   (b) IRT
   (c) DRO
   (d) PRP

6. If reinforcers from one source are depleted and responding in another source increases we call this
   (a) negative contrast
   (b) positive contrast
   (c) substitutability
   (d) anticipatory contrast

7. A change in maximal generalization responding away from S^Δ to the other side of S^D is called
   (a) gradient shift
   (b) relative control
   (c) stimulus control
   (d) peak shift

8. A shaping procedure whereby control gradually changes from one element to another is called
   (a) approximations
   (b) fading
   (c) transfer
   (d) conditional discrimination

9. If you trained a pigeon to turn a circle when a TURN sign was presented you could say the bird was
   (a) discriminating
   (b) conceptually oriented
   (c) reading
   (d) superstitious

10. With careful shaping and fading one might develop a discrimination without
    (a) reinforcement
    (b) extinction
    (c) contrast
    (d) errors

Answers to brief quiz (*page*): c(208); b(208); c(208); d(210); c(214); b(214); d(219); b(223); c(229); d(221)

CHAPTER 9
Choice and Preference

IN THIS CHAPTER

1. Find out about how to study choice and preference in the laboratory.
2. Learn about the matching law as a basic behavioral principle of choice and preference.
3. Discover how behavior analysts have used mathematics to quantify the basic processes of choice and preference.
4. Inquire about optimal foraging, behavioral economics, and self-control.
5. Learn about the quantitative law of effect and its application to human behavior.

Over the course of a day, an individual makes many decisions that range from ones of great importance to ones of small consequence. A person is said to make a decision when buying a new car, when choosing to spend an evening with one friend rather than another, or when deciding what to eat for supper. Animals also make a variety of decisions; they may choose mates with particular characteristics, select one type of food over another, or decide to leave a territory.

From a behavioral view, the analysis of **choice** is concerned with the distribution of operant behavior among alternative sources of reinforcement. When several choices are available, one alternative may be chosen more frequently than others. When this occurs, it is called **preference** for an alternative source of reinforcement. For example, a person may choose between two food markets (a large supermarket and the corner store) on the basis of price, location, and variety. Each time the individual goes to one store rather than the other, he or she is said to choose. Eventually, the person may shop more frequently at the supermarket than at the local grocery, and when this occurs the person is showing preference for the supermarket alternative.

Many people describe choosing to do something, or a preference for one activity over another, as a subjective experience. For example, you may simply like one person better than others, and based on this you feel good about spending a day with that person. From a behavioral perspective, your likes and feelings are real, but they do not provide an objective scientific account of what you decide to do. To provide that account, it is necessary to identify the conditions that affected your attraction to (or preference for) the individual.

Experimental Analysis of Choice and Preference

For behavior analysts, the study of choice is based on principles of operant behavior. In previous chapters, operant behavior was analyzed in situations in which one response class was reinforced on a single schedule of reinforcement. For example, a child is reinforced with contingent attention from a teacher for correctly completing a page of arithmetic

problems. The teacher provides one source of reinforcement (attention) when the child emits the target operant (math solutions). The single-operant analysis is important for the discovery of basic principles and applications. However, this same situation may be analyzed as a choice among alternatives. The child may choose to do math problems or emit other behavior (e.g., look out the window or talk to another child). This analysis of choice extends the operant paradigm or model to more complex environments in which several response and reinforcement alternatives are available.

In the natural environment, there are many alternatives that schedule reinforcement for operant behavior. A child may distribute time and behavior among parents, peer group, and sport activities. Each alternative may require specific behavior and provide reinforcement at a particular rate and magnitude. To understand, predict, or change the child's behavior, all of these response–consequence relationships must be taken into account. Thus, the operant analysis of choice and preference begins to contact the complexity of everyday life and offers new principles for application.

The Choice Paradigm

The Two-Key Procedure

In the laboratory, choice and preference are investigated by arranging **concurrent schedules of reinforcement**. Figure 9.1 shows a concurrent operant setting. In the laboratory, two or more simple schedules (i.e., FR, VR, FI, or VI) are simultaneously available on different response keys (Ferster & Skinner, 1957). Each key is associated with a separate schedule

FIG. 9.1. *A two-key operant chamber for birds. Schedules of food reinforcement are arranged simultaneously on each key. Author Photo.*

of reinforcement, and the organism is free to distribute behavior between the alternative schedules. The distribution of time and behavior among alternatives is the behavioral measure of choice and preference. For example, a food-deprived bird may be exposed to a situation in which the left response key is programmed to deliver 20 presentations of the food hopper each hour, whereas the right key delivers 60 reinforcers an hour. To obtain reinforcement from either key, the pigeon must respond according to the schedule on that key. If the bird responds exclusively to the right key (and never to the left) and meets the schedule requirement, then 60 reinforcers will be delivered each hour. Because the bird could have responded to either side, we may say that it prefers to spend its time on the right alternative.

Concurrent schedules of reinforcement have received considerable research attention, because they may be used as an analytical tool for understanding choice and preference. This selection of an experimental paradigm or model is based on the reasonable assumption that contingencies of reinforcement contribute substantially to choice behavior. Simply stated, all other factors being equal, the more reinforcement provided by an alternative, the more time and energy spent on that alternative. For example, in choosing between spending an evening with two friends, the one who has in the past provided the most social reinforcement will probably be the one selected. Reinforcement may be social approval, affection, interesting conversation, or other aspects of the friend's behavior. The experience of deciding to spend the evening with one rather than the other may be something like, "I just feel like spending the evening with John." Of course, in everyday life, choosing is seldom as uncomplicated as this, and a more common decision might have been to spend the evening with both friends. However, to understand how reinforcement processes are working, it is necessary to control the other factors so that the independent effects of reinforcement on choice may be observed.

Concurrent Ratio Schedules

Figure 9.2 shows a two-key concurrent-operant setting for humans. Consider that you are asked to participate in an experiment in which you may earn up to $50 an hour. As an experimental participant, you are taken to a room that has two response keys separated by a distance of 8 ft. Halfway between the two keys is a small opening just big enough to place your hand in. The room is empty, except for the unusual-looking apparatus. You are told to do anything you want. What do you do? You probably walk about and inspect your surroundings and, feeling somewhat foolish, eventually press one of the response keys. Immediately following this action, $1 is dispensed by a coin machine and is held on a plate inside the small opening. The dollar remains available for about 5 s, and then the plate falls away and the dollar disappears. Assuming that you have retrieved the dollar, will you press one of the keys again? In reality, this depends on several factors: Perhaps you are wealthy and the dollar is irrelevant; perhaps you decide to "get the best of the experimenter" and show that you are not a rat; maybe you do not want to appear greedy, and so on. However, assume for the moment that you are a typical poor student and you press the key again. After some time pressing both keys and counting the number of key presses, you discover a rule. The left key pays a dollar for each 100 responses, whereas the right side pays a dollar for 250 responses. Does it make sense to spend your effort on the right key when you can make money faster on the other alternative? Of course it does not, and you decide to spend all of your work on the key that pays the most. This same result has been found with other organisms. When two ratio schedules are programmed as concurrent schedules, then the alternative that produces more rapid reinforcement is chosen exclusively (Herrnstein & Loveland, 1975).

FIG. 9.2.   *A two-key operant chamber for humans. Pressing the keys results in money from a coin dispenser (middle), depending on the schedules of reinforcement. Author Photo.*

Because ratio schedules result in exclusive responding to the alternative with the highest rate of payoff, these schedules are seldom used to study choice. We have discovered something about choice: Ratio schedules produce exclusive preference (in contrast, see McDonald, 1988, on how to program concurrent ratio schedules to produce response distributions similar to those that occur on interval schedules). Although this result is interesting, it suggests that other schedules should be used to investigate choice and preference. This is because once exclusive responding occurs, it is not possible to study how responses are distributed between the alternatives.

Concurrent Interval Schedules

Consider, however, what you might do if interval schedules were programmed on the two keys. Remember that on an interval schedule a single response must occur after a defined amount of time. If you spend all of your time pressing the same key, you will miss reinforcement that is programmed on the other alternative. For example, if the left key is scheduled to pay a dollar every 2 min; and the right key, every 6 min, then a reasonable tactic is to spend most of your time responding on the left key but every once in a while to check out the other alternative. This behavior will result in obtaining most of the money set up by both schedules. In fact, when exposed to concurrent interval schedules, most animals distribute their time and behavior between the two alternatives in such a manner (de Villiers, 1977). Thus, the first prerequisite of the choice paradigm is that interval schedules must be used to study the distribution of behavior.

Interval schedules are said to be independent of one another when they are presented concurrently. This is because responding on one alternative does not affect the rate of

reinforcement programmed for the other. For example, a fixed-interval 6-min schedule (FI 6 min) is programmed to deliver reinforcement every 6 min. Of course, a response must be made after the fixed interval has elapsed. Pretend that you are faced with a situation in which the left key pays a dollar every 2 min (FI 2 min). The right key delivers a dollar when you make a response after 6 min. You have 1 hr a day in the experiment. If you just respond to the FI 2-min schedule, you would earn approximately $30. On the other hand, you could increase the number of reinforcers an hour by occasionally pressing the FI 6-min key. This occurs because the left key pays a total of $30 each hour and the right key pays an additional $10. After many hours of choosing between the alternatives, you may develop a stable pattern of responding. This steady-state performance is predictable. You should respond for approximately 6 min on the FI 2-min alternative and obtain three reinforcers (i.e., $3). After the third reinforcer, you may feel like switching to the FI 6-min key, on which a reinforcer is immediately available. You obtain the money on this key and immediately return to the richer schedule (left key). This steady-state pattern of responding may be repeated over and over with little variation.

Concurrent Variable-Interval Schedules

Recall that there are two major types of interval schedules. On variable-interval schedules (VI), the time between each programmed reinforcer changes, and the average time to reinforcement defines the specific schedule (e.g., VI 60 s). Because the organism is unable to discriminate the time to reinforcement on VI schedules, the regular switching pattern that characterizes concurrent FI FI performance does not occur. This is an advantage for the analysis of choice because the organism must respond on both alternatives and because switching does not result always in reinforcement. Thus, operant behavior maintained by concurrent VI VI schedules is sensitive to the rate of reinforcement on each alternative. For this reason, VI schedules are typically used to study choice.

Alternation and the Changeover Response

At this point, the choice paradigm is almost complete. Again, however, consider what you would do in the following situation. The two keys are separated and you cannot press both at the same time. The left key now pays a dollar on a VI 2-min schedule, and responses to the right alternative are reinforced on VI 6 min. The left key pays $30 each hour, and the right one delivers $10 if you respond. Assuming you obtain all programmed reinforcers on both schedules, you may earn $40 for each experimental session. What can you do to earn the most per hour? If you stay on the VI 2-min side, you end up missing the 10 reinforcers on the other alternative. However, if you frequently change over from key to key, most of the reinforcers on both schedules will be obtained. This is in fact what most animals do when faced with these contingencies (de Villiers, 1977).

Simple alternation between response alternatives prevents an analysis of choice, because the distribution of behavior remains the same (approximately 50/50) no matter what the programmed rates of reinforcement are. Frequent switching between alternatives may occur because of the correlation between the rate of switching and the overall rate of reinforcement (dollars per session). In other words, as the rate of switching increases, so does the hourly payoff. Another way of looking at this alternation is that organisms are accidentally reinforced for the changeover response. This alternation is called concurrent superstition (Catania, 1966) and occurs because as time is spent on an alternative, the other schedule is timing out. As the organism spends more time on the left key, the probability of a reinforcer being set up on the right key increases. This means that a changeover to the right

alternative will be reinforced, even though the contingencies do not require the changeover response. Thus, switching to the other response key is an operant that is inadvertently strengthened.

The Changeover Delay

The control procedure used to stop rapid switching between alternatives is called a changeover delay, or COD (Shull & Pliskoff, 1967). The COD contingency stipulates that responses do not have an effect immediately following a change from one schedule to another. After switching to a new alternative, a brief time is required before a response is reinforced (e.g., 3-s delay). For example, if an organism has just changed to an alternative that is ready to deliver reinforcement, there is a 3-s delay before a response is effective. As soon as the 3-s delay has elapsed, a response is reinforced. Of course, if the schedule has not timed out, the COD is irrelevant because reinforcement is not yet available. The COD contingency operates in both directions whenever a change is made from one alternative to another. The COD prevents frequent switching between alternatives. To obtain reinforcement, an organism must spend a minimal amount of time on an alternative before switching to another schedule. For example, with a 3-s COD, changing over every 2 s will never result in reinforcement. The COD is therefore an important and necessary feature of the operant-choice procedure for the investigator.

Experimental Procedures To Study Choice

The basic paradigm for investigating choice and preference is now complete. In summary, a researcher interested in behavioral choice should

1. arrange two or more concurrently available schedules of reinforcement
2. program interval schedules on each alternative
3. use variable- rather than fixed-interval schedules
4. require a COD in order to stop frequent alternation between or among the schedules

The Findley Procedure

An interesting variation on the basic choice procedure was described by Findley (1958). The procedure involves a single response key that changes color. Each color is a stimulus that signals a particular schedule of reinforcement. The color and the associated schedule may be changed when a response is made to a second key. This key is called the changeover key. For example, a pigeon may respond on a VI 30-s schedule that is signaled by red illumination of the response key. When the bird pecks a second changeover key, the color on the response key changes from red to blue. In the presence of the blue light, the pigeon may respond on a VI 90-s schedule of reinforcement. Another response on the changeover key reinstates the red light and the VI 30-s schedule. The advantage of the Findley procedure is that the response of changing from one alternative to another is explicitly defined and measured. Figure 9.3 compares the two-key and Findley procedures, showing that the Findley method allows for the measurement and control of the changeover response.

Current evidence suggests that the same principles of choice account for behavior in both the two-key and the changeover procedures. For this reason, researchers have not made a theoretical distinction between them. However, such a distinction may be important for the analysis of human behavior. Sunahara and Pierce (1982) have suggested that the two-key procedure may provide a model for social interaction. For example, in a group discussion
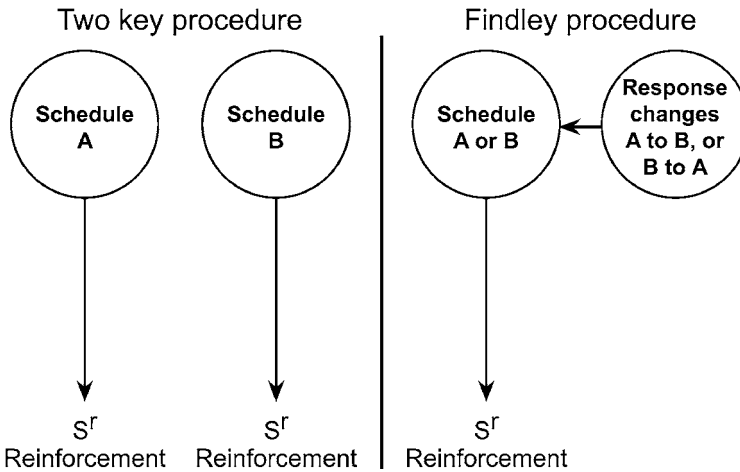
FIG. 9.3. *Comparison of two-key and Findley procedures. Notice that the Findley method highlights the changeover response.*

a person may distribute talk and attention to several group members. These members may be viewed as alternative sources of social reinforcement for the person. On the other hand, the changeover-key procedure may model role taking, in which an individual responds differentially to another person. In this case, the individual may change over between the reinforcement schedules provided by the other person as either a friend or a boss. For example, while at work the changeover may be made by saying, "Could I discuss a personal problem with you?" In other words, a person who is both your friend and your supervisor at work may sometimes deliver social reinforcers as a friend and at other times as a boss. Your social role may change when differential reinforcement (from supervisor or friend) is provided by the other individual.

The Matching Law

In 1961, Richard Herrnstein (Fig. 9.4) published an influential paper that described the distribution of behavior on concurrent schedules of positive reinforcement. He found that pigeons matched relative rates of behavior to relative rates of reinforcement. For example, when 90% of the total reinforcement was provided by schedule A (and 10% by schedule B), approximately 90% of the bird's key pecks were on this schedule. This relationship is known as the matching law. To understand this law, we turn to Herrnstein's (1961b) experiment.

Proportional Matching

Herrnstein's Experiment

In this study, Herrnstein investigated the behavior of pigeons on a two-key concurrent schedule. Concurrent VI VI schedules of food reinforcement were programmed with a 1.5-s COD. The birds were exposed to different pairs of concurrent variable-interval schedules for several days. Each pair of concurrent schedules was maintained until response rates

FIG. 9.4.   *Richard Herrnstein. Reprinted with permission.*

stabilized. That is, behavior on each schedule did not significantly change from session to session. After several days of stable responding, a new pair of schedule values was presented. The overall rate of reinforcement was held constant at 40 per hour for all pairs of schedules. Thus, if the schedule on the left key was programmed to deliver 20 reinforcers an hour (VI 3 min), then the right key also provided 20 reinforcers. If the left key supplied 10 reinforcers, then the right key supplied 30 reinforcers. The schedule values that Herrnstein used are presented in Fig. 9.5.

The data in Fig. 9.5 show the schedules operating on the two keys, A and B. As previously stated, the total number of scheduled reinforcers is held constant for each pair of VI schedules. This is indicated in the third column, in which the sum of the reinforcements per hour (Rft/hr) is equal to 40 for each set of schedules. Because the overall rate of reinforcement remains constant, changes in the distribution of behavior cannot be attributed to this factor. Note that when key A is programmed to deliver 20 reinforcers an hour, so is key B. When this occurs, the responses per hour (Rsp/hr) are the same on each key. However, the responses per hour (or absolute rate) are not the critical measure of preference. Recall that choice and preference are measured as the distribution of time or behavior

Key	Schedule	Rft/hr	Rsp/hr	Relative reinforcement	Relative responses
A	VI 3-min	20.00	2000	0.50	0.50
B	VI 3-min	20.00	2000	0.50	0.50
A	VI 9-min	6.7	250	0.17	0.08
B	VI 1.8-min	33.30	3000	0.83	0.92
A	VI 1.5-min	40.00	4800	1.00	1.00
B	Extinction	0.00	0	0.00	0.00
A	VI 4.5-min	13.30	1750	0.33	0.31
B	VI 2.25-min	26.70	3900	0.66	0.69

FIG. 9.5.   *A table of schedule values and data. Reinforcement per hour (Rft/hr), responses per hour (Rsp/hr), relative reinforcement (proportions), and relative responses (proportions) are shown.* Note: *Adapted from Fig. 1 of "Relative and Absolute Strength of Responses as a Function of Frequency of Reinforcement," by R. J. Herrnstein, 1961b,* Journal of the Experimental Analysis of Behavior, 4, *pp. 267–272.*

between alternatives. To express the idea of distribution, it is important to direct attention to relative measures. Because of this, Herrnstein focused on the relative rates of response. In Fig. 9.5, the relative rate of response is expressed as a proportion. That is, the rate of response on key A is the numerator, and the sum of the rates on both keys is the denominator. The proportional rate of response on key A is shown in the final column, labeled Relative Responses.

Calculation of Proportions

To calculate the proportional rate of responses to key A for the pair of schedules VI 4.5 min VI 2.25 min, the following simple formula is used:

$$B_a/(B_a + B_b).$$

The value B_a is behavior measured as the rate of response on key A, or 1,750 pecks per hour. The rate of response on key B is 3,900 pecks per hour and is represented by the B_b term. Thus, the proportional rate of response on key A is

$$1,750/(1,750 + 3,900) = 0.31.$$

In a similar fashion, the proportion of reinforcement on key A may be calculated as

$$R_a/(R_a + R_b).$$

The R_a term refers to the scheduled rate of reinforcement on key A, or 13.3 reinforcers per hour. Rate of reinforcement on key B is designated by the symbol R_b and is 26.7 reinforcers each hour. The proportional rate of reinforcement on key A is calculated as

$$13.3/(13.3 + 26.7) = 0.33.$$

These calculations show that the relative rate of response (0.31) is very close to the relative rate of reinforcement (0.33). If you compare these values for the other pairs of schedules, you will see that the proportional rate of response approximates the proportional rate of reinforcement.

Importance of Relative Rates

Herrnstein showed that the major dependent variable in choice experiments was the **relative rate of response**. He also found that the relative rate of reinforcement was the primary independent variable. Thus, in an operant-choice experiment, the researcher manipulates the **relative rates of reinforcement** on each key and observes the relative rate of response to the respective alternatives.

Figure 9.5 shows that Herrnstein manipulated the independent variable, the relative rate of reinforcement on key A, over a range of values. Because there are several values of the independent variable and a corresponding set of values for the dependent variable, it is possible to plot the relationship. Figure 9.6 shows the relationship between the proportional rate of reinforcement, $R_a/(R_a + R_b)$, and the proportional rate of response, $B_a/(B_a + B_b)$, for pigeon 231 based on the values in Fig. 9.5.

The Matching Equation

As the relative rate of reinforcement increases, so does the relative rate of response. Further, for each increase in relative reinforcement there is about the same increase in the
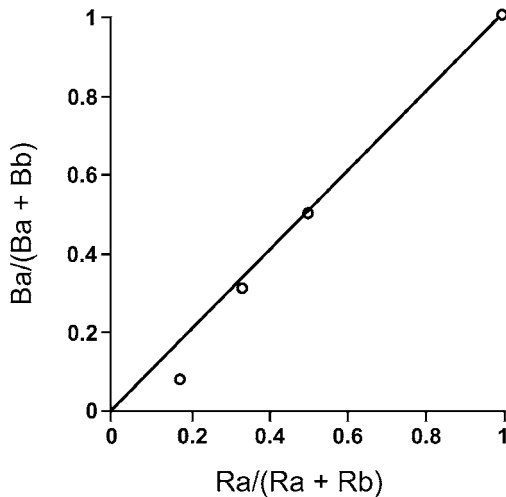
FIG. 9.6. *Matching between proportional rate of response and proportional rate of reinforcement for bird 231. Figure is based on results from Herrnstein (1961b) and the data reported in Fig. 9.5. Copyright 1961 by the Society for the Experimental Analysis of Behavior, Inc. graph by author.*

relative rate of response. This equality of the relative rates of reinforcement and the relative rates of response is expressed as proportions in Equation 9.1.

$$B_a/(B_a + B_b) = R_a/(R_a + R_b). \tag{9.1}$$

Notice that we have simply taken the $B_a/(B_a + B_b)$ and the $R_a/(R_a + R_b)$ expressions, which give the proportion of responses and reinforcers on key A, and mathematically stated that they are equal. In verbal form, we are stating that relative rate of response matches (or equals) the relative rate of reinforcement. This statement, whether expressed verbally or mathematically, is known as the matching law. In Fig. 9.6, **matching** is shown as the solid black line. Notice that this line results when the proportional rate of reinforcement exactly matches the proportional rate of response. The matching law is an ideal representation of choice behavior. The actual data from pigeon 231 approximate the matching relationship. Herrnstein (1961b) also reported the results of two other pigeons that were well described by the matching law.

Extension of the Matching Law

The Generality of Matching

This equality of the rates of both response and reinforcement is called a law of behavior, because it describes how a variety of organisms choose among alternatives (de Villiers, 1977). Animals such as pigeons (Davison & Ferguson, 1978), wagtails (Houston, 1986), cows (Matthews & Temple, 1979), and rats (Poling, 1978) have demonstrated matching in choice situations. Interestingly, this same law applies to humans in a number of different settings (Bradshaw & Szabadi, 1988; Pierce & Epling, 1983). Reinforcers have ranged from food (Herrnstein, 1961b) to points that are subsequently exchanged for money (Bradshaw, Ruddle, & Szabadi, 1981). Behavior has been as diverse as lever pressing by rats (Norman & McSweeney, 1978) and conversation in humans (Conger & Killeen, 1974; Pierce, Epling, & Greer, 1981). Environments in which matching has been observed have included T-mazes, operant chambers, and open spaces with free-ranging flocks of birds (Baum, 1974a) as well as discrete-trial and free operant choice by human groups (Madden, Peden, & Yamaguchi, 2002). Also, special education students have been found to spend time on math problems

proportional to the relative rate of reinforcement (e.g., Mace, Neef, Shade, & Mauro, 1994). Thus, the matching law describes the distribution of individual (and group) behavior across species, type of response, reinforcers, and settings.

Matching and Human Communication

An interesting test of the matching law was reported by Conger and Killeen (1974). These researchers assessed human performance in a group-discussion situation. A group was composed of three experimenters and one subject. The subject was not aware that the other group members were confederates in the experiment and was asked to discuss attitudes toward drug abuse. One of the confederates prompted the subject to talk. The other two confederates were assigned the role of an audience. Each listener reinforced the subject's talk with brief positive words or phrases when a hidden cue light came on. The cue lights were scheduled so that the listeners gave different rates of reinforcement to the speaker. When the results for several subjects were combined, the relative time spent talking to the listener matched relative rate of agreement from the listener. These results suggest that the matching law operates in everyday social interaction.

Departures from Matching

Of course, in the complex world of people and other animals, matching does not always occur (Baum, 1974b). This is because in complex environments, contingencies of positive and negative reinforcement may interact, reinforcers differ in value, and histories of reinforcement are not controlled. In addition, discrimination of alternative sources of reinforcement may be weak or absent. For example, pretend you are talking to two people after class at the local bar and grill. You have a crush on one of these two, and the other you do not really care for. Both of these people attend to your conversation with equal rates of social approval, eye contact, and commentary. You can see that even though the rates of reinforcement are the same, you will probably spend more time talking to the person you like best. Because this is a common occurrence in the nonlaboratory world, you might ask, "What is the use of matching, and how can it be a law of behavior?"

The principle of matching is called a law, because it describes the regularity underlying choice. Many scientific laws work in a similar fashion. Anyone who has an elementary understanding of physics can tell you that objects of equal mass fall to the earth at the same rate. Observation, however, tells you that a pound of feathers and a pound of rocks do not fall at the same velocity. We can only see the lawful relations between mass and rate of descent when other conditions are controlled. In a vacuum, a pound of feathers and a pound of rocks fall at equal rates, and the law of gravity is observed. Similarly, with appropriate laboratory control, the relative rate of response matches the relative rate of reinforcement.

Matching Time on an Alternative

Behavioral choice can also be measured as time spent on an alternative (Baum & Rachlin, 1969; Brownstein & Pliskoff, 1968). Time spent is a useful measure of behavior when the response is continuous, as in talking to another person. In the laboratory, rather than measure the number of responses, the time spent on an alternative may be used to describe the distribution of behavior. The matching law can also be expressed in terms of the relative time spent on an alternative. Equation 9.2 is similar to Equation 9.1 but states the matching

relationship in terms of time:

$$T_a/(T_a + T_b) = R_a/(R_a + R_b). \tag{9.2}$$

In this equation, the time spent on alternative A is represented by T_a, and the time spent on alternative B is T_b. Again, R_a and R_b represent the respective rates of reinforcement for these alternatives. The equation states that relative time spent on an alternative equals the relative rate of reinforcement from that alternative. This extension of the matching law to continuous responses such as standing in one place or looking at objects is important. Most behavior outside of the laboratory does not occur as discrete responses. In this case, Equation 9.2 may be used to describe choice and preference.

Matching on More Than Two Alternatives

Equations 9.1 and 9.2 state that relative behavior matches the relative rate of reinforcement. A consideration of either equation makes it evident that to change behavior, the rate of reinforcement for the target response may be changed; alternatively, the rate of reinforcement for other concurrent operants may be altered. Both of these procedures change the relative rate of reinforcement for the specified behavior. Equation 9.3 represents the relative rate of response as a function of several alternative sources of reinforcement:

$$B_a/(B_a + B_b + \dots B_n) = R_a/(R_a + R_b + \dots R_n). \tag{9.3}$$

In the laboratory, most experiments are conducted with only two concurrent schedules of reinforcement. However, the matching law also describes the situation in which an organism may choose among several sources of reinforcement (Davison & Hunter, 1976; Elsmore & McBride, 1994; Miller & Loveland, 1974; Pliskoff & Brown, 1976). In Equation 9.3, behavior allocated to alternative A (B_a) is expressed relative to the sum of all behavior directed to the known alternatives ($B_a + B_b + \dots B_n$). Reinforcement provided by alternative A (R_a) is stated relative to all known sources of reinforcement ($R_a + R_b + \dots R_n$). Again, notice that an equality of proportions (matching) is stated.

ADVANCED ISSUE: QUANTIFICATION OF BEHAVIORAL CHOICE AND THE GENERALIZED MATCHING LAW

The proportion equations (Equations 9.1, 9.2, and 9.3) describe the distribution of behavior when alternatives differ only in rate of reinforcement. However, in complex environments other factors also contribute to choice and preference.

Sources of Error in Matching Experiments

Suppose a pigeon has been trained to peck a yellow key for food on a single VI schedule. This experience establishes the yellow key as a discriminative stimulus that controls pecking. In a subsequent experiment, the animal is presented with concurrent VI VI schedules of reinforcement. The left key is illuminated with a blue light, and the right Key is illuminated with a yellow one. Both of the variable-interval schedules are programmed to deliver 30 reinforcers each hour. Although the programmed rates of reinforcement

are the same, the bird is likely to distribute more of its behavior to the yellow key. In this case, stimulus control exerted by yellow is an additional variable that affects choice.

In this example, the yellow key is a known source of experimental error that came from the bird's history of reinforcement. However, many unknown variables also affect choice in a concurrent-operant setting. These factors arise from the biology and environmental history of the organism. For example, sources of error may include different amounts of effort for the responses, qualitative differences in reinforcement such as food versus water, a history of punishment, a tendency to respond to the right alternative rather than to the left alternative, and sensory capacities.

Matching of Ratios

To include these and other conditions within the matching law, it is useful to express the law in terms of ratios rather than in terms of proportions. A simple algebraic transformation of Equation 9.1 gives the matching law in terms of ratios:

1. Proportion equation: $B_a/(B_a + B_b) = R_a/(R_a + R_b)$.
2. Cross-multiplying: $B_a/(R_a + R_b) = R_a/(B_a + B_b)$.
3. Then: $(B_a * R_a) + (B_a * R_b) = (R_a * B_a) + (R_a * B_b)$.
4. Canceling: $B_a * R_b = R_a * B_b$.
5. Ratio equation: $B_a/B_b = R_a/R_b$.

In the ratio equation, B_a and B_b represent the rate of response or the time spent on the A and B alternatives. The terms R_a and R_b express the rates of reinforcement. When the relative rate of response matches the relative rate of reinforcement, the ratio equation is simply a restatement of the proportional form of the matching law.

The Power Law

A generalized form of the ratio equation may, however, be used to handle the situation in which unknown factors influence the distribution of behavior. These factors produce systematic departures from ideal matching but may be represented as two constants (parameters) in the generalized matching equation, as suggested by Baum (1974b):

$$B_a/B_b = k(R_a/R_b)^a. \tag{9.4}$$

In this form, the matching equation is represented as a **power law** in which the coefficient k and the exponent a are values that represent two sources of error for a given experiment. When these parameters are equal to 1, Equation 9.4 is the simple ratio form of the matching law.

Bias

Baum suggested that variation in the value of k from 1 reflects preference caused by some factor that has not been identified. For example, consider a pigeon placed in a chamber in which two response keys are available. One of the keys has a small dark speck that is not known to the experimenter. Recall that pigeons have excellent visual acuity and a tendency to peck at stimuli that approximate a piece of grain. Given a choice between the two keys, there will be a systematic response bias for the key with the spot on it.

The presence of such bias is indicated by a value of k different from 1. Generally, **bias** is some unknown asymmetry between the alternatives that affects preference over and above the relative rates of reinforcement.

Sensitivity

When the exponent a takes on a value other than 1, another source of error is present. A value of a greater than 1 indicates that changes in the response ratio (B_a/B_b) are larger than changes in the ratio of reinforcement (R_a/R_b). Baum (1974b) called this outcome **overmatching**, because the relative behavior increased faster than predicted from the relative rate of reinforcement. Although overmatching has been observed, it is not the most common result in behavioral-choice experiments. The typical outcome is that the exponent a takes on a value less than 1 (Baum, 1979; Davison & McCarthy, 1988; Myers & Myers, 1977; Wearden & Burgess, 1982). This result is described as **undermatching**. Undermatching refers to a situation in which changes in the response ratio are less than changes in the reinforcement ratio.

   One interpretation of undermatching is that changes in relative rates of reinforcement are not well discriminated by the organism (Baum, 1974b). Sensitivity to the operating schedules is adequate when the value of a is close to 1. An organism may not detect subtle changes in the schedules, and its distribution of behavior lags behind the current distribution of reinforcement. This slower change in the distribution of behavior is reflected by a value of a less than 1. For example, if a pigeon is exposed to concurrent VI VI schedules without a COD procedure, then the likely outcome is that the bird will rapidly and repeatedly switch between alternatives. This rapid alternation usually results in the pigeon being less sensitive to changes in the reinforcement ratio, and undermatching is the outcome. However, a COD may be used to prevent the superstitious switching and increase sensitivity to the rates of reinforcement on the alternatives. The COD is therefore a procedure that reduces undermatching, and this is reflected by values of a that are close to 1.

   Although problems of discrimination or sensitivity may account for deviations of a from 1, some researchers believe that undermatching is so common that it should be regarded as an accurate description of choice and preference (Davison, 1981). If this position is correct, then matching is not the lawful process underlying choice. Most behavior analysts have not adopted this position and view matching as a fundamental process. Nonetheless, the origin of undermatching is currently a focus of debate and is not resolved at this time (Allen, 1981; Baum, 1979; Davison & Jenkins, 1985; Prelec, 1984; Wearden, 1983).

Estimating Bias and Sensitivity

Dr. William Baum (1974b) formulated the generalized matching law, as shown in Equation 9.4. In the same article, he suggested that Equation 9.4 could be represented as a straight line when expressed in logarithmic form. In this form, it is relatively easy to portray and interpret deviations from matching (i.e., bias and sensitivity) on a line graph. Baum (Fig. 9.7) suggested that in linear form, the value of the slope of the line measured sensitivity to the reinforcement schedules, whereas the intercept reflected the amount of bias.

FIG. 9.7. *William Baum. Reprinted with permission.*

Algebra for a Straight Line

The algebraic equation for a straight line is

$$Y = M + N(X)$$

In this equation, N is the slope and M is the intercept. The value of X (horizontal axis) is varied, and this changes the value of Y (vertical axis). Assume that X takes on values of 1 through 10, M = 0, and N = 2. When X is 1, the simple algebraic equation is Y = 0 + 2 (1) or Y = 2. The equation can be solved for the other nine values of X and the (X,Y) pairs plotted on a graph. Figure 9.8 is a plot of the (X,Y) pairs over the range of the X values. The rate at which the line rises, or the slope of the line, is equal to the
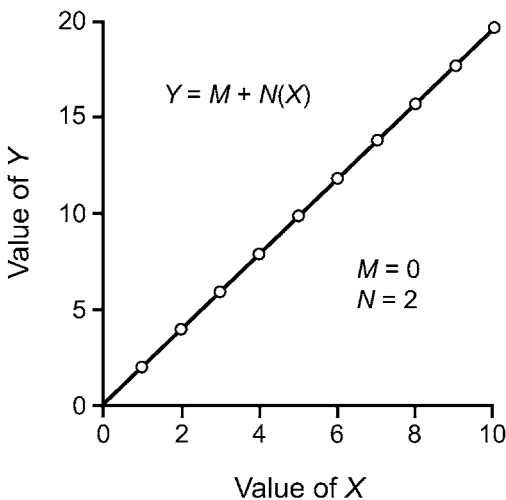
FIG. 9.8. *A plot of the algebraic equation for a straight line. Slope is set at 2.0, and intercept is zero.*

value of N and has a value of 2 in this example. The intercept M is zero in this case and is the point at which the line crosses the Y coordinate.

A Log-Linear Matching Equation

To write the matching law as a straight line, Baum suggested that Equation 9.4 be expressed in the logarithmic form of Equation 9.5:

$$\log(B_a/B_b) = \log k + [a * \log(R_a/R_b)]. \tag{9.5}$$

Notice that in this form, $\log(B_a/B_b)$ is the same as the Y value in the algebraic equation for a straight line. Similarly, $\log(R_a/R_b)$ is the same as the X term. The value a is the same as N and is the slope of the line. Finally, $\log k$ is the intercept, as is the M term in the algebraic equation.

The Case of Matching

Figure 9.9 shows the application of Equation 9.5 to idealized experimental data. The first and second columns give the number of reinforcers an hour delivered on the A and B alternatives. Notice that the rate of reinforcement on alternative B is held constant at 5 per hour, whereas the rate of reinforcement for alternative A is varied from 5 to 600 reinforcers. The relative rate of reinforcement is shown in column 3, expressed as a ratio (i.e., R_a/R_b). For example, the first ratio for the data labeled "matching" is $5/5 = 1$, and the other ratios may be obtained in a similar manner. The fourth column is the logarithm of the ratio values. Logarithms are obtained from a calculator and are defined as the exponent of base 10 that yields the original number. For example, 2.0 is the logarithm of 100, because 10 raised to the second power is 100. Similarly, in Fig. 9.9

Rft/hr A	Rft/hr B	(R_a/R_b)	X - Value log (R_a/R_b)	Slope (a)	Intercept (log k)	Y - Value log (Ba/Bb)
			MATCHING			
5	5	1	0.00	1.00	0.00	0.00
30	5	6	0.78	1.00	0.00	0.78
100	5	20	1.30	1.00	0.00	1.30
600	5	120	2.08	1.00	0.00	2.08
			UNDERMATCHING			
5	5	1	0.00	0.50	0.00	0.00
30	5	6	0.78	0.50	0.00	0.39
100	5	20	1.30	0.50	0.00	0.65
600	5	120	2.08	0.50	0.00	0.14
			BIAS			
5	5	1	0.00	1.00	1.50	1.50
30	5	6	0.78	1.00	1.50	2.28
100	5	20	1.30	1.00	1.50	2.80
600	5	120	2.08	1.00	1.50	3.58

FIG. 9.9. *Application of log-linear matching equation (Equation 9.5) to idealized experimental data. Shown are reinforcements per hour (Rft/hr) for alternatives A and B, the ratio of the rein-forcement rates (R_a/R_b), and the log ratio of the reinforcement rates (X values). The log ratios of the response rates (Y values) were obtained by setting the slope and intercept to values that produce matching, undermatching, or bias.*

the logarithm of the ratio 120 is 2.08, because 10 to the 2.08 power is equal to the original 120 value.

Notice that logarithms are simply a transformation of scale of the original numbers. Such a transformation is suggested, because logarithms of ratios plot as a straight line on X-Y coordinates, whereas the original ratios may not be linear. Actual experiments involve both positive and negative logarithms, because ratios may be less than 1. For simplicity, the constructed examples in Fig. 9.9 only use values that yield positive logarithms.

Columns 5 and 6 provide values for the slope and intercept for the log–ratio equation. When relative rate of response is assumed to match (or equal) relative rate of reinforcement, the slope (a) assumes a value of 1.00, and the value of the intercept (log k) is zero. With slope and intercept so defined, the values of Y or $\log(B_a/B_b)$ may be obtained from the values of X or $\log(R_a/R_b)$, by solving Equation 9.5. For example, the first Y value of 0.00 for the final column is obtained by substituting the appropriate values into the log-ratio equation, $\log(B_a/B_b) = 0.00 + [1.00 * (0.00)]$. The second value of Y is 0.78, or $\log(B_a/B_b) = 0.00 + [1.00 * (0.78)]$, and so on.

Figure 9.10(a) plots the "matching" data. The values of X or $\log(R_a/R_b)$ were set for this idealized experiment, and Y or $\log(B_a/B_b)$ values were obtained by solving Equation 9.5
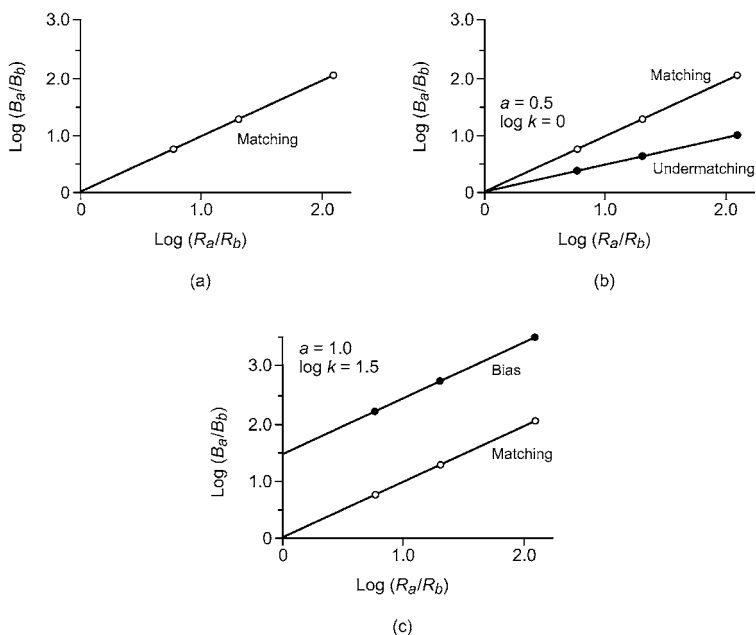
FIG. 9.10. *(A) An X-Y plot of the data for "Matching" from Fig. 9.9. The value of the slope is set at 1 (a = 1), and the intercept is set at zero (log k = 0). The matching line means that a unit increase in relative rate of reinforcement [log(R_a/R_b)] produces a unit increase in relative rate of response [log(B_a/B_b)]. (B) An X-Y plot of the data for "Undermatching" from Fig. 9.9. The value of the slope is set at less than 1 (a = 0.5), and the intercept is set at zero (log k = 0). Undermatching with a slope of 0.5 means that a unit increase in relative rate of reinforcement [log(R_a/R_b)] produces a half-unit increase in relative rate of response [log(B_a/B_b)]. (C) An X-Y plot of the data for "Bias" from Fig. 9.9. The value of the slope is set at 1 (a = 1), and the intercept is more than zero (log k = 1.5). A bias of this amount means that the new X-Y plot is deflected 1.5 units from the matching line.*

when a = 1 and log k = 0. Notice that the plot is a straight line that rises at 45°. The rate of rise in the line is equal to the value of the slope (i.e., a = 1). This value means that a unit change in X (i.e., from 0 to 1) results in an equivalent change in the value of Y. With the intercept (log k) set at 0, the line passes through the origin (X = 0, Y = 0). The result is a matching line in which log ratio of responses equals log ratio of reinforcement.

The Case of Undermatching

The data of Fig. 9.9 labeled "undermatching" represent the same idealized experiment. The value of the intercept remains the same (log k = 0); however, the slope now takes on a value less than 1 (a = 0.5). Based on Equation 9.5, this change in slope results in new values of Y or $\log(B_a/B_b)$. Figure 9.10(b) is a graph of the line resulting from the change in slope. When compared to the matching line (a = 1), the new line rises at a slower rate (a = 0.5). This situation is known as undermatching and implies that the subject gives less relative behavior to alternative A [$\log(B_a/B_b)$] than expected on the basis of relative rate of reinforcement [$\log(R_a/R_b)$]. For example, if log-ratio reinforcement changes from 0 to 1, the log ratio of behavior will change only from 0 to 0.5. This suggests poor discrimination by the subject of the operating schedules of reinforcement (i.e., sensitivity).

The Case of Bias

It is also possible to have a systematic bias for one of the alternatives. For example, a right-handed person may prefer to press a key more on the right side than on the left side. This tendency to respond to the right side may occur even though both keys schedule equal rates of reinforcement. Recall that response bias refers to any systematic preference for one alternative that is not explained by the relative rates of reinforcement. In terms of the idealized experiment, the data labeled "bias" in Fig. 9.9 show that the slope of the line is 1 (matching), but the intercept (log k) now assumes a value of 1.5 rather than zero. A plot of the X or $\log(R_a/R_b)$ and Y or $\log(B_a/B_b)$ values in Fig. 9.10(c) reveals a line that is systematically deflected 1.5 units from the matching line.

Experiments and Log-Linear Estimates

Setting the Values of the Independent Variable

In actual experiments on choice and preference, the values of the slope and intercept are not known until the experiment is conducted. The experimenter sets the values of the independent variable, $\log(R_a/R_b)$, by programming different schedules of reinforcement on the alternatives. For example, one alternative may be VI 30 s and the other VI 60 s. The VI 30-s schedule is set to pay off at 120 reinforcers per hour, and the VI 60-s schedule is set to pay off at 60 reinforcers each hour. The relative rate of reinforcement is expressed as the ratio 120/60 = 2. To describe the results in terms of Equation 9.5, the reinforcement ratio, 2, is transformed to a logarithm, using a calculator with logarithmic functions. Experiments are designed to span a reasonable range of log-ratio reinforcement values. The minimum number of log-ratio reinforcement values is 3, but most experiments program more than three values of the independent variable.

Each experimental subject is exposed to different pairs of concurrent schedules of reinforcement. The subject is maintained on these schedules until the rates of

response are stable, according to preset criteria. At this point, the relative rates of response are calculated (B_a/B_b) and transformed to logarithms. For example, a subject on concurrent VI 30-s VI 60-s schedule may generate 1,000 responses per hour on the VI 30-s alternative and 500 on the VI 60-s schedule. Thus, the response ratio is 1,000/500 = 2, or 2 to 1. The response ratio, 2, is transformed to a logarithm. For each value of $\log(R_a/R_b)$, the observed value the dependent variable $\log(B_a/B_b)$ is plotted on X,Y coordinates.

To illustrate the application of Equation 9.5, consider an experiment conducted in 1973 by White and Davison. In this experiment, several pigeons were exposed to 12 sets of concurrent schedules. Each pair of schedules programmed a different reinforcement ratio. The pigeons were maintained on the schedules until key pecking was stable from day to day. The data for pigeon 22 are plotted in Fig. 9.11(a) on logarithmic coordinates. Plotting the reinforcement and response ratios on logarithmic coordinates is the same
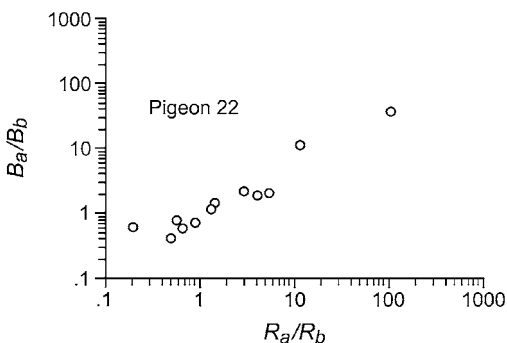
(a)
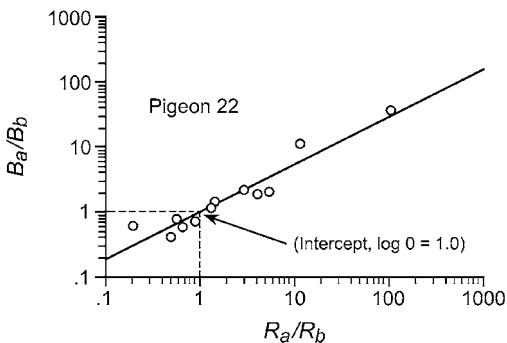
(b)

FIG. 9.11. *(A) Reinforcement and response ratios for pigeon 22 plotted on logarithmic coordinates, based on Table 1 from White and Davison (1973). Note. From "Performance in Concurrent Fixed-Interval Schedules," by A. J. white and M. C. Davison, 1973,* Journal of the Experimental Analysis of Behavior, 19, *pp. 147–153. Copyright 1973 by the Society for the Experimental Analysis of Behavior, Inc. (B) The line of best fit for the data of pigeon 22. Note. Also from White and Davison, 1973. Copyright 1973 by the Society for the Experimental Analysis of Behavior, Inc. author generated figures.*

as plotting the log ratios on ordinary graph paper. Notice that actual results are not as orderly as the data of the idealized experiment. This is because errors in measurement, inconsistencies of procedure, and random events operate to affect response ratios in actual experiments. The results appear to move upward to the right in a linear manner, but it is not possible to draw a simple line through the plot.

Estimates of Slope and Intercept

To find the line that best fits the results, a statistical technique (i.e., least-squares regression) is used to estimate values for the slope and intercept of Equation 9.5. The idea is to select slope and intercept values that minimize the errors in prediction. For a given value of the reinforcement ratio (x-axis), an error is the difference between the response-ratio value on the line (called the predicted value) and the actual or observed response ratio.

The mathematics that underlie this statistical technique are complicated and beyond the scope of this book. However, most personal computers have programs that will do the calculations for you. For example, you can use a program like Microsoft Excel and a PC computer to obtain the best-fitting line, using linear regression analysis. The estimate of slope was $a = 0.77$, indicating that pigeon 22 undermatched to the reinforcement ratios. The estimate of the intercept was zero ($\log k = 0$), indicating that there was no response bias. With these estimates of slope and intercept, Equation 9.5 may be used to draw the best-fitting line.

In Figure 9.11(b), the line of best fit has been drawn. You can obtain the line of best fit by substituting values for $\log(R_a/R_b)$ and finding the predicted $\log(B_a/B_b)$ values. You only need to find two points on the X,Y coordinates to draw the line. Notice that the data and best-fit line are plotted on a graph with logarithmic coordinates. Because there was no bias ($\log k = 0$), the line must pass through the point $X = 1$, $Y = 1$ when R_a/R_b and B_a/B_b values are plotted on logarithmic paper.

As a final point, you may be interested in how well the matching equation fit the results of pigeon 22. One measure of accuracy is called explained variance. This measure varies between 0 and 1 in value. When the explained variance is 0, it is not possible to predict the response ratios from the reinforcement ratios. When the explained variance is 1, there is perfect prediction from the reinforcement ratios to the response ratios. In this instance, the explained variance is 0.92, indicating 92% accuracy. The log-linear matching equation is a good description of the pigeon's behavior on concurrent schedules of reinforcement.

Implications of the Matching Law

The matching law has practical implications. A few researchers have shown that the matching equations are useful in applied settings (see Borrero & Vollmer, 2002; Epling & Pierce, 1983; McDowell, 1981, 1982, 1988; Myerson & Hale, 1984; Plaud, 1992, for a review). For example, a common problem with children is that they do not obey their parents (Patterson, 1976). In some cases, this problem becomes severe, and parents complain that their children are out of control. When this happens, the parents may seek professional help.

Matching and Child Compliance

A traditional applied behavior analysis of this problem involves objectively identifying the target responses, finding effective reinforcers, and then establishing contingencies between behavior and consequences. However, the matching equations suggest that other sources of reinforcement should be taken into account.

$$\frac{\text{Child's Compliance to Mother}}{(\text{Compliance to Mother}) + (\text{Compliance to Others})} = \frac{\text{Reinforcement from Mother}}{(S^{r+}\ \text{Mother}) + (S^{r+}\ \text{Others})}$$

For example, according to the proportion equation, to change the child's rate of compliance to the mother, the applied analyst should consider the father and siblings as additional sources of reinforcement. The rate of compliance with the requests of one parent may be low, because this behavior is concurrently reinforced at a high rate by other family members. For example, if maternal reinforcement (e.g., praise, approval, and attention) is given at a lower rate than that of the father, then modification of the rate of maternal attention for compliant behavior will increase obedience only if the father's rate of reinforcement remains the same. Frequently, however, parents compete for their children's behavior, and a shift away from the father can easily lead to an increase in the rate of social reinforcement from him. An increase in the father's attention and approval could further decrease the frequency of child compliance toward the mother, even though she has increased her rate of reinforcement. This analysis reflects the typical two-key concurrent paradigm. The child responds to, and switches among, alternative schedules of reinforcement set up by parents and siblings.

Matching, Modification, and Reinforcement Schedules

The matching law has implications for the kind of reinforcement schedules that should be used for behavior modification. Myerson and Hale (1984) discussed the applied setting in terms of concurrent schedules of reinforcement. People emit a variety of responses, many of which are maintained by concurrently available sources of reinforcement. Some of these responses may be socially appropriate, whereas others are considered undesirable. In a classroom, appropriate behavior for students includes working on assignments, following instructions, and attending to the teacher. In contrast, yelling and screaming, talking out of turn, and throwing paper airplanes are usually viewed as undesirable. All of these activities, appropriate or inappropriate, are presumably maintained by teacher attention, peer approval, sensory stimulation, and other sources of reinforcement. However, the schedules of reinforcement-maintaining behavior in complex settings like a classroom are usually not known. When the objective is to increase a specific operant and the competing schedules are unknown, Myerson and Hale (1984) recommend the use of VI schedules to reinforce target behavior.

To simplify the analysis, we will treat all on-task operants as part of the more general class of appropriate behavior and off-task operants as inappropriate behavior. Assume that the reinforcement for inappropriate behavior is delivered on a ratio schedule. To increase desired behavior by a student, ratio contingencies may be arranged by the teacher. This means that the situation is analyzed as a concurrent ratio schedule. Recall that on concurrent ratio schedules, exclusive preference develops for the alternative with the higher rate of reinforcement (Herrnstein & Loveland, 1975). Ratio schedules are in effect when a teacher implements a grading system based on the number of correct solutions for assignments.

The teacher's intervention will increase the students' on-task behavior, only if the rate of reinforcement by the teacher is higher than the ratio schedule controlling inappropriate behavior. Basically, an intervention is either completely successful or a total failure when ratio schedules are used to modify behavior. In contrast, interval schedules of reinforcement will always redirect behavior to the desired alternative, although such a schedule may not completely eliminate inappropriate responding.

When behavior is maintained by interval contingencies, interval schedules remain the most desirable method for behavior change. Myerson and Hale (1984) used the matching equations to show that behavior-change techniques based on interval schedules are more effective than ratio interventions. They stated that "if the behavior analyst offers a VI schedule of reinforcement for competing responses two times as rich as the VI schedule for inappropriate behavior, the result will be the same as would be obtained with a VR schedule three times as rich as the schedule for inappropriate behavior" (pp. 373–374). Generally, behavior change will be more predictable and successful if interval schedules are used to reinforce appropriate behavior.

Additional Aspects of Choice and Preference

Optimal Foraging, Matching, and Melioration

One of the fundamental problems of evolutionary biology and behavioral ecology concerns the concept of "optimal foraging" of animals (Krebs & Davies, 1978). Foraging involves prey selection where prey can be either animal or vegetable. Thus, a cow taking an occasional mouthful of grass throughout a field and a redshank wading in the mud and probing with its beak for an occasional worm are examples of foraging behavior. Because the function of foraging is food, foraging can be viewed as operant behavior regulated by food reinforcement. The natural contingencies of foraging present animals with alternative sources of food called patches. Food patches provide items at various rates and in this sense are similar to concurrent schedules of reinforcement arranged in the laboratory.

Optimal foraging is said to occur when animals obtain the highest overall rate of reinforcement from their foraging. That is, over time organisms are expected to select between patches so as to optimize (obtain the most possible of) their food resources. In this view, animals are like organic computers comparing their behavioral distributions with overall outcomes and stabilizing on a response distribution that **maximizes** the overall rate of reinforcement.

In contrast to the optimal foraging hypothesis, Herrnstein (1982) proposed a process of **melioration** (doing the best at the moment). Organisms, he argued, are sensitive to fluctuations in the momentary rates of reinforcement rather than to long-term changes in the overall rates of reinforcement. That is, an organism remains on one schedule until the local rates of reinforcement decline relative to that offered by a second schedule. Herrnstein (1997, pp. 74–99) showed that the steady-state outcome of the process of melioration is the matching law where the relative rate of response matches the relative rate of reinforcement. Thus, in a foraging situation involving two patches, Herrnstein's melioration analysis predicts matching of the distributions of behavior and reinforcement (e.g., Herrnstein & Prelec, 1997). Optimal foraging theory, on the other hand, predicts maximization of the overall rate of reinforcement.

It is not possible to examine all the evidence for melioration, matching, and maximizing in this chapter, but Herrnstein (1982) has argued that melioration and matching are the basic processes of choice. That is, when melioration and matching are tested in choice situations that distinguish matching from maximizing, matching theory has usually predicted the actual distributions of the behavior.

One example of the application of matching theory to natural foraging is reported by Baum (1974a) for a flock of free-ranging wild pigeons. The subjects were 20 pigeons that lived in a wooden frame house in Cambridge, Massachusetts. An opening allowed them to freely enter and leave the attic of the house. An operant apparatus with a platform was placed in the living space opposite to the opening to the outside. The front panel of the apparatus contained three translucent response keys, and when available, an opening allowed access to a hopper of mixed grain. Pigeons were autoshaped to peck to the center key, and following this training, a perch replaced the platform so that only one pigeon at a time could operate the keys to obtain food. Pigeons were now shaped to peck the illuminated center key on a VI 30-s schedule of food reinforcement. When a stable performance was observed, the center key was no longer illuminated or operative, and the two side keys became active. Responses to the illuminated side keys were reinforced on two concurrent VI VI schedules. Relative rates of reinforcement on the two keys were varied, and the relative rate of response was measured.

Although only one bird at a time could respond on the concurrent schedules of reinforcement, Baum (1974b) treated the aggregate pecks of the group as the dependent measure. When the group of 20 pigeons chose between the two side keys, each of which occasionally produced food, the ratio of pecks to these keys approximately equaled the ratio of grain presentations obtained from them. That is, the aggregate behavior of the flock of 20 pigeons was in accord with the generalized matching equation (see this chapter). This research suggests that the matching law applies to the behavior of wild pigeons in natural environments. Generally, principles of choice based on laboratory experiments can predict the foraging behavior of animals in ecologically valid settings.

Behavioral Economics, Choice, and Addiction

Choice and concurrent schedules of reinforcement may be analyzed from a microeconomic point of view (Rachlin, Green, Kagel, & Battalio, 1976). **Behavioral economics** involves the use of basic economic concepts and principles (law of demand, price, substitutability, and so on) to analyze, predict, and control behavior in choice situations. One of the more interesting areas of behavioral economics concerns laboratory experiments that allow animals to work for drugs such as alcohol, heroin, and cocaine. Thus, Nader and Woolverton (1992) showed that monkeys' choice of cocaine over food was a function of drug dose, but that choosing cocaine decreased as the price (number of responses per infusion) increased. That is, the reinforcing effects of the drug increased with dose, but these effects were modified by price, an economic factor. In another experiment, Carroll, Lac, and Nygaard (1989) examined the effects of a substitute commodity on the use of cocaine. Rats nearly doubled their administration of cocaine when water was the other option than when the option was a sweet solution. These effects were not found in a control group that self-administered an inert saline solution, suggesting that (a) cocaine infusion functioned as reinforcement for self-administration and (b) that the sweet solution substituted for cocaine. Again, the reinforcing effects of the drug were altered by an economic factor, in this case, the presence of a substitute commodity (see Carroll, 1993, for similar effects with monkeys and the drug PCP).

The concept of substitute commodities (reinforcers) may be useful in understanding the treatment of heroin addicts with methadone. From an economic perspective, methadone is a partial substitute for heroin, because it provides only some of the reinforcing effects of the actual drug. Also, methadone is administered in a clinical setting that is less reinforcing than the social context in which heroin is often used (Hursh, 1991). Based on this analysis, it is unlikely that the availability of methadone treatment will, by itself, eliminate the use of heroin.

To reduce drug abuse, Vuchinich (1999) suggests a multifaceted approach that (a) increases the cost of using drugs by law enforcement that reduces the supply (i.e., price goes up); (b) provides easy access to other nondrug activities (e.g., sports, musical entertainment, etc.) and arranges reinforcement from family, friends, and work for staying drug free; and (c) provides reinforcement for nondrug behavior promptly, as delayed reinforcement is ineffective. These principles can be applied to many behavior problems, including smoking, use of alcohol, and compulsive gambling (Bickel & Vuchinich, 2000). It is no longer necessary or sensible to treat people as if they had an underlying illness or disease (e.g., alcoholism). Behavioral economics and learning principles offer direct interventions to modify excessive or addictive behavior.

Self-Control and Preference Reversal

Students often face the choice of going out to party or staying home and "hitting the books." Often, when given the options, students pick the immediate reward of partying with friends over the long-term benefits of studying, learning the subject matter, and high grades. When a person (or other animal) selects the smaller, immediate payoff over the larger, delayed benefits, we may say that he or she shows **impulsive behavior**. On the other hand, a person who chooses the larger, delayed reward while rejecting the smaller, immediate payoff is said to show **self-controlled behavior**. In terms of a student's choices to either party or study, choosing to party with friends is impulsive behavior, whereas choosing to stay home and study is self-controlled behavior.

One of the interesting things about self-control situations is that our preferences change over time. That is, we may value studying over partying a week before the party but value partying when the night of the party arrives. Howard Rachlin (1970, 1974) and George Ainslie (1975) independently suggested that these preference reversals could be analyzed as changes in reinforcement effectiveness with increasing delay. The **Ainslie–Rachlin principle** is that *reinforcement value decreases as the delay between making a choice and obtaining the reinforcer increases*.

The value of learning and high grades on the night of the party (choice point) is lower than having fun with friends, because the payoffs for studying are delayed until the end of term. But if we move back in time from the choice point to a week before the party, the value of studying relative to partying reverses. That is, adding delay to each reinforcement option before a choice is made reverses the value of the alternative reinforcers. More generally, at some time removed from making a choice, the value of the smaller, immediate reinforcer will be less than the value of the larger, delayed reward, indicating a **preference reversal**. When preference reversal occurs, people (and other animals) will make a commitment response to forego the smaller, immediate reward and lock themselves into the larger, delayed payoff (see chap. 13 and self-control). The **commitment response** is some behavior emitted at a time prior to the choice point that eliminates or reduces the probability of impulsive behavior. A student who invites a classmate over to study on Friday night (commitment response) ensures that she will "hit the books" and give up partying when the choice arrives.

Preference reversal and commitment occurs over extended periods in humans and involves many complexities (e.g., Green, Fry, & Myerson, 1994; Logue, Pena-Correal, Rodriguez, & Kabela, 1986). In animals, delays of reinforcement by a few seconds can change the value of the options, instill commitment, and ensure self-control over impulsiveness. As an example of preference reversal, consider an experiment by Green, Fisher, Perlow, and Sherman (1981), where pigeons responded on two schedules of reinforcement, using a trials procedure. The birds were given numerous trials each day. On each trial a bird made its choice by pecking one of two keys. A single peck at the red key resulted in a 2-s access to grain, whereas a peck at the green key delivered a 6-s access to food. The intriguing aspect of the experiment involved adding a brief delay between a peck and the delivery of food. Under one condition, there was a 2-s delay for the 2-s reinforcer (red key) and a 6-s delay for a 6-s access to food (green key). The data indicated that birds were impulsive, choosing the 2-s reinforcer on nearly every trial and losing about two thirds of their potential access to food.

In another procedure, 18 additional s were added to the delays for each key so that the delays were now 20 s for the 2-s reinforcer and 24 s for the 6-s access to food. When the birds were required to choose far in advance, they pecked the green key that delivered a 6-s access to food on more than 80% of the trials. In other words, the pigeons showed preference reversal and self-control when both reinforcers were farther away.

Other research by Ainslie (1974) and by Rachlin and Green (1972) shows that pigeons can learn to make a commitment response, thereby reducing the probability of impulsive behavior. To illustrate, in the Rachlin and Green (1972) experiment, pigeons were presented with two keys. If the birds pecked the red key, they received a 2-s access to food (small, immediate reinforcer). Pecking the green key, on the other hand, resulted in a 4-s access to food, but after a 4-s delay (large, delayed reinforcer). At a time prior to the choice between red and green options, the birds could make a commitment response. Both keys were illuminated white during the commitment phase. Pecking the left key produced a 10-s blackout that was followed by the choice between the reinforcement options (green and red keys). Pecks to the right key also produced a 10-s blackout, but only the large, delayed reinforcer was subsequently presented (no choice, only green key available). Thus, the birds could commit themselves to obtaining the larger reinforcer by pecking the right key.

Rachlin and Green calculated (using a matching equation for amounts and delays) that the birds would value the larger reward about 1.5 times more than they valued the smaller one when the 10-s delay (blackout) preceded the choice between reinforcement options (red and green keys). Based on the preference for the larger reward at this point, the birds should peck the right key and eliminate their subsequent choice between red and green options. (Only the green key becomes available.) That is, the birds were predicted to make a commitment. At the choice point, however, the smaller reward would be infinitely preferable to the larger reinforcer. Given the preference for the smaller reinforcer at the choice point, the birds were expected to behave impulsively, pecking the red option (small, immediate reinforcer).

The behavior of the pigeons was in accord with predictions. When pigeons had to choose between the red and the green options, they always pecked the red key and received a 2-s access to food (small, immediate reinforcer). When the choice was delayed by 10 s, the birds pecked the right key about 65% of the time, thereby often eliminating subsequent choice and receiving the large reinforcer. The experiment therefore showed impulsiveness, preference reversal, and commitment by pigeons in a self-control situation. Generally, animal research supports the Ainslie–Rachlin principle and suggests that basic learning processes are part of self-control and impulsivenss in humans (see Rachlin, 2000, on self-control and a new model based on behavior principles and economics; also see Rachlin & Laibson, 1997, for papers by Richard Herrnstein on the matching law and self-control).

Matching on a Single Schedule of Reinforcement

The matching law suggests that operant behavior is determined by the rate of reinforcement for one alternative relative to all other known sources of reinforcement. Even in situations in which a contingency exists between a single response and a reinforcement schedule, organisms may have several reinforced alternatives that are unknown to the researcher. Also, many of the activities that produce reinforcement are beyond experimental control. A rat that is lever pressing for food may gain additional reinforcement from exploring the operant chamber, scratching itself, and so on. In a similar fashion, rather than work for teacher attention a pupil may look out the window, talk to a friend, or even daydream. Thus, even in a single-operant setting, multiple sources of reinforcement are operating. Richard Herrnstein (1970, 1974) argued this point and suggested that all operant behavior must be understood as behavior emitted in the context of other alternative sources of reinforcement. Based on these ideas, Herrnstein proposed a matching equation that describes the absolute rate of response on a single schedule of reinforcement. This mathematical formulation is called the **quantitative law of effect**. The law states that the *absolute rate of response on a schedule of reinforcement is a hyperbolic function of rate of reinforcement on the schedule relative to the total rate of reinforcement*, both scheduled and extraneous reinforcement. That is, as the rate of reinforcement on the schedule increases, the rate of response also rises, but eventually further increases in the rate of reinforcement produce less and less of an increase in the rate of response (hyperbolic). Also, the rise in the rate of response with an increasing rate of reinforcement is modified by extraneous sources of reinforcement. The greater the extraneous reinforcement the less the increase in rate of response with increasing rate of scheduled reinforcement. One implication is that control of behavior by a schedule of reinforcement is reduced as the sources of extraneous reinforcement increase.

Extraneous sources of reinforcement include any unknown contingencies that support the behavior of the organism. For example, a rat that is pressing a lever for food on a particular schedule of reinforcement could receive extraneous reinforcement for scratching, sniffing, and numerous other behaviors. The rate of response for food will be a function of both the programmed schedule as well as the extraneous schedules controlling other behavior. In humans, a student's mathematical performance will be both a function of the schedule of correct solutions as well as an extraneous reinforcement for other behavior from classmates or teachers, internal neurochemical processes, and changes to the physical/chemical environment (e.g., smell of food drifting from the cafeteria). A more complete presentation of Herrnstein's matching equation for a single schedule of reinforcement is found in the following section on this topic.

ADVANCED ISSUE: A MATCHING EQUATION FOR A SINGLE SCHEDULE OF REINFORCEMENT

Herrnstein (1970, 1974) proposed a matching equation to describe responding on a single schedule of reinforcement. The equation relates absolute (rather than relative) response and reinforcement rates, using alternative sources of reinforcement as the context. Because the equation is expressed in absolute rates, it is usually considered a more fundamental expression of matching theory. Herrnstein's equation (the quantitative law

of effect) may be derived from a restatement of the proportional matching law:

$$B_a/(B_a + B_e) = R_a/(R_a + R_e).$$

The difference between this equation and the proportional equation (Equation 9.1) is that B_e refers to all behavior directed to extraneous sources of reinforcement, and R_e represents these sources. For example, lever pressing is the specified operant (B_a) that produces food at some rate of reinforcement (R_a). Notice that pressing the lever is expressed relative to the other activity of the organism (B_e). This activity is reinforced by events that are not under experimental control (R_e). A rat may obtain reinforcement from grooming, even though this is not prescribed by the experimental procedures. Many other activities result in extraneous sources of reinforcement.

To solve the equation for the absolute rate of response (B_a), it is important to recognize that $B_a + B_e$ is equal to the **total behavioral output** for a given situation. Because B_a represents lever pressing and B_e represents all other activity, the sum must equal all the behavior of the animal in the experimental setting. It is convenient to express this sum as the value k or the *total behavioral output*. The quantity k may now be substituted into the preceding equation:

$$B_a/k = R_a/(R_a + R_e).$$

When each side of the equation is multiplied by k, the absolute response rate (B_a) is expressed as

$$B_a = k(R_a)/(R_a + R_e). \tag{9.6}$$

This kind of equation produces a hyperbolic line that rises to asymptote on X,Y coordinates. Herrnstein's equation therefore states that the absolute rate of response (B_a) is a *hyperbolic* function of the scheduled rate of reinforcement (R_a) and all extraneous sources of reinforcement (R_e). The constant k, or the total behavioral output, sets the upper limit on the hyperbolic curve (McDowell, 1986).

Extraneous Sources of Reinforcement

The constant R_e represents extraneous sources of reinforcement and modifies the impact of the scheduled rate of reinforcement. In Equation 9.6, extraneous reinforcement (R_e) is added to the programmed rate of reinforcement (R_a), and R_a is divided by this sum. As the value of R_e increases, the impact of R_a must decline. This means that, for a given schedule of reinforcement, the absolute rate of response (B_a) will be low when R_e is large and high when R_e is small.

Pretend that you volunteer to participate in an experiment that involves dialing for dollars. Your task is to dial phone numbers that result in either an answer or a busy signal. When a call is completed, a message says, "Congratulations, you have just won a dollar," and simultaneously a coin machine dispenses money to you. The experiment is controlled by a computer that schedules the rate of reinforcement for dialing. Reinforcement consists of the message and the dollar. Experimental sessions are held after classes for 1 hr, 5 days a week, for 6 months. During this period, the scheduled payoff for dialing the phone is varied to produce different rates of reinforcement. Sometimes the rate of reinforcement is high (e.g., $120 per hour), and during other sessions it is low (e.g., $2 per hour). A given rate of reinforcement is maintained until dialing occurs at a stable rate.
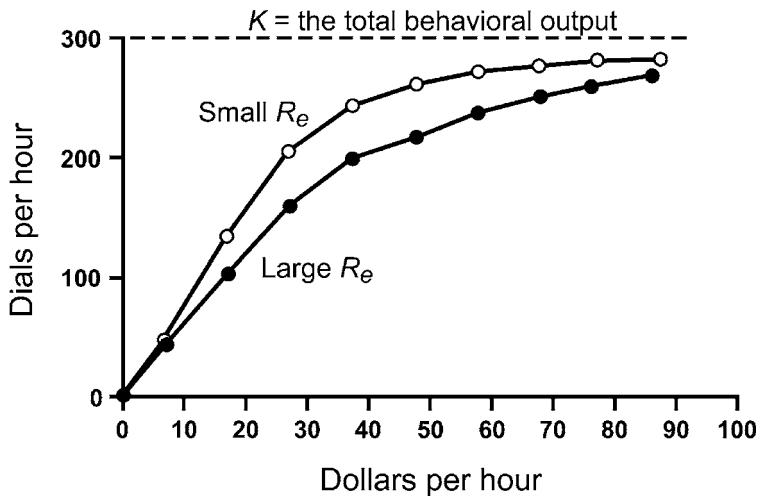
FIG. 9.12.   *Two idealized plots of Equation 9.6, Herrnstein's hyperbola. Both curves approach the asymptote k, which represents the total behavioral output for the experiment. The value of R_e, or extraneous reinforcement, is large for one curve and is small for the other.*

Figure 9.12 shows the possible results of this experiment in terms of Equation 9.6. The number of phone calls per hour is plotted against the number of dollars earned each hour. Herrnstein's hyperbolic equation suggests that your rate of dialing will increase rapidly as the rate of reinforcement goes up. As the rate of reinforcement becomes larger and larger, the increase in the rate of response becomes less and less, and the curve flattens out.

Two hyperbolic curves are presented in Fig. 9.12. Both curves rise toward (but never meet) the line k, which represents all your activity in the experimental setting. These curves depict the effects of high versus low values of R_e or extraneous reinforcement. A comparison of the curves indicates that your rate of dialing may be high or low for the same rate of reinforcement (R_a). The impact of the scheduled rate of reinforcement on the response rate is modified by the value of R_e in the situation.

In a rich environment, R_e is large, and monetary payments produce a relatively low response rate. When the environment is lean, R_e has a small value, and the dollars produce a higher rate of dialing. For example, if you were dialing in a laboratory cubicle (small R_e), your rate of calls should be higher than if you were dialing in a spacious, well-decorated room with a picturesque view of the countryside (large R_e). Add a television set to the room, and your dialing would be even lower. Thus, your behavior in the dialing-for-dollars experiment varies in accord with the scheduled payoffs and the background or context, as represented by the R_e value.

Experimental Evidence and the Quantitative Law of Effect

The quantitative law of effect (Equation 9.6) has been analyzed in laboratory experiments. In an early investigation, Catania and Reynolds (1968) conducted an exhaustive study of six pigeons that pecked a key for food on different variable-interval (VI) schedules. The rate of reinforcement ranged from 8 to 300 food presentations each hour. Herrnstein
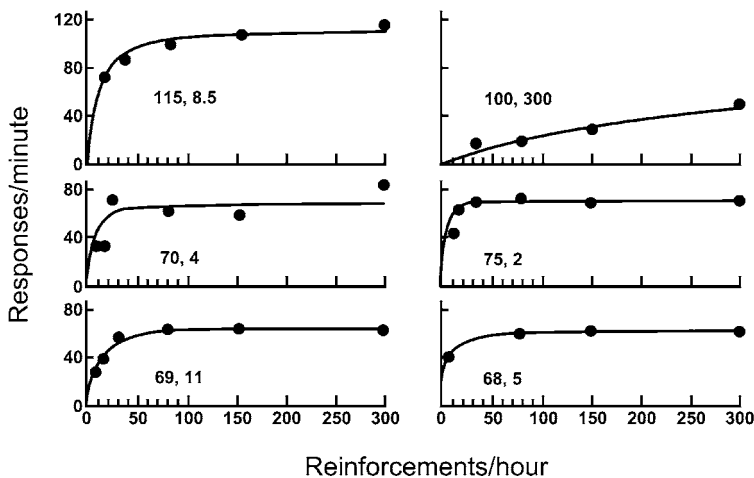
FIG. 9.13. *Rate of response as a function of rate of food reinforcement for six pigeons on single VI schedules. The k and R_evalues for each fitted curve are shown. Reprinted from Fig. 8 of "On the Law of Effect," by R. J. Herrnstein, 1970,* Journal of the Experimental Analysis of Behavior, 21, *pp. 243–266; which in turn is based on data from Catania and Reynolds, 1968; copyright 1970 by the Society for the Experimental Analysis of Behavior, Inc.*

(1970), in his classic article on the law of effect, replotted the data from the Catania and Reynolds experiment on X,Y coordinates. Figure 9.13 shows the plots for the six birds, with reinforcements per hour on the X-axis and responses per minute on the Y-axis.

Herrnstein used a statistical procedure to fit his equation to the data of each pigeon. Figure 9.13 presents the curves that best fit these results. Notice that all of the birds produce rates of response that are described as a hyperbolic function of rate of reinforcement. Some of the curves fit the data almost perfectly (e.g., pigeon 281), whereas others are less satisfactory (e.g., pigeon 129). Overall, Herrnstein's quantitative law of effect is well supported by these findings.

The quantitative law of effect has been extended to magnitude of food reinforcement, brain stimulation, quality of reinforcement, delay of positive reinforcement, rate of negative reinforcement, magnitude or intensity of negative reinforcement, and delay of negative reinforcement (see de Villiers, 1977, for a thorough review). In a summary of the evidence, Peter de Villiers (1977) stated:

> The remarkable generality of Herrnstein's equation is apparent from this survey. The behavior of rats, pigeons, monkeys and . . . people is equally well accounted for, whether the behavior is lever pressing, key pecking, running speed, or response latency in a variety of experimental settings. The reinforcers can be as different as food, sugar water, escape from shock or loud noise or cold water, electrical stimulation of a variety of brain loci, or turning a comedy record back on. Out of 53 tests of Equation [9.6] on group data the least-squares fit of the equation accounts for over 90% of the variance in 42 cases and for over 80% in another six cases. Out of 45 tests on individual data, the equation accounts for over 90% of the variance in 32 cases and for over 80% in another seven cases. The literature appears to contain no evidence for a substantially different equation than Equation [9.6]. . . . This equation therefore provides a powerful but simple framework for the quantification of the relation between response strength and both positive and negative reinforcement. (p. 262)

ON THE APPLIED SIDE: APPLICATION OF THE
QUANTITATIVE LAW OF EFFECT

Dr. Jack McDowell (Fig. 9.14) was the first researcher to use Herrnstein's matching equation
for a single schedule of reinforcement (Equation 9.6) to describe human behavior in a
natural setting. Many people are interested in his work on applications of matching theory
to the treatment of clinical problems. However, McDowell states, "I really think of myself
as a basic researcher" (personal communication, March 3, 1989). As a college student, he
started out as a physics major and gained a strong background in natural science. He recalls
that, "I regarded psychology as a discipline with interesting problems but terrible methods.
Indeed, I thought it was absurd to consider psychology a science. Then I took a course in
what we now call behavior analysis. I was surprised to find a specialty in psychology that
looked like what I had always thought of as science. So I changed my major to psychology and
later entered a behavioral graduate program" (personal communication, March 3, 1989). In
1972, at Yale University, McDowell worked on the philosophical foundations of behavior
modification. By 1978, he had completed a clinical internship at the State University of
New York, Stony Brook, and a year later he received his Ph.D. in clinical psychology.
McDowell's doctoral dissertation focused on the mathematical description of behavior, and
he has maintained this emphasis throughout his career. At the time of this writing, he is a
professor of clinical psychology and psychobiology at Emory University in Atlanta, Georgia;
he also maintains a private practice in behavior therapy.

Mathematics and Behavior Modification

McDowell's expertise in mathematics and behavior modification spurred him to apply Her-
rnstein's matching equation for a single operant to a clinically relevant problem. Carr and
McDowell (1980) had been involved in the treatment of a 10-year-old boy who repeatedly
and severely scratched himself (Fig. 9.15). Before treatment the boy had a large number
of open sores on his scalp, face, back, arms, and legs. In addition, the boy's body was cov-
ered with scabs, scars, and skin discoloration, where new wounds could be produced. In
their 1980 paper, Carr and McDowell demonstrated that the boy's scratching was operant
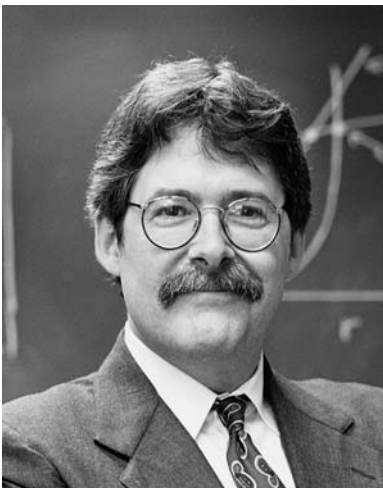
FIG. 9.14. *Jack McDowell. Reprinted with permission.*
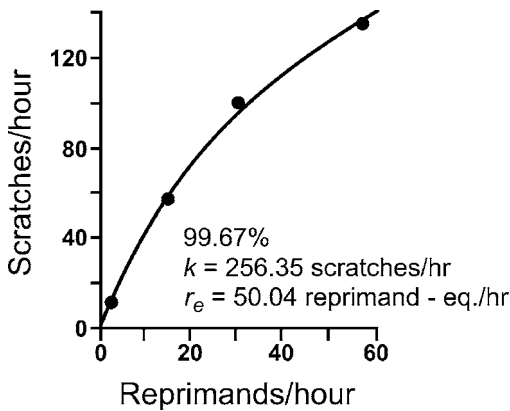
FIG. 9.15. *Rate of social reinforcement and self-injurious scratching of a young boy. The data were fitted by Herrnstein's single-operant equation (Equation 9.6). Values of k and R_e and percentage variance accounted for by the curve fit are shown. Adapted from* Quantification of Steady-State Operant Behavior *(pp. 311–324), by J. J. McDowell, 1981, Amsterdam: Elsevier/North-Holland.*

behavior. Careful observation showed that the scratching occurred predominantly when he and other family members were in the living room watching television. This suggested that the self-injurious behavior was under stimulus control. In other words, the family and setting made scratching more likely to occur.

Next, Carr and McDowell (1980) looked for potential reinforcing consequences maintaining the boy's self-injurious behavior. The researchers suspected that the consequences were social, because scratching appeared to be under the stimulus control of family members. In any family interaction there are many social exchanges, and the task was to identify those consequences that reliably followed the boy's scratching. Observation showed that family members reliably reprimanded the boy when he engaged in self-injury. Reprimands are seemingly negative events, but the literature makes it clear that both approval and disapproval may serve as reinforcement. Although social reinforcement by reprimands was a good guess, it was still necessary to show that these consequences in fact functioned as reinforcement. The first step was to take baseline measures of the rate of scratching and the rate of reprimands. Following this, the family members were required to ignore the boy's behavior. That is, the presumed reinforcer was withdrawn (i.e., extinction), and the researchers continued to monitor the rate of scratching. Next, the potential reinforcer was reinstated by having the family members again reprimand the boy for his misconduct. Relative to baseline, the scratching decreased when reprimands were withdrawn and increased when they were reinstated. This test identified the reprimands as positive reinforcement for scratching. Once the reinforcement for scratching was identified, behavior modification was used to eliminate the self-injurious behavior.

In a subsequent report, McDowell (1981) analyzed the boy's baseline data in terms of the quantitative law of effect. He plotted the reprimands per hour on the X-axis and scratches per hour on the Y-axis. McDowell then fit the matching equation for a single schedule of reinforcement (Equation 9.6) to the points on the graph. Figure 9.15 shows the plot and the curve of best fit. The matching equation provides an excellent description of the boy's behavior. You will notice that most of the points are on, or very close to, the hyperbolic curve. McDowell has indicated the significance of this demonstration. He states:

> As shown in the figure [9.15] the single-alternative hyperbola accounted for nearly all the variance in the data. This is especially noteworthy because the behavior occurred in an uncontrolled environment where other factors that might have influenced the behavior had ample opportunity to do so. It may be worth emphasizing that the rates of reprimanding . . . occurred naturally; that is, they were not experimentally arranged. . . . Thus, the data . . . demonstrate the relevance of matching theory to the natural ecology of human behavior. (McDowell, 1988, pp. 103–104)

Overall, the quantitative law of effect or Herrnstein's hyperbolic equation has been an important contribution to the understanding of human behavior and to the modification of human behavior in applied settings (see Martens, Lochner, & Kelly, 1992, for further evidence; Fisher & Mazur, 1997, for a review).

KEY WORDS

Ainslie–Rachlin principle	Findley procedure	Preference
Behavioral economics	Generalized matching	Preference reversal
Bias	law	Quantitative law of
Changeover delay (COD)	Impulsive behavior	effect
Changeover response	Log-linear matching	Relative rate of
Choice	equation	reinforcement
Commitment response	Matching law	Relative rate of response
Concurrent schedules of	Maximization	Self-control behavior
reinforcement	Melioration	Total behavioral output
Extraneous sources of	Overmatching	Two-key procedure
reinforcement (R_e)	Power law for matching	Undermatching

ON THE WEB

http://www.pigeon.psy.tufts.edu/eam/eam7.htm This module is designed to illustrate the patch problems of optimal foraging. Students can control the rate of reinforcement within a patch and its depletion rate.

http://www.envmed.rochester.edu/wwwrap/behavior/jeab_articles_exp/1999/jeab-71-03-0355.pdf An article is available by William Baum and his associates on foraging, the generalized matching law, and contingency discrimination. This is a good example of the experimental analysis of choice in the context of foraging.

http://www.psych.auckland.ac.nz/psych/ugrad/STAGE3/461.309FC/Teach309/Theories%20of%20Matching/MATCHMAX.htm The Web site gives more detailed accounts of matching, maximizing, melioration, and tests of these alternative theoretical models.

STUDY QUESTIONS

1. In a behavioral view, what is meant by choice and preference? Give a common example. (235)
2. Compare a single-operant analysis to an analysis based on alternative sources of reinforcement. (236)
3. Describe the two-key procedure in terms of a pigeon experiment. Why have concurrent schedules of reinforcement received so much attention? (236–237)
4. What are concurrent-ratio schedules and what is the steady-state effect of such contingencies? What about concurrent fixed-interval schedules? Describe the advantage of concurrent VI VI schedules. (237)
5. Summarize the analytical problems of rapid switching or changing over between concurrent schedules. Why does switching occur? How does a changeover delay (COD) help solve the problem? (239)

6. State four laboratory procedures used to study choice. What is a Findley procedure and how does it compare with the two-key method? When would you use a Findley procedure? (240)

7. State the relationship known as the matching law. Describe Herrnstein's (1961b) experiment and what he found. (241)

8. Know how to calculate the proportional rate of response and proportional rate of reinforcement. Write the matching equation in terms of proportions and know what each term means. Create a graph showing the matching relationship. (243)

9. Cite evidence about the generality of the matching law. Give an example of matching in human communication. (244)

9. How can departures from matching occur? What is time matching and when is it applicable? Write a matching equation for time spent on alternatives and know what the terms mean. (245)

11. Be able to write a matching equation for more than two alternatives. (246)

12. **ADVANCED ISSUE**: In a concurrent VI VI experiment in which matching is expected, how can sources of error arise? Transform the proportional-matching equation to a ratio-matching expression. Write the power law for matching of ratios. Define the a and k values of the generalized matching equation. Be able to discuss bias and sensitivity. (246–247)

13. **ADVANCED ISSUE (MORE)**: Write the algebraic equation for a straight line. Know the concepts of slope and intercept. Write the generalized matching (power law) equation in log-linear form. What is the slope and intercept of the log-linear equation? Be able to read a table of results that shows ratio matching. (249)

14. **ADVANCED ISSUE (MORE)**: Understand how the logarithms of the ratios are obtained. Know that the logarithm of a number is simply a transformation of scale. State what the slope and intercept values must be for ideal matching. Know how to plot the log ratios of reinforcement and response on X,Y coordinates. Explain where the line intercepts the Y coordinate and the rate at which the line rises (i.e., slope). What is undermatching (refer to slope)? Be able to tell the difference between ideal matching and undermatching by plots on X,Y coordinates. Do the same for bias (refer to intercept). (252)

15. **ADVANCED ISSUE (MORE)**: Know how to set the values of log-ratio reinforcement for a matching experiment. Explain how the log-ratio of response is obtained. How do we show the relationship between relative rate of reinforcement and relative rate of response? (253)

16. **ADVANCE ISSUE (END)**: Discuss the plot of pigeon 22 by White and Davison (1973). How are statistical estimates of slope (sensitivity) and intercept (bias) obtained? What were the bias and sensitivity estimates for pigeon 22 and what do the values mean? Read a plot on X,Y coordinates of the results. How does a measure of explained variance relate to prediction accuracy? (253)

17. Draw out the implications of the matching law in terms of child compliance and parental rates of reinforcement. (254)

18. Why do Myerson and Hale (1984) recommend the use of VI schedules in behavior modification? (255)

19. Be able to discuss optimal foraging, matching, and melioration. Give an example of the application of matching theory to foraging by a flock of free-ranging wild pigeons. (256)

20. Discuss the behavioral economic analysis of choice and addiction, referring to price and substitute commodities. (257)

21. In terms of behavior analysis, define impulsive and self-controlled behavior. State the Ainslie–Rachlin principle and how this leads to preference reversal. What is a commitment response? Give an example of an experiment with birds on preference reversal and self-control. Describe a second experiment on commitment and self-control in pigeons. What are the general conclusions from this research? (258)

22. What is the quantitative law of effect and extraneous sources of reinforcement? (261)

23. **ADVANCED ISSUE**: Be able to show how the proportional-matching equation may be used to obtain an expression of absolute response rate (quantitative law of effect). Write the Herrnstein absolute rate equation and know what each term means. (261)

24. **ADVANCE ISSUE (END)**: According to the quantitative law of effect, how do background sources of reinforcement (R_e) modify the impact of a schedule of reinforcement? Give an example based on dialing for dollars. Read a graph of the dialing-for-dollars experiment and interpret the two hyperbolic curves in terms of R_e. (260)

25. Read Herrnstein's graph of the data from six birds (Catania & Reynolds, 1968) using the quantitative law of effect. How generalizable is the absolute rate equation? (263)

26. Discuss McDowell's (1981, 1988; Carr & McDowell, 1980) use of the quantitative law of effect in behavior modification. Read a graph of self-injurious behavior, relating reprimands per hour to the number of scratches each hour. What is the theoretical importance of this relationship? (264)

BRIEF QUIZ

1. In terms of behavior, choice is concerned with
   (a) the distribution of behavior among alternative sources of reinforcement
   (b) the decision-making capabilities of the organism
   (c) the information processing during decision making
   (d) the differential reinforcement of alternative behavior

2. To investigate choice in the laboratory, use
   (a) a Skinner box with a single manipulandum
   (b) two cumulative recorders that are running successively
   (c) concurrent schedules of reinforcement
   (d) both a and b

3. In order to prevent switching on concurrent schedules
   (a) program an intermittent schedule of reinforcement
   (b) program a changeover delay
   (c) program a multiple schedule
   (d) program a DRO contingency

4. To investigate switching on concurrent schedules
   (a) use a Findley procedure
   (b) use a single response key that changes color with the schedule
   (c) use a changeover key
   (d) all of the above

5. Herrnstein's (1961) experiment using a two-key concurrent VI VI schedule is described by
   (a) the matching law for a single alternative
   (b) the quantitative law of effect

    (c) the proportional-matching equation
    (d) the nonmatching function for multiple alternatives

6. The matching law has described the choice behavior of
    (a) pigeons
    (b) wagtails
    (c) rats
    (d) all of the above

7. When the response is continuous rather than discrete, use a matching equation for
    (a) time spent on each alternative
    (b) rate of response on each alternative
    (c) several concurrent schedules of reinforcement
    (d) the single operant

8. The equation for matching of ratios of rates of response to rates of reinforcement
    (a) is stated in terms of a power law
    (b) includes a value for bias
    (c) includes a value for sensitivity
    (d) all of these

9. In contrast to optimal foraging, Herrnstein (1982) proposed a process of
    (a) maximization
    (b) melioration
    (c) multiple-schedule inference
    (d) monotonic matching

10. Behavioral economics involves the use of
    (a) economic principles to describe and analyze behavioral choice
    (b) economic factors to predict animal behavior in the marketplace
    (c) economic indicators when pigeons are trading goods and services
    (d) economic satisfaction due to reinforcement

Answers to brief quiz (*page*): a(235); c(236); b(240); d(240); c(243); d(244); d(245); b(247); a(256); a(257)

CHAPTER 10
Conditioned Reinforcement

IN THIS CHAPTER

1. Learn about conditioned reinforcement and how chain schedules are used to investigate it.
2. Find out about multiple functions of stimuli in homogeneous and heterogenous chains.
3. Investigate the procedure of backward chaining and how it can be used to improve your golf game.
4. Learn how to make conditioned reinforcement most effective and learn about problems with an informational account of conditioned reinforcement.
5. Find out about the delay-reduction hypothesis, concurrent chain schedules, and conditioned reinforcement.
6. Investigate generalized conditioned reinforcement, human behavior, and the token ecomomy.

Human behavior is often regulated by consequences whose effects depend on a history of conditioning. Praise, criticism, good grades, and money are consequences that may strengthen or weaken behavior. Such events acquire these effects as consequences because of the different experiences that people have had throughout their lives. Some people have learned the value of what others say about their actions—others are indifferent. Henry Ford marketed and sold cars because of monetary reinforcement, status, and power, but Mother Teresa took care of the poor for other reasons. In these examples, the effectiveness of a behavioral consequence depends on a personal history of conditioning. A positive reinforcer may be defined as a stimulus or event the delivery of which will increase or maintain the rate of the response upon which it is contingent. The critical component is the influence on response rate, not what exactly the stimulus or event is.

Conditioned reinforcement occurs when behavior is strengthened by events that have an effect because of a conditioning history. The important aspect of the history involves a correspondence between an arbitrary event and a currently effective reinforcer. Once the arbitrary event becomes able to increase the frequency of an operant, it is called a **conditioned reinforcer**. (It may also be called a secondary reinforcer, but **conditioned** is best.) For example, the sound of the pellet feeder operating becomes a conditioned reinforcer for a rat that presses a lever because the sound is paired with food. The immediate effect of lever pressing or key pecking is the sound of the feeder, not the consumption of food. Food is a biological or **unconditioned reinforcer** that accompanies the sound of the feeder. Magazine training is the procedure of deliberately and contiguously pairing the sound of food delivery with the immediate access to the food. The point in this case is to be able to deliver an auditory reinforcer, the feeder sound, wherever the subject is or whenever you wish. One way to demonstrate the reinforcing effectiveness of the feeder sound is to arrange a contingency between some other operant (e.g., pressing a spot on the wall) and delivering only the sound. If operant rate increases, the process is conditioned reinforcement and the sound is a conditioned reinforcer.

In his book *The Behavior of Organisms*, Skinner (1938) described a procedure that resulted in conditioned reinforcement. Rats were exposed to a clicking sound and were given food. Later the animals were not fed, but the click was used to train lever pressing. Lever pressing increased although it only produced the clicking sound. Because the click was no longer accompanied by food, each occurrence of the sound was also an extinction trial. For this reason, the sound declined in reinforcing effectiveness and lever pressing for clicks decreased at the same time. It should occur to you that the pairing process of establishing a conditioned reinforcer is similar to the development of a CS in respondent conditioning. A previously neutral stimulus is contiguously presented with a functioning reinforcer and this stimulus becomes capable of maintaining behavior upon which it is contingent. Of course, as in respondent conditioning, presenting the CS without the occasional US leads to the absence of the CR because the CS loses its eliciting ability.

This **new-response method** for studying conditioned reinforcement sometimes results in short-lived effects. Because of extinction (the sound without the food), the conditioned reinforcer quickly loses its effectiveness and is only capable of maintaining a few responses (see Kelleher & Gollub, 1962; Miller, 1951; Myers, 1958; Wike, 1966). On the other hand, Skinner (1938, p. 82 and Fig. 13) reported that ". . . considerable conditioning can be effected before a state of extinction." This conclusion is in accord with Alferink, Crossman, & Cheney (1973). These researchers demonstrated the conditioned reinforcing strength of the hopper light in maintaining pecking even in the presence of free food. Trained pigeons continued to peck on a FR 300 schedule of hopper light presentation even with the hopper propped up so that food was always available. At the present time it is not possible to say when conditioned reinforcement based on the new-response method will be short-lived or enduring. Experience with conditioned reinforcement in everyday life suggests, however, that these events can support a lot of behavior without noticable extinction.

Animals typically engage in long and complex sequences of behavior that are often far removed from unconditioned reinforcement. This is particularly true for humans. People get up in the morning, take buses to work, carry out their jobs, talk to other workers, and so on. These operants occur day after day and are maintained by conditioned reinforcement. Thus, conditioned reinforcement is a durable process, but the new-response method does not always reveal how this occurs. Because of this, behavioral researchers have turned to procedures that clarify the long-lasting effects of conditioned reinforcement.

Chain Schedules and Conditioned Reinforcement

One way to investigate conditioned reinforcement is to construct sequences of behavior in the laboratory. A **chain schedule of reinforcement** involves two or more simple schedules (CRF, FI, VI, FR, or VR), each of which is presented sequentially and is signaled by an arbitrary stimulus. Only the final or terminal link of the chain results in unconditioned reinforcement. Figure 10.1 shows the Mechner notation for a three-component chain schedule of reinforcement. The schedule is a chain VI FR FI, and each link (or component) of the chain is signaled by a red, blue, or green light. For example, in the presence of the red light, a pigeon must emit a key peck after an average of 1 min has elapsed (VI 60 s). When the peck occurs, the light changes from red to blue and the bird must peck the key 50 times (FR 50) to produce the green light. In the presence of the green light, a single peck after 2 min (FI 120 s) produces food and the light changes back to red (i.e., the chain starts over).
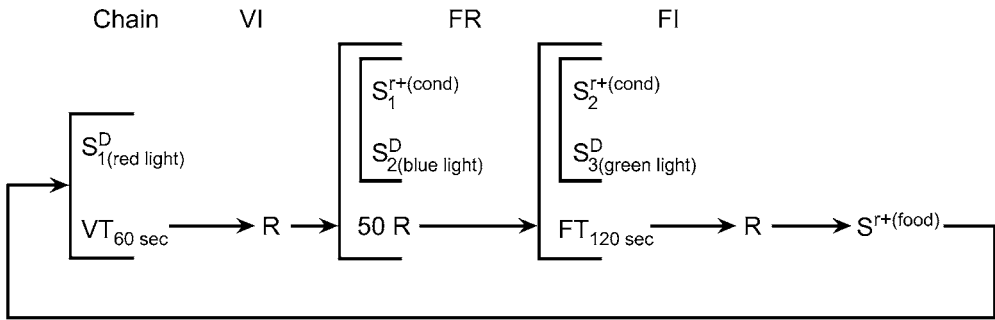
FIG. 10.1. *Mechner notation for a three-component chain schedule of reinforcement, VI 60 s FR 50 FI 120 s. Notice that the red light only has a discriminative stimulus function, while the blue and green lights have multiple functions, including S^D and $S^{r(cond)}$.*

When the pigeon pecks in the red component, the only consequence is that the light changes to blue. Once the blue condition is in effect, 50 responses turn on the green light. If the bird pecks for the blue and green lights, the change in color is reinforcement. Recall that any stimulus that strengthens behavior is by definition a reinforcing stimulus. Thus, these lights have multiple functions: They are S^Ds that set the occasion for pecking the key in each link and conditioned reinforcement, $S^{r(cond)}$, for behavior that produces them. The notation in Fig. 10.1 indicates that the red light is only a discriminative stimulus. You might suspect that it is a conditioned reinforcer, and it may have this function. However, the chain procedure as outlined does not require a separate response to produce the red light (the last response in the chain produces food and afterward the red light automatically comes on), and for this reason a conditioned reinforcing function is not demonstrated.

Multiple-Stimulus Functions

Consider a sequence of two schedules, FR 50 FI 120 s, in which the components are not signaled. Formally, this is called a **tandem schedule**. A tandem is a schedule of reinforcement in which unconditioned reinforcement is programmed after completing two or more schedules, presented sequentially *without discriminative stimuli*. In other words, a tandem schedule as shown in Fig. 10.2 is the same as an unsignaled chain.

Gollub (1958) compared the behavior of pigeons on similar tandem and chain schedules of reinforcement. On a tandem FI 60 s FI 60 s, performance resembled the pattern observed on a simple FI 120-s schedule. The birds produced the typical scallop pattern observed on fixed-interval schedules—pausing after the presentation of food, and accelerating in response rate to the moment of reinforcement. When the tandem schedule was changed to a chain FI 60 s FI 60 s by adding distinctive stimuli to the links, the effect of conditioned reinforcement was apparent. After some experience on the chain schedule, the birds responded
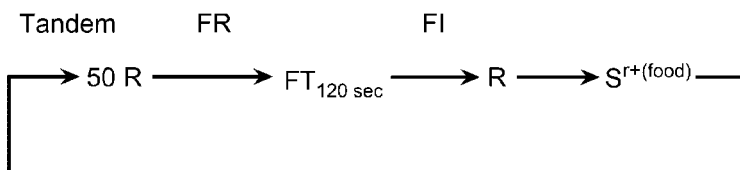
FIG. 10.2. *A tandem schedule of reinforcement is the same as an unsignaled chain.*

faster in the initial link than they had on the tandem. In effect, the birds produced two FI scallops rather than one during the 120 s. This change in behavior may be attributed to the discriminative stimulus in the final link that also reinforced responses in the first component. In other words, the discriminative stimulus signaling the terminal link is also a conditioned reinforcer for responses in the first component of the chain (see also Ferster & Skinner, 1957).

Homogeneous and Heterogeneous Chains

Operant chains are classified as **homogeneous chains** when the topography or form of response is similar in each component. For example, in the chain schedule discussed earlier, the bird pecks the same key in each link. Because a similar response occurs in each component, this is a homogeneous chain. In contrast, a **heterogeneous chain** requires a different response for each link. Dog trainers make use of heterogeneous chains when they teach complex behavioral sequences to their animals. In going for a walk, a seeing-eye dog stops at intersections, moves forward when the traffic is clear, pauses at a curb, avoids potholes, and finds the way home. Each of these different responses is occasioned by a specific stimulus and results in conditioned reinforcement. Although heterogeneous chains are common in everyday life and are created easily in the laboratory, they are usually too complex for experimental analysis. For this reason, conditioned reinforcement is typically investigated with homogeneous chains.

Chain schedules show how sequences of behavior are maintained by conditioned reinforcement in everyday life. Conditioned reinforcers in chains remain effective because the terminal link continues to schedule unconditioned reinforcement. Viewed as a heterogeneous chain schedule, going to a restaurant may involve the following links: A person calls and makes a reservation, gets dressed for the occasion, drives to the restaurant, parks the car, enters and is seated, orders dinner, and eats the meal. In this example, the S^Ds are the completion of the response requirements for each link. That is, being dressed for dinner (S^D) sets the occasion for going to the car and driving to the restaurant. Conditioned reinforcement involves the opportunity to engage in the next activity—bringing the person closer to unconditioned reinforcement.

Of course, each of these components may be subdivided into finer and finer links in the chained performance. For example, dressing for dinner is composed of many different responses with identifiable discriminative stimuli (e.g., putting on shoes sets the occasion for tying laces). Even tying shoelaces may be separated into finer and finer links of a heterogeneous chain. The degree of detail in describing a chain performance depends on the analytical problem. An analysis of going out for dinner does not require details about how a person ties his or her shoes. On the other hand, a behavior analyst teaching a retarded child to dress may focus on fine details of the chained performance.

FOCUS ON ISSUES: BACKWARD CHAINING

Imagine that you have just been hired as a behavioral technician at a group home for retarded children. One of your first assignments is to use the principle of conditioned reinforcement to teach a child to make his bed. The child is profoundly retarded and cannot easily follow instructions or examples. He does have good motor coordination and is reinforced by potato chips. You and the child are in one of the bedrooms with sheets, blankets, and pillowcases stacked on the bed. You have decided to use potato chips as a reinforcer for bed making.

Many people would start at the beginning of the sequence by unfolding a sheet, shaking it out, and placing it over the mattress. This tactic works for students (or children) who are easily able to follow instructions. However, this is not the case for this child and the initial links of the chain are far removed from unconditioned reinforcement. Also, there are no conditioned reinforcers established along the way for completing the components.

The alternative way of teaching is to use a technique called **backward chaining**. The idea is to begin training at the end of the sequence. That is, you first teach the behavior in the final link of the chain. The child is reinforced with chips when he places the top of the bedspread over the pillow. Once this behavior is well established, the bedspread is pulled down further. Unconditioned reinforcement now occurs when the child pulls covers up to the pillow and then finishes making the bed. In this manner, responses that are more and more remote from the final performance are maintained by conditioned reinforcement (engaging in the next sequence). Of course, you eventually pair chips with social approval (i.e., "Your bed looks great!") and maintain the behavior without direct unconditioned reinforcement.

In everyday life, backward chaining has been used to train athletic skills. O'Brien and Simek (1983) taught golf using principles of backward chaining. In their article they state:

> The teaching of sports has been largely unaffected by the advances in learning other operants. Golf, for example, is still routinely taught by handing the novice a driver and instructing him verbally how to get his body, arms and head to combine to hit a 250 yard drive. The usual result of such instruction is a series of swings that end in wiffs, tops and divots. This is followed by more verbal explanations, some highly complex modeling, and loosely administered feedback. Endless repetitions of this chain then follow.
>
> A behavioral analysis of golf would suggest that the reinforcer for this exercise is putting the ball in the hole. The trip from tee to green represents a complex response chain in which the swing of the club up over the head and back to hit the ball is shortened as one gets closer to the hole. The final shot may be a putt of six inches or less leading to the reinforcement of seeing the ball disappear into the ground. This putt requires a backswing of only a few inches but involves the same basic stroke as the long backswinged shot from the tee. Since the short putt seems to be the simplest response and the one closest to reinforcement, it would seem appropriate to teach the golf chain by starting with the putt and working back to the drive. (pp. 175–176)

O'Brien and Simek designed two experiments to compare the acquisition of golf by backward chaining against traditional teaching methods.

In one of their experiments, 12 college students were randomly assigned to eight lessons of backward chaining or traditional methods of learning golf. Students in both groups received standard instruction from an amateur golfer who had experience teaching the sport. In the backward-chaining condition, students were first taught to make 6-inch putts until they were able to sink the ball four times in a row. Over a series of 10 steps, the putting distance was increased to 30 feet, and the students consistently had to come within 2 feet of the hole. Next, approach shots using clubs appropriate to the distance from the hole were trained to a stipulated criterion. In the last step, a 200-yard shot from the tee had to come within 90 feet of the hole one-third of the time.

After eight lessons, students in both groups played 18 holes of golf on a course that was rated by the Professional Golfers Association as par 70 or moderately difficult. The average score for the backward-chaining group was 98 strokes, and the traditional group scored 116 swings. Four out of six golfers in the backward-chaining condition broke 100 strokes, but only one of the traditionally taught students was able to do this.

The superiority of the backward-chaining method in athletics or other areas of learning results from the principle of conditioned reinforcement. Behavior that is closest to

unconditioned reinforcement is taught first. By doing this, the instructor ensures that operants in the sequence are maintained by effective consequences. With this method, each step in the chain may be added as the previous link is mastered.

Determinants of Conditioned Reinforcement

Operant chains show how complex sequences of behavior can be maintained by events that have acquired a reinforcement function based on the past experience of an organism. The task for experimental analysis is to identify the critical conditions that contribute to the strength of conditioned reinforcement. It is also important to specify the factors that determine the reinforcing effectiveness of conditioned stimuli.

Strength of Conditioned Reinforcement

Frequency of Unconditioned Reinforcement

The effectiveness of a conditioned reinforcer depends on the frequency of unconditioned reinforcement correlated with it. Autor (1960) found that preference for a conditioned reinforcer increased with the frequency of unconditioned reinforcement in its presence. The power or effectiveness of a conditioned reinforcer increases with more and more presentations of unconditioned reinforcement, but eventually levels off. As the frequency of unconditioned reinforcement goes up, the strength of a conditioned reinforcer reaches a maximum value. This relationship is strikingly similar to the increase in associative strength of a CS as described by the Rescorla–Wagner model of classical conditioning (see Chapter 3).

Variability of Unconditioned Reinforcement

Variability of unconditioned reinforcement also affects the strength of a conditioned reinforcer. Fantino (1967) showed that birds preferred a conditioned reinforcer that was correlated with an alternating schedule (FR 1 half of the time and FR 99 for the other 50% of the trials) to one that was associated with a fixed schedule with the same rate of payoff (FR 50). Thus, variability of unconditioned reinforcement increases the value of a conditioned reinforcer (see also Davison, 1969, 1972; Fantino, 1965; Herrnstein, 1964a). Variable schedules increase the effectiveness of conditioned reinforcement because these schedules occasionally program short intervals to unconditioned reinforcement. Compared with fixed schedules, these short intervals enhance responding and the value of stimuli correlated with them (Herrnstein, 1964b).

Establishing Operations

The effectiveness of a conditioned reinforcer is enhanced by events that establish unconditioned reinforcement. A bird will respond for a light correlated with food more when it is hungry than when it is well fed. People attend to signs for washrooms, restaurants, and hospitals when their bladders are full, they have not eaten for some time, or they are sick. Generally, conditioned reinforcement depends on stimuli that establish unconditioned reinforcement (Michael, 1982a).

Delay to Unconditioned Reinforcement

On a chain schedule, the longer the delay between a discriminative stimulus and unconditioned reinforcement the less effective it is as a conditioned reinforcer. Gollub (1958) compared the performance of pigeons on three different schedules—FI 5 min, chain FI 1 FI 1 FI 1 FI 1 FI 1 min, and tandem FI 1 FI 1 FI 1 FI 1 FI 1 min. On the simple FI 5-min schedule a blue key light was on throughout the interval. On the chain, a different key color was associated with each of the five links. The components of the tandem schedule were not signaled by separate colored lights, but a blue key light was on throughout the links. Birds responded to the tandem as they did to the simple FI—producing the typical FI scallop. On the extended chain schedule, responding was disrupted in the early components, and some of the birds stopped responding after prolonged exposure to the schedule (see also Fantino, 1969b). Disruption of responding occurs because the S^Ds in the early links (farthest from unconditioned reinforcement) signal a long time to unconditioned reinforcement and are weak conditioned reinforcers. A similar effect occurs when people give up when faced with a long and complex task. Students who drop out of school may do so because the signs of progress are weak conditioned reinforcers—far removed from a diploma or degree.

Establishing Conditioned Reinforcement

Many experiments have used an extinction procedure to investigate conditioned reinforcement. In most of these experiments, a conspicuous stimulus is presented just before the delivery of food. The **new-response method** involves pairing a distinctive stimulus such as a click with unconditioned reinforcement. After several pairings, the stimulus is presented without unconditioned reinforcement and is used to shape a new response. Another extinction technique is called the **established-response method**. An operant that produces unconditioned reinforcement is accompanied by a distinctive stimulus, just prior to reinforcement. When responding is well established, extinction is implemented but half of the subjects continue to get the stimulus that accompanied unconditioned reinforcement. The other subjects undergo extinction without the distinctive stimulus. Generally, subjects with the stimulus present respond more than the subjects who do not get the stimulus associated with unconditioned reinforcement. This result is interpreted as evidence for the effects of conditioned reinforcement.

Pairing, Discrimination, and Conditioned Reinforcement

Both extinction methods for analyzing conditioned reinforcement involve the presentation of a stimulus that was closely followed by unconditioned reinforcement. This procedure is similar to CS–US pairings used in respondent conditioning. One interpretation, therefore, is that conditioned reinforcement is based on classical conditioning. This interpretation is called the stimulus–stimulus or **S–S account of conditioned reinforcement**. That is, all CSs are also conditioned reinforcers.

Although this is a straightforward account, the experimental procedures allow for an alternative analysis. In both the new-response and established-response methods, the stimulus (e.g., a click) sets the occasion for behavior that produces unconditioned reinforcement. For example, the click of a feeder (S^D) sets the occasion for approaching the food tray (operant) and eating food (S^r). Thus, the **discriminative-stimulus account** is that an S^D is a conditioned reinforcer only and does not function as a CS associated with food.

Many experiments have attempted to distinguish between the S^D and S–S accounts of conditioned reinforcement (see Gollub, 1977; Hendry, 1969, for reviews). For example,

Schoenfeld, Antonitis, and Bersh (1950) presented a light for 1 s as an animal ate food. This procedure paired food and light, but the light could not be a discriminative stimulus since it did not precede the food delivery. Following this training, the animals were placed on extinction and there was no effect of conditioned reinforcement.

Given this finding, it seems reasonable to conclude that a stimulus must be discriminative in order to become a conditioned reinforcer. Unfortunately, current research shows that simultaneous pairing of CS and US results in weak conditioning (see Chapter 3). For this and other reasons, it has not been possible to have a definitive test of the S^D and S–S accounts of conditioned reinforcement.

On a practical level, distinguishing between these accounts of conditioned reinforcement makes little difference. In most situations, procedures that establish a stimulus as an S^D also result in that stimulus becoming a conditioned reinforcer. Similarly, when a stimulus is conditioned as a CS it almost always has an operant reinforcement function. In both cases, contemporary research (Fantino, 1977) suggests that the critical factor is the temporal delay between the onset of the stimulus and the later presentation of unconditioned reinforcement.

Information and Conditioned Reinforcement

Stimuli that provide information about unconditioned reinforcement may become effective conditioned reinforcers. Egger and Miller (1962) used the extinction method to test for conditioned reinforcement. They conditioned rats by pairing two different stimuli (S_1 and S_2) with food. Figure 10.3 describes the procedures and major results. In their experiment (panel A), S_1 came on and S_2 was presented a half-second later. Both stimuli were turned off when the animals were given food. Both S_1 and S_2 were paired with food, but only S_1 became an effective conditioned reinforcer. In another condition (panel B), S_1 and S_2 were presented as before, but S_1 was occasionally presented alone. Food was never given when S_1 occurred by itself. Under these conditions, S_2 became a conditioned reinforcer.
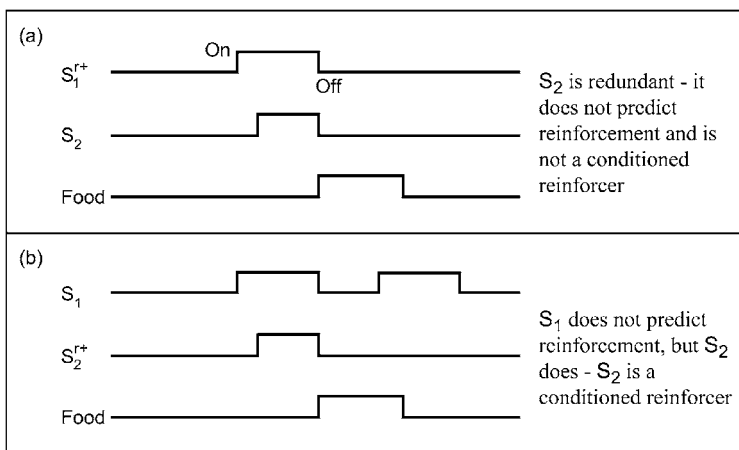
FIG. 10.3. *Procedures and major results of an experiment using the extinction method to test for conditioned reinforcement. From "Secondary Reinforcement in Rats as a Function of Information Value and Reliability of the Stimulus," by M. D. Egger and N. E. Miller, 1962,* Journal of Experimental Psychology, 64, *pp. 97–104. Copyright 1962. Author figure.*

To understand this experiment, consider the informativeness of S_2 in each situation. When S_1 and S_2 are equally correlated with food, but S_2 always follows S_1, S_2 is *redundant*—providing no additional information about the occurrence of food. Because it is redundant, S_2 gains little conditioned reinforcement value. In the second situation, S_1 only predicts food in the presence of S_2 and for this reason S_2 is informative and becomes a conditioned reinforcer. These results, along with later experiments (e.g., Egger & Miller, 1963), suggest that a stimulus will become a conditioned reinforcer if it provides information about the occurrence of unconditioned reinforcement.

Good News and Bad News

The informativeness of a stimulus should not depend on whether it is correlated with positive or negative events, because bad news is just as informative as good news. Wyckoff (1952, 1969) designed an observing-response procedure to evaluate the strength of a conditioned reinforcer that predicted good or bad news. In this procedure, periods of reinforcement and extinction alternate throughout a session, but the contingencies are not signaled by S^Ds or S^Δs. The contingency is called a **mixed schedule of reinforcement**. A mixed schedule is the same as a multiple schedule, but without discriminative stimuli. Once the animal is responding on the mixed schedule, an observing response is added to the contingencies. The **observing response** is a topographically different operant that functions to produce an S^D or S^Δ depending on whether reinforcement or extinction is in effect. In other words, an observing response changes the mixed to a multiple schedule. Figure 10.4 shows the relationships among mixed, multiple, tandem, and chain schedules of reinforcement.

Wyckoff (1969) showed that pigeons would stand on a pedal in order to observe red and green colors associated with FI 30-second reinforcement or EXT 30 seconds. Before the birds had an observing response available, they pecked equally in the reinforcement and extinction phases—showing failure to discriminate between the schedules. When the observing response was added, the pigeons showed a high rate of pecking in the reinforcement phase and very low rates during extinction. Because the observing response was maintained, the results suggest that stimuli correlated with either reinforcement or extinction (good or bad news) became conditioned reinforcers.
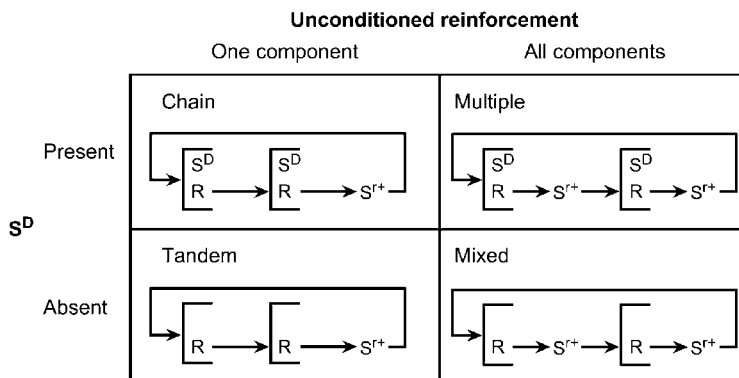
FIG. 10.4. *The relationships among mixed, multiple, tandem, and chain schedules of reinforcement.*

Although Wyckoff's data are consistent with an information view of conditioned reinforcement, it is noteworthy that his pigeons only spent about 50% of the time making the observing response. One possibility is that the birds were observing the stimulus correlated with reinforcement (red color) but not the stimulus that signaled extinction (green color). In other words, the birds may have only responded for good news.

In fact, subsequent experiments by Dinsmoor et al. (1972), and Killeen et al. (1980) supported the good-news interpretation of conditioned reinforcement. In Dinsmoor et al. (1972) pigeons were trained to peck a key on a VI 30-s schedule of food reinforcement that alternated with unpredictable periods of extinction. The birds could peck another key in order to turn on a green light correlated with reinforcement and a red light correlated with extinction. That is, if reinforcement was in effect, an observing response turned on the green light, and if extinction was occurring, the response turned on the red light.

Observing responses were maintained when they produced information about both reinforcement and extinction. In the next part of the experiment, observing responses only produced the green light signaling reinforcement, or the red light associated with extinction. In this case, observing responses produced either good or bad news, but not both. When observing responses resulted in the green light correlated with reinforcement, the birds pecked at a high rate. In contrast, the pigeons would not peck a key that only produced a stimulus (red) signaling extinction. Thus, good news functions as conditioned reinforcement, but bad news does not.

The good-news conclusion is also supported by research using aversive, rather than positive, consequences. Badia, Harsh, Coker, and Abbott (1976) exposed rats to electric shocks. The shocks were delivered on several variable-time schedules, independent of the rats' behavior. During training, a light was always on and a tone occurred just before each shock. In Experiment 2 of their study, the researchers allowed the animals to press a lever that turned on the light for 1 min. During this time, if shocks were scheduled, they were signaled by a tone. In one condition, the light was never accompanied by tone and shocks. That is, when the light was on the animal was completely safe from shocks. Other conditions presented more and more tones and shocks when the animal turned on the light. In these conditions, the light predicted less and less safety, and responding for the light decreased. In other words, the animals responded for a stimulus correlated with a shock-free period, but not for information about shock given by the tone signals (see also DeFran, 1972; Dinsmoor, Flint, Smith, & Viemeister, 1969). Once again, conditioned reinforcement is based on good news but not on bad news.

There are human examples of the good- and bad-news effect (see Case, Ploog, & Fantino, 1990 for good news effects; Lieberman, Cathro, Nichol, & Watson, 1997 for bad news effects). Students who usually do well on mathematics exams quickly look up their marks on posted lists, while those who have done poorly wait for their grades to come in the mail. Seeing a grade is a conditioned reinforcer for students who are skilled at mathematics, but not for those who find the subject difficult. People who have taken care of their teeth find it easy to make a dental appointment, but those with inadequate dental health postpone the visit. Visiting the dentist is a safe period for patients with good teeth, but it signals "pulling and drilling" for those with poor dental hygiene. Unfortunately, the worse things get in such situations, the less likely people are to do anything about them—until it is too late.

Overall, research has shown that stimuli correlated with positive or negative reinforcement maintain an observing response (Dinsmoor et al., 1972; Fantino, 1977), and stimuli that are correlated with extinction or punishment do not (Blanchard, 1975; Jenkins & Boakes, 1973; Katz, 1976). For this reason, the mere informativeness of a stimulus is not the basis of conditioned reinforcement.

Delay Reduction and Conditioned Reinforcement

Fantino and Logan (1979) have reviewed the observing response studies and point out that:

> only the more positively valued of two stimuli should maintain observing, since the less positive stimulus is correlated with an increase, not a reduction, in time to positive reinforcement (or a reduction, not an increase, in time to an aversive event). . . . Conditioned reinforcers are those stimuli correlated with a reduction in time to reinforcement (or an increase in time to an aversive event). (p. 207)

This statement is based on Edmund Fantino's (1969a) **delay-reduction hypothesis**. Stimuli closer in time to positive reinforcement, or further in time from an aversive event, are more effective conditioned reinforcers. Stimuli that signal no reduction in time to reinforcement (S^Δ) or no safety from an aversive event (S^{ave}) do not function as conditioned reinforcement. Generally, the value of a conditioned reinforcer is due to its delay reduction—how close it is to reinforcement or how far it is from punishment.

Modern views of conditioned reinforcement are largely based on the concept of delay reduction (Fantino, 1969a; Squires & Fantino, 1971). The idea is to compare the relative value of two (or more) stimuli that are correlated with different amounts of time to reinforcement. To do this, a complex-choice procedure involving concurrent-chains schedules is used. On these schedules, an organism may choose between alternatives that signal different amounts of time to reinforcement.

Concurrent-Chains Schedules of Reinforcement

In Chapter 9, we discussed the analysis of choice based on *concurrent schedules of reinforcement*. We have also noted the importance of chains schedules for the study of conditioned reinforcement. These schedules allow a researcher to change the temporal location of a stimulus in relation to unconditioned reinforcement. For example, the terminal-link discriminative stimulus (S^D2) on a chain VI 20 s VI 10 s is six times closer to unconditioned reinforcement than the one on a chain VI 20 s VI 60 s. This relation is shown in Fig. 10.5. In
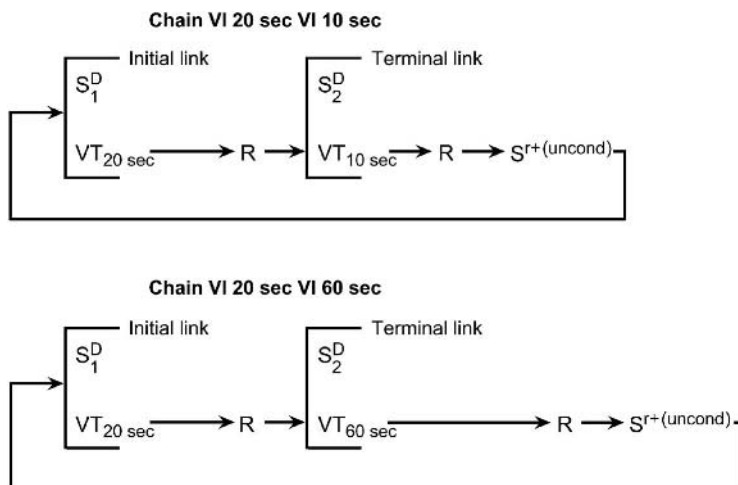
FIG. 10.5. *Comparison of chain VI 20 s VI 10 s with chain VI 20 s VI 60 s. Notice that the S^D closer to unconditioned reinforcement should be a more effective conditioned reinforcer.*
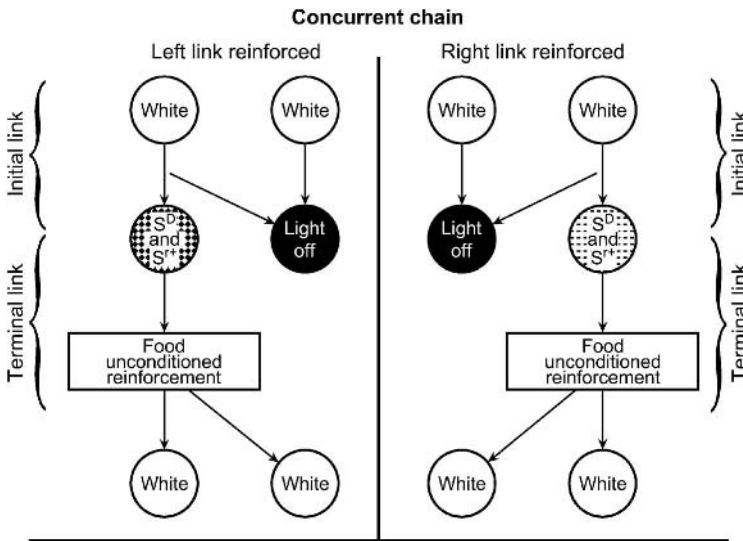
FIG. 10.6. *A two-key concurrent-chains schedule of reinforcement. A chain VI 20 s VI 10 s is programmed on the left key, and a chain VI 20 s VI 60 s on the right.*

terms of time, a terminal-link S^D that is nearer to unconditioned reinforcement should be a stronger conditioned reinforcer than one associated with a longer delay. Thus, a terminal-link S^D accompanying a VI 10-s schedule ought to be a more effective conditioned reinforcer than a discriminative stimulus correlated with VI 60 s.

To assess the effects of delay, organisms must be able to choose between stimuli associated with different reductions in time to unconditioned reinforcement. For example, using a two-key choice procedure, a chain VI 20 s VI 10 s may be programmed on the left key and a chain VI 20 s VI 60 s on the right key.

This two-key concurrent-chains procedure is diagrammed in Fig. 10.6. Consider the situation in which responses to the left key are eventually reinforced with food. To start, both left and right keys are illuminated with white lights. A bird makes left- and right-key pecks and after the left VI 20-s schedule times out, the first peck to the left key has two effects. The light on the right key goes out and the VI 20-s schedule on that key stops timing. That is, the key becomes dark and inoperative. At the same time, the left key changes from white to a diamond pattern. In the presence of this pattern, pecking the left key is reinforced with food on a VI 10-second schedule. After unconditioned reinforcement, both left and right keys are again illuminated white and the bird chooses between the two alternatives.

A similar sequence occurs when the right key times out and the bird pecks this key. The left key becomes dark and inoperative and the right key changes from white to a dotted pattern. In the presence of this pattern, pecking the right key is reinforced with food on a VI 60-second schedule. Following reinforcement, the discriminative stimuli in the initial links of the two chains (left and right white keys) are in effect and the bird again chooses to enter one of the terminal links (left or right).

The patterned stimuli on the left and right keys have two functions. These stimuli are S^Ds that set the occasion for pecking for food in the terminal links of the two chain schedules. In addition, the patterned stimuli function as conditioned reinforcement for pecking one or the other white keys in the initial links, or choice phase of the experiment. That is, reinforcement for pecking in the choice phase is the onset of the stimuli (S^D and

S^r) associated with unconditioned reinforcement in the terminal links. Because the bird is free to distribute pecks, the distribution of behavior in the initial links is a measure of the relative effectiveness of the two conditioned reinforcers.

Delay Reduction and Concurrent Chains

Humans often respond on concurrent-chains schedules of reinforcement. A businessperson who frequently flies from Kansas City to Denver may call either Delta or American Airlines to book a ticket. Many people are trying to book flights, and the telephone lines to both companies are always busy. To contact an agent, the businessperson calls one airline and then the other. Eventually, one of the calls is successful, but both companies have recorded messages that state, "All lines are busy at the moment; please hold until an agent is available." After the caller waits for some time, an agent answers and the ticket is booked.

In this example, calling the two airlines is the choice phase. The length of time to complete a call and get the hold message (initial-link schedules) is determined by the number of telephone lines at each airline and the number of people phoning the companies. The recorded message is conditioned reinforcement for dialing that company. The amount of time waiting on hold to book a flight (terminal-link schedule) is a function of the number of available agents. Waiting in the terminal link is reinforced by booking the flight. The sequence is repeated the next time the businessperson has a meeting in Denver.

To predict how much more (or less) reinforcing it is to be placed on hold at Delta relative to American Airlines, it is useful to consider a situation in which the initial- and terminal-link schedules are known for each company. Say that, on average, the telephone lines of both companies are busy for 120 s before a call is successful. In other words, the initial links for Delta and American are similar to concurrent VI 120-s schedules. The terminal-link schedules are different for the two airlines. It takes an average of 30 s to talk to a Delta agent after being placed on hold. That is, the terminal link for Delta is similar to a VI 30-s schedule. After being placed on hold at American, it takes an average of 90 s to reach an agent, so that the terminal link for American is similar to a VI 90-s schedule. Thus, the sequence for booking a ticket at Delta is chain VI 120 s VI 30 s, and the sequence is chain VI 120 s VI 90 s at American.

In this situation, Fantino's delay-reduction hypothesis predicts that the businessperson will prefer Delta over American. This is because more of the total time to reinforcement has elapsed when the person is placed on hold at Delta when compared to American. The conditioned reinforcement in this situation is getting the message, "All lines are busy at the moment; please hold until an agent is available." After the message occurs, it is faster to book a ticket at Delta compared with American. There has been relatively more reduction in delay to reinforcement when the Delta message occurs.

ADVANCED ISSUE: QUANTITATIVE ANALYSIS OF CONDITIONED REINFORCEMENT

Consider how long it takes to get placed on hold at the two airlines. The time to be placed on hold at both airlines is 120 s. If the person is dialing back and forth between Delta and American, the average time to get through is 120 s divided by the two choices,

or 60 s (i.e., 120/2 = 60). This is because the initial-link schedules are simultaneously available and are both timing out.

Next, consider how long it takes to contact an agent once placed on hold at one or the other airline. In this case, the person is stuck on hold at one airline and can no longer dial the other company. The average time in the terminal links of the two chains is 30 s for Delta plus 90 s for American divided by the two links, or 60 s [i.e., (30 + 90)/2 = 60]. That is, over many bookings the person has sometimes waited 90 s for an American agent and at other times 30 s for a Delta agent. On average, the length of time spent waiting on hold is 60 s.

Based on the average times in the initial and terminal links (60 s + 60 s), the overall average total time, T, to book a flight is 120 s or 2 min. Given that it takes an average of $T = 120$ s to book a flight, how much will the businessperson prefer booking at Delta relative to American Airlines? Recall that it takes an average of 30 s to contact an agent at Delta and 90 s at American, after being placed on hold. This terminal-link time is represented as $t_{2\,DELTA} = 30$ s and $t_{2\,AMERICAN} = 90$ s.

Of the average total time, 90 s has elapsed when the person is placed on hold at Delta $(T - t_{2\,DELTA} = 120 - 30 = 90$ s$)$. That is, the reduction in delay to reinforcement (booking a flight) is 90 s at Delta. The delay reduction at American is 30 s $(T - t_{2\,AMERICAN} = 120 - 90 = 30$ s$)$.

The greater the delay reduction at Delta relative to American, the more the conditioned reinforcement value of Delta compared with American. This relation may be expressed as

$$\frac{R_{DELTA}}{R_{DELTA} + R_{AMERICAN}} = \frac{T - t_{2DELTA}}{(T - t_{2DELTA})(T - t_{2AMERICAN})}$$

$$= \frac{120 - 30}{(120 - 30) + (120 - 90)}$$

$$= \frac{90}{90 + 30}$$

$$= 0.75.$$

The R values represent responses or, in this example, the number of calls to Delta (R_{DELTA}) and American ($R_{AMERICAN}$), respectively. The relative number of calls made to Delta is equal to the relative reduction in time to book a flight (reinforcement). This time is calculated as the proportion of delay reduction at Delta to the total delay reduction. According to the calculation, 0.75 or 75% of the businessperson's calls will be directed to Delta Airlines.

Experimental Test of Delay Reduction

Edmund Fantino Fig. 10.7 (at the time of this writing, a professor of psychology at the University of California, San Diego) first proposed and tested the delay-reduction analysis of conditioned reinforcement. He was trained in operant conditioning at Harvard University, where he worked in B. F. Skinner's laboratory and graduated with a Ph.D. in 1964. After a brief stay at Yale University, he joined the faculty at San Diego and continued his research on the experimental analysis of choice. Fantino recounts his discovery of

FIG. 10.7. *Edmund Fantino. Reprinted with permission.*

the delay-reduction hypothesis in the following passage:

> One of my first experiments at [San Diego], on choice behavior, was producing strange but consistent results in each of four pigeons. I was losing sleep over these results until one morning I awoke with the following hypothesis: Choice responses don't match rates of reinforcement of the outcomes but instead match the relative reduction in delay to reinforcement associated with these outcomes. This delay-reduction hypothesis then served to guide scores of experiments assessing its generality and limitations in areas such as choice, conditioned reinforcement, elicited responding, self-control, observing and experimental analogs of foraging decisions. (E. Fantino, personal communication, February, 28 1992).

Fantino (1969a) proposed a general equation for preference on a concurrent-chains schedule that was based on delay reduction. Equation 10.1 is a generalized statement of the formula used to calculate preference for Delta and American:

$$\frac{R_L}{R_L + R_R} = \frac{T - t_2}{(T - t_{2L}) + (T - t_{2R})}. \tag{10.1}$$

In this equation, R_L and R_R represent the rates of response on the left and right initial links of a concurrent-chains schedule of reinforcement. The symbol T is the average time to reinforcement (see the airlines example for calculation). The time required in the left and right terminal links is represented by t_{2L} and t_{2R} in the equation. The equation states that relative rate of response is a function of relative reduction in time to unconditioned reinforcement.

The delay-reduction equation emphasizes conditioned reinforcement as a major determinant of choice. This is because the onset of the terminal-link S^D for each chain is correlated with a reduction in time to unconditioned reinforcement. This reduction is $T - t_{2L}$ for the left alternative and is $T - t_{2R}$ for the right. Recall that the greater the reduction in time to unconditioned reinforcement signaled by a stimulus, the greater the conditioned-reinforcement value of that stimulus. The delay-reduction equation is a mathematical expression of this idea.

Fantino (1969a) designed an experiment to test the delay-reduction equation. The subjects were six pigeons which responded for food on concurrent-chains schedules of reinforcement. In this experiment, the terminal links were always set at $t_{2L} = 30$ s and $t_{2R} = 90$ s. Notice that for the left alternative the relative rate of unconditioned reinforcement is 0.75 and according to the matching law the birds should spend 75%
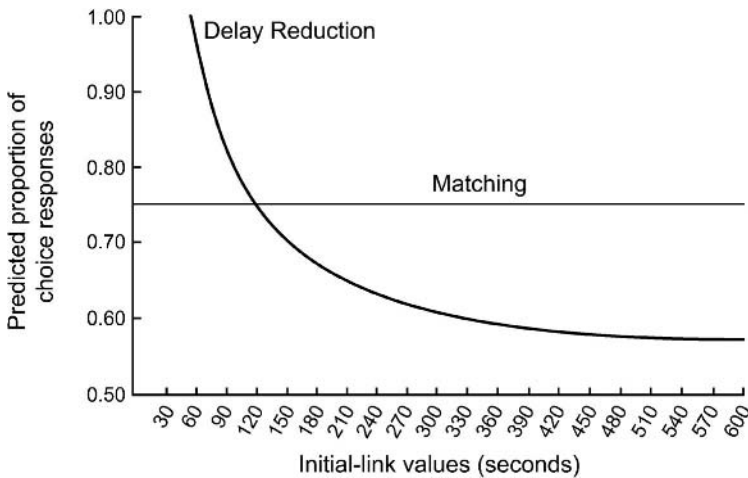
FIG. 10.8. *Proportion of responses predicted by the delay-reduction equation for the shorter (VI 30 s) terminal link as time is added equally to the initial links of the concurrent-chains schedule Adapted from "Conditioned Reinforcement, Choice, and the Psychological Distance to Reward,"* *by E. Fantino, in* Conditioned Reinforcement, *edited by D. P. Hendry, 1969, Homewood, Il: Dorsey press, pp. 163–191.*

of their time on the left key. The situation becomes more complex when initial-link schedules are varied. Fantino's experiment involved adding initial links to the VI 30-s and VI 90-s schedules. That is, he investigated concurrent-chains schedules with 30- and 90-s terminal links. The schedules in the initial links were always the same for both alternatives, but the values of these schedules were varied over the course of the experiment. For example, in one condition the initial links were VI 30 s on the left and VI 30 s on the right. In another condition, the initial-link schedules were both VI 600 s. Other initial-link values between these two extremes were also investigated. The important question is what happens to the pigeons' preference for the shorter (VI 30 s) terminal link as time is increased in the first link of the chains.

Figure 10.8 shows the proportion of responses predicted by Equation 10.1 for the shorter (VI 30 s) terminal link as time is added equally to the initial links of the concurrent-chains schedule. When the schedules were chain VI 30 s VI 30 s on the left and chain VI 30 s VI 90 s on the right, the birds responded almost exclusively to the left alternative. When the chains were VI 120 s VI 30 s on the left and VI 120 s VI 90 s on the right, the pigeons showed response distributions close to matching (0.75 responses on the left). Finally, when time in the initial links was greatly increased to VI 600 seconds, the birds showed no preference for either alternative. As you can see in Fig. 10.8, these results are in accord with the declining preference predicted by the delay-reduction equation.

Generalized Conditioned Reinforcement

Formally, a **generalized conditioned reinforcer** is any event or stimulus that is associated with, or exchangeable for, many sources of unconditioned reinforcement. Generalized reinforcement does not depend on deprivation or satiation for any specific reinforcer. Skinner

(1953) describes its effects in the following passage:

> A conditioned reinforcer is generalized when it is paired with more than one unconditioned reinforcer. The generalized reinforcer is useful because the momentary condition of the organism is not likely to be important. The operant strength generated by a single reinforcement is observed only under an appropriate condition of deprivation—when we reinforce with food, we gain control over the hungry man. But if a conditioned reinforcer has been paired with reinforcers appropriate to many conditions, at least one appropriate state of deprivation is more likely to prevail upon a later occasion. A response is therefore more likely to occur. When we reinforce with money, for example, our subsequent control is relatively independent of momentary deprivations. (p. 77)

Generalized Social Reinforcement

A major source of generalized reinforcement is mediated by the behavior of other people. Social consequences such as praise, attention, status, and affection are powerful reinforcers for most people. Approval, attention, affection, and praise function as **generalized social reinforcement** for human behavior (Kazdin & Klock, 1973; Kirby & Shields, 1972; Ruggles & LeBlanc, 1982; see Vollmer & Hackenberg, 2001 for a discussion). In a classroom, a child's misbehavior may be followed regularly by attention, as when the teacher says, "What are you doing out of your seat?" The teacher may complain that the student is an unmanageable child. But the problem may concern the social reinforcement contingency between the student's misbehavior and the teacher attention.

Misbehavior usually captures the teacher's attention because it is highly intense (even aggressive) activity. Attention is reinforcing to most children because it necessarily precedes other types of reinforcement from people. When attention is contingent on misbehavior, misbehavior increases. The solution to the problem is not to change the child, but to alter the contingency of reinforcement. One possibility is to ignore misbehavior (extinction) and attend to the child at any time other than when he or she is misbehaving (differential reinforcement of other behavior, or DRO). "Catch them being good" is the operative phrase.

The importance of generalized social reinforcement involving approval and affection is recognized in the following passage from Skinner (1953):

> Another person is likely to reinforce only that part of one's behavior of which he approves, and any sign of his approval therefore becomes reinforcing in its own right. Behavior which evokes a smile or the verbal response "That's right" or "Good" or any other commendation is strengthened. We use this generalized reinforcer to establish and shape the behavior of others, particularly in education. For example, we teach both children and adults to speak correctly by saying "That's right" when appropriate behavior is emitted.
>
> A still stronger generalized reinforcer is affection. It may be especially connected with sexual contact as a unconditioned reinforcer but when anyone who shows affection supplies other kinds of reinforcement as well, the effect is generalized.
>
> It is difficult to define, observe, and measure attention, approval, and affection. They are not things but aspects of the behavior of others. Their subtle physical dimensions present difficulties not only for the scientist who must study them but also for the individual who is reinforced by them. If we do not easily see that someone is paying attention or that he approves or is affectionate, our behavior will not be consistently reinforced. It may therefore be weak, may tend to occur at the wrong time, and so on. We do not "know what to do to get attention or affection or when to do it." The child struggling for attention, the lover for a sign of affection, and the artist for professional approval show the persevering behavior which . . . results from only intermittent reinforcement. (pp. 78–79)

Skinner goes on to discuss the submissiveness of others as generalized reinforcement (see also Patterson, 1982; 2002). In an aggressive episode, two people use threats and possibly physical attack to control each other's behavior. Eventually, one of the combatants gives up, and this submissive behavior serves as reinforcement for the aggressive behavior of the other person. Giving up the argument often results in cessation of the attack by the aggressor, and this is reinforcement for the submissive behavior displayed by the other. Unfortunately, the contingencies of aggression and submission arrange for an indefinite escalation of conflict, which may inadvertently result in serious harm that is legally judged as assault or murder.

The contingencies of aggression may account for many instances of abuse involving children, spouses, the elderly, and individuals incarcerated in prisons and mental hospitals. To the extent that these people are dependent on the benevolence of their parents, spouses, or caretakers, they must give in to the demands of their keepers. Consider a woman who is unemployed, has few friends, and is married to a man who physically assaults her. When her husband becomes aggressive, she has little recourse other than submission. If she calls the police or tells a neighbor, she risks losing her home and income, and she may have learned that her husband will only become more angry. For these reasons, the husband's aggressive behavior is shaped to more extreme levels.

Occasionally, victims develop an emotional attachment to the people who mistreat them. This kind of affectionate behavior may be shaped as part of the aggressive episode. The contingencies could involve negative reinforcement, as when the aggressor's attack is reduced or removed by signs of affection from the victim. After some exposure to these contingencies, victims may even claim to love their abusers.

There are several steps that may be taken to reduce the incidence of victim abuse in our society. One solution involves the issue of control and countercontrol. To prevent abusive control, the victim must be able to arrange consequences that deter the actions of the aggressor. This *countercontrol* by victims is established when society provides agencies or individuals who monitor abusers and take action on behalf of the victims. Countercontrol may also involve passing laws to protect the rights of persons who are in highly dependent situations. Another possibility is to teach alternative behavior in terms of negotiation and conflict resolution. Finally, a society that supports aggression for entertainment in sports, television, and movies should not be surprised at having high levels of violence in daily life.

Tokens, Money, and Generalized Reinforcement

Other conditioned reinforcers are economic in the sense of being exchangeable for goods and services. Awards, prizes, and scholarships support an enormous range of human activity. Perhaps the most important source of economic reinforcement is money. One way to understand the reinforcing effects of money is to view it as a type of token (coins or bills) exchangeable at a later time for a variety of goods and services.

Token reinforcement has been demonstrated in chimpanzees (Fig. 10.9; see also Cowles, 1937). Chimpanzees (*Pan troglodytes*) were trained to exchange poker chips for raisins. After tokens and fruit were paired, the animals learned to select one of several patterns to get poker chips that were later exchanged for raisins. The animals collected several tokens and went to another room, where they inserted the chips in a vending machine for raisins. Because the discriminative operant (pattern selection) was maintained, the chips were by definition conditioned reinforcers.

Another study (Wolfe, 1936) also showed that chimpanzees would tolerate a delay between getting a token and exchanging it for food. The animals earned white chips, which could be inserted into a vending machine that immediately delivered grapes. Inserting the chip into the machine was shaped by successive approximation. The experimenter placed

FIG. 10.9.   *Token reinforcement and chimpanzee behavior. This photograph of the "Chimp-O-Mat" from the 1930s illustrates notable research demonstrating conditioned reinforcement. Reprinted with permission from Yerkes National Primate Research Center, Emory University.*

a token partway in the vending slot, and any push by the chimpanzee caused the chip to drop—resulting in a grape. This procedure continued until the animals started retrieving the chips and inserting them in the slot. Following this training, the animals were taught to pull a lever to get chips. At this point, access to the vending machine was delayed but the chimpanzees continued to work for tokens. Some animals even began saving their tokens much like people save money. When delays occurred after the chimpanzees had inserted the tokens into the vending machine, the reinforcing effectiveness of the tokens declined (the delay to reinforcement was increased, hence the delay reduction hypothesis was supported). This suggests that the token bridged the interval between earning and spending.

Kelleher (1956; 1958) trained chimpanzees to press a telephone key for poker chips (token) on fixed ratio (FR) schedules of reinforcement. In addition to varying the FR size, Kelleher also varied the number of poker chips collected before it was possible to exchange them for food. The results for FR schedules of token reinforcement were comparable to those obtained with food reinforcement, showing high stable rates of response. The only noteable difference between tokens and food was the occurrence of prolonged pauses at the beginning of sessions with higher FR values for token reinforcement.

Sousa and Matsuzawa (2001) explored the effectiveness of token reinforcement in maintaining chimpanzees' performance on discrimination tasks and studied the "saving" behavior of the animals. One experiment involved token reinforcement for a matching-to-sample task in which the tokens were exchanged for food by three adult female chimpanzees. Subjects' performances were maintained at constant high levels of accuracy, suggesting that the tokens were almost equivalent to food reinforcement. The results also showed the emergence of saving behavior. Chimpanzees spontaneously saved the tokens during the matching-to-sample task before exchanging them for food. The chimpanzees also learned a new symbolic discrimination task with token reinforcement. During this learning process a rarely reported phenomenon emerged: one of the subjects showed symmetry, a form of stimulus equivalence (see Chapter 12 for more on stimulus equivalence).

For people, money is a form of token reinforcement that maintains an enormous diversity and amount of behavior. A major difference between the chimpanzees' tokens and money is that money is exchangeable for many different reinforcers. For this reason, money is a **generalized conditioned reinforcer**. Most behavioral experiments involving humans have used money as reinforcement. Money is relatively independent of momentary deprivation, is easily quantified, and is exchangeable for numerous goods and services outside of the laboratory.

Schedules of monetary reinforcement have been used to assess matching (see Chapter 10) and delay reduction with humans. Belke, Pierce, and Powell (1989) created a human-operant chamber, and people were required to pick up tokens from a dispenser and exchange them for 25¢ apiece. At first, a single token was exchanged for 25¢, then two tokens for 50¢, and then four tokens for $1. By extending the delay between earning and exchanging tokens, subjects learned to collect up to 40 tokens before trading them for $10.

In this experiment, there were no instructions and pressing left or right keys was shaped by monetary reinforcement. Various reinforcement schedules were then programmed to test matching, maximizing, and delay-reduction accounts of human choice and preference. Human performance on monetary schedules of reinforcement was better described by matching and maximizing models than by the delay-reduction equation. Relative rate of monetary reinforcement was the most important determinant of behavior in this situation. (See Jackson & Hackenberg, 1996 on maximization by pigeons when tokens were substituted for food).

The applied advantage of money and tokens is that they are tangible objects that are observed easily, and their exchange value can be specified precisely. For this reason, a large amount of research has been conducted on experimental communities in which economic reinforcement is scheduled for effective patterns of behavior.

ON THE APPLIED SIDE: THE TOKEN ECONOMY

One of the most important applications of behavior analysis is based on using tokens as generalized conditioned reinforcement. Tokens are arbitrary items like poker chips, tickets, coins, checkmarks in a daily log, and stars or happy-face symbols given to students. To establish these objects as reinforcement, the applied researcher has a person exchange tokens for a variety of backup reinforcers. A child may exchange five stars for a period of free play, a selection of toys, access to drawing materials, or an opportunity to use a Lego set.

A **token economy** is a set of contingencies or a system based on token reinforcement. That is, the contingencies specify when, and under what conditions, particular forms of behavior are reinforced with tokens. It is an economy in the sense that the tokens may be exchanged for goods and services much like money is in our economy. This exchange of tokens for a variety of backup reinforcers ensures that the tokens become conditioned reinforcers.

Systems of token reinforcement have been used to improve the behavior of psychiatric patients (Ayllon & Azrin, 1968), juvenile delinquents (Fixsen, Phillips, Phillips, & Wolf, 1976), pupils in remedial classrooms (Breyer & Allen, 1975), normal children in the home (Alvord & Cheney, 1994), and medical patients who must follow a plan of treatment (Carton & Schweitzer, 1996; Dapcich-Miura & Hovell, 1979). Token economies also have been designed for alcoholics, drug addicts, prisoners, nursing-home residents, and retarded persons (see Kazdin, 1977, for a review).

One of the first token systems was designed for psychiatric patients who lived in a large mental hospital. Schaefer and Martin (1966) attempted to modify the behavior of 40 female patients who were diagnosed as long-term schizophrenics. A general characteristic of these women was that they seemed uninterested in the activities and happenings on the ward. Additionally, many of the women showed little interest in personal hygiene (i.e., they

showed a low probability of washing, grooming, brushing teeth, and so on). In general, Schaefer and Martin referred to this class of behavior as apathetic and designed a token system to increase social and physical involvement by these patients.

The women were randomly assigned to a treatment or control group. Women in the control group received tokens no matter what they did (i.e., noncontingent reinforcement). Patients in the contingent reinforcement group obtained tokens for specific classes of behavior. Tokens could be traded for a variety of privileges and luxuries. The response classes were personal hygiene, job performance, and social interaction. For example, a patient earned tokens when she spoke pleasantly to others during group therapy. A social response like "Good morning, how are you?" resulted in a ward attendant giving her a token and praising her effort. Other responses that were reinforced included personal hygiene like attractive use of cosmetics, showering, and generally maintaining a well-groomed appearance. Finally, tokens were earned for specified jobs such as wiping tables and vacuuming carpets and furniture.

Notice that the reinforcement system encouraged behavior that was incompatible with the label "apathetic." A person who is socially responsive, who is well groomed, and who carries out daily jobs is usually described as being involved with life. To implement the program, general response classes such as personal hygiene had to be specified and instances of each class, such as brushing teeth or combing hair, had to be defined. Once the behavior was well defined, ward staff were trained to identify positive instances and deliver tokens for appropriate responses.

Over a 3-month period of the study, the ward staff counted instances of involved and apathetic behavior. Responses in each class of behavior—hygiene, social interaction, and work—increased for women in the contingent-token system, but not for patients who were simply given the tokens. Responses that were successful in the token economy apparently were also effective outside the hospital. Only 14% of the patients who were discharged from the token system returned to the hospital, and this compared favorably with an average return rate of 28%.

Although Schaefer and Martin (1966) successfully maintained behavioral gains after patients were discharged, not all token systems are equally effective (see Kazdin, 1983, for a review). Programs that teach social and life skills have lower return rates than those that do not. This presumably occurs because patients taught these skills can take better care of themselves and interact more appropriately with others. Of course, these operants are valued by members of the social community who reinforce and thereby maintain this behavior.

Token economies that gradually introduce the patient to the world outside the hospital also maintain behavior better than those programs with abrupt transitions from hospital to home. A patient on a token-economy ward may successively earn day passes, overnight stays, weekend release, discharge to a group home, and eventually a return to normal living. This gradual transition to everyday life has two major effects. First, contrived reinforcement on the token system is slowly reduced or faded and, at the same time, natural consequences outside of the hospital are contacted. Second, the positive responses of patients are shifted from the relatively dense schedules of reinforcement provided by the token system to the more intermittent reinforcement of the ordinary environment.

Because of increasing budget constraints for many mental hospitals in the United States, there has been an alarming increase in the rapid discharge of psychiatric patients. Many of these individuals have been relegated to the ranks of the poor and homeless. According to our analysis of the token economy, this kind of policy is shortsighted. Programs that teach a range of useful skills and that allow for successful entry into work and community settings are more humane and economically productive in the long run. Generally, programs of behavior management and change offer alternative solutions for many social problems (Glenwick & Jason, 1980).

KEY WORDS

Backward chaining
Chain schedule of
    reinforcement
Concurrent-chains
    schedule
Conditioned reinforcement
Conditioned reinforcer
Delay-reduction hypothesis
Discriminative-stimulus
    account of conditioned
    reinforcement

Established-response method
Generalized conditioned
    reinforcement
Generalized social
    reinforcement
Heterogenous chain
    schedule
Homogeneous chain
    schedule
Information account of
    conditioned reinforcement

Mixed schedule of
    reinforcement
New-response method
Observing response
S–S account of
    conditioned
    reinforcement
Tandem schedule
Token economy
Unconditioned
    reinforcement

ON THE WEB

http://www.pri.kyoto-u.ac.jp/koudou-shinkei/shikou/chimphome/index-E.htm This is Ai, a chimpanzee who has been learning linguistic skills since 1978 at the Primate Research Institute, Kyoto University. The Web site introduces you to the study of chimpanzee intelligence, to generalized conditioned reinforcement, and to the chimps' everyday life.

http://www.behavior.org/parenting/index.cfm?page=http%3A//www.behavior.org/parenting/parenting_hometoken_blurb.cfm To learn more about using token economies in your home and about parenting go to this site at the Cambridge Center for Behavioral Studies.

http://members.tripod.com/PoPsMin/classtokenecon.html This site focuses on the use of a token economy in classrooms with attention deficit disordered (ADD) children.

http://www.polyxo.com/visualsupport/tokeneconomies.html The use of a token economy with autistic children is described at this Web site.

http://www.envmed.rochester.edu/wwwvgl/jaba_articles/2001/vollmer-34–241.pdf Go to this site to obtain a copy of an article on reinforcement contingencies and social reinforcement by Vollmer and Hackenberg (2001) in the *Journal of Applied Behavior Analysis*.

STUDY QUESTIONS

1. What is conditioned reinforcement? Give some common examples. Distinguish between unconditioned and conditioned reinforcers. (270)
2. Describe Skinner's (1938) procedure for rats that resulted in conditioned reinforcement. Summarize the new-response method and the problem with this technique for analyzing conditioned reinforcement. (271)
3. Define a chain schedule of reinforcement. Write the Mechner notation for a chain VI FR FI schedule of reinforcement. (271–272)
4. Discuss multiple functions of stimuli on chain schedules. Compare the performance of pigeons on tandem and chain fixed-interval schedules, referring to an experiment by Gollub (1958). What accounts for these performance differences? (272)
5. Distinguish between homogeneous and heterogeneous chains. Give an everyday example of a heterogeneous chain. Why do the conditioned reinforcers remain

effective in such a chain? How much detail should be given when describing human performance on a chain schedule? (273)

6. **FOCUS ON**: What is backward chaining? When is backward chaining most useful in training human behavior? Describe backward chaining in the performance of making a bed. How can backward chaining be applied to playing golf? Why is backward chaining effective in training complex and skillful athletic performance? (274)

7. Describe the relationship between frequency of unconditioned reinforcement and strength of conditioned reinforcement. How do variability of unconditioned reinforcement, establishing operations, and delay to unconditioned reinforcement affect conditioned reinforcement? (275)

8. Be able to describe the established-response method and how it differs from the new-response technique. (276)

9. Outline the S–S account of conditioned reinforcement. What is the alternative operant account? Currently, is there a definitive test? Why or why not? (276)

10. State the information hypothesis of conditioned reinforcement. Summarize Egger and Miller's (1962) experiment and how it relates to this hypothesis. (277)

11. What does the information hypothesis imply about good and bad news? Describe Wyckoff's (1969) experimental procedures and results. What finding suggested that Wyckoff's (1969) pigeons may only respond for good news? (278)

12. How did Dinsmoor et al. (1972) clarify the conditioned-reinforcement effectiveness of good and bad news? (279)

13. State how the conditioned-reinforcement value of good news (but not bad) is shown with aversive procedures. Give a common example of the good and bad news effect. Be able to state the general principle underlying the good and bad news effect. (279)

14. State Fantino's (1969a) delay-reduction hypothesis. What procedures do contemporary researchers use to evaluate conditioned reinforcement and delay reduction? (280)

15. In Mechner notation, write two separate chain schedules (VI 20 s VI 10 s; VI 20 s VI 60 s). Now write a concurrent-chains schedule using the same basic schedules. (280–281)

16. How is the concurrent-chains procedure used to study delay reduction? What are the two functions of stimuli correlated with the onset of the terminal-link schedule? What is the measure of relative effectiveness of the conditioned reinforcers? (282)

17. Be able to talk about a businessperson calling Delta and American Airlines as an example of delay reduction and conditioned reinforcement. (282)

18. **ADVANCED ISSUE**: In the Delta and American example, how is the average time in the initial link (time-to-hold message) calculated? Calculate the average time in the terminal links in terms of the example. Now obtain the average total time to terminal reinforcement. Obtain the delay reduction at Delta and the same at American. Write the relative delay reduction for Delta and relate this to the distribution of dialing the respective airlines. (283)

19. **ADVANCED ISSUE**: Write a general equation for delay reduction and know what each term means. Show how Fantino (1969a) varied the initial-link schedules to test the delay-reduction hypothesis. What does proportional matching predict for Fantino's experiment? (284)

20. Define generalized conditioned reinforcement. How is a generalized reinforcer relatively independent of the momentary condition of an organism? (285)

21. Discuss generalized reinforcement and social contingencies involving attention, approval, and affection. (286)
22. Analyze an aggressive episode in terms of submissiveness of the victim (generalized reinforcement) and cessation of threats and physical injury by the attacker. How do these contingencies extend to other cases of abuse in our society? What can be done? (287)
23. Discuss token reinforcement with chimpanzees. How does token reinforcement relate to human behavior and money? What is the applied advantage of money and tokens? (287)
24. What is a token economy? Describe some uses of token systems. Outline the modification program used by Schaefer and Martin (1966) and the major findings. How can the behavioral gains of a token economy be maintained in everyday life? (289)

BRIEF QUIZ

1. In the laboratory, when a clicking sound is followed by food, the clicking sound
   (a) takes on a conditioned reinforcement function
   (b) will support an operant that produces it
   (c) can become an enduring reinforcing stimulus
   (d) all of the above
2. Backward chaining involves
   (a) teaching the initial component or link first
   (b) teaching the final component or link first
   (c) teaching from the middle to the last component or link
   (d) teaching the final component or link in random order
3. On a chain schedule of reinforcement, the longer the delay between the SD and unconditioned reinforcement
   (a) the greater the stimulus control
   (b) the less effective the SD as a conditioned reinforcer
   (c) the more the value of the unconditioned reinforcer
   (d) the less the value of the unconditioned reinforcer
4. In terms of good news and bad news, research suggests that
   (a) stimuli correlated with positive or negative reinforcement maintain an observing response
   (b) stimuli correlated with punishment and extinction maintain an observing response
   (c) stimuli correlated with negative reinforcment and punishment maintain an observing response
   (d) stimuli correlated with positive reinforcement and extinction maintain an observing response
5. The behavior analysis of booking a flight on Delta or American airlines illustrates
   (a) how behavior is distributed on concurrent schedules of reinforcement
   (b) how behavior is distributed on concurrent-chains schedules of reinforcement
   (c) the role of delay reduction in choice situations
   (d) both (b) and (c)
6. According to Skinner (1953), a generalized conditioned reinforcer
   (a) is extremely useful because it can be carried around and made contingent on behaivor

(b) is not very useful because it relies on the momentary deprivation/satiation of the organism

(c) is produced by pairing a conditioned reinforcer with more than one unconditioned reinforcer

(d) is produced by backward chaining of the unconditioned and conditioned reinforcers

7. Attention from other people is usually reinforcing for children because
   (a) attention has preceded a variety of reinforcements from people
   (b) attention is needed for children to develop into emotionally healthy people
   (c) attention is around children all the time so they get used to it
   (d) attention is a fundamental necessity of life that children thrive on

8. Victims sometimes become emotionally attached to people who mistreat them. How could this happen?
   (a) punishment of affectionate behavior of the victim
   (b) negative reinforcement of affectionate behavior of the victim
   (c) longing for a real emotional attachment to the parents
   (d) a misplaced sexual drive that is directed at the abuser

9. The research on token reinforcement and chimpanzees shows that
   (a) token and food reinforcement are similar in maintaining behavior
   (b) tokens can bridge the interval between earning and spending
   (c) tokens reinforcement can maintain and train performance on discrimination tasks
   (d) all of the above

10. Systems of token reinforcement in humans have been used to improve behavior of
   (a) psychiatric patients
   (b) juvenile delinquents
   (c) normal children
   (d) medical patients
   (e) all of the above

Answers to brief quiz (*page*): d(270); b(274); b(276); a(279); d(282); c(286); a(286); b(287); d(287); e(289)

CHAPTER 11
Correspondence Relations: Imitation and Rule-Governed Behavior

IN THIS CHAPTER

1. Find out about contingencies of correspondence and the regulation of human behavior.
2. Learn about spontaneous imitation in natural settings and the laboratory.
3. Investigate the research on human infant imitation.
4. Inquire about generalized imitation and observational learning.
5. Distinguish between rule-governed and contingency-shaped behavior.
6. Learn about instructions and sensitivity of behavior to contingencies.

People often do what others do. A child who observes his brother raid the cookie jar may engage in similar behavior—at least until they are both caught by their parent. Adults sometimes watch their teenagers' dancing and repeat aspects of these performances at a neighborhood party. Both of these examples involve **correspondence relations** between the demonstrated behavior and the replicated performance. Technically, we may say that the behavior of one person sets the occasion for an equivalent response by the other.

There are other correspondence relations established by our culture. People look for and reinforce the correspondence between saying and doing (e.g., Lovaas, 1961; Matthews, Shimoff, & Catania, 1987; Paniagua & Baer, 1982; Risley & Hart, 1968; also see Lattal & Doepke, 2001 on correspondence as complex conditional discrimination). When a child promises to clean her room and actually does so, parents are pleased; failure to follow through on the promise may make the parents angry. A large part of socialization involves arranging social reinforcement for correspondence between what is said and what is done (see Luciano, Herruzo, & Barnes-Holmes, 2001 on training generalized correspondence in children). By the time a person is an adult, people expect consistency between spoken words and later performance. A minister who preaches moral conduct and lives a moral life is valued; when moral words and moral deeds do not match, people become upset and act to correct the inconsistency. In such instances, what is said does not correspond adequately with what is done.

Consistency also is important when people report on private internal events. In these cases, the correspondence is between the internal stimulation and the report. The social community establishes accurate description of private stimulation (see Chapter 1 on "Report of Feelings"). Successful training of such reports involves reinforcing self-descriptive statements in the presence of presumed private events. Because public cues and private events usually go together, people use external cures to train correspondence between reports and internal stimulation (see also Chapter 12; and see "Focus on Research: Reports of Internal Events by Pigeons"). When a child says she is hurt in the presence of clear external signs of physical damage and the private stimulation of pain are well correlated, the child can eventually report internal happenings solely on the basis of the private stimulation (e.g., the occurrence of pain).

A problem of privacy also is faced when the community must establish consistency between private social acts and the report of those actions. In this case, correspondence is between doing and saying (Baer & Detrich, 1990; Deacon & Konarski, 1987; Lubinski & Thompson, 1987). During socialization children are asked to report on their behavior in a variety of situations. A child who returns her empty plate to the kitchen may be asked if she ate her carrots. The response, "Yes, I ate every last one" can be verified and reinforced for accuracy (see Paniagua, 1989, on lying in children as "do-then-report" correspondence).

This repertoire of doing and saying sometimes has serious implications in adult life. When an employee describes sexual harassment in the workplace, there is some attempt to check on the correspondence between what is said and the actual happenings. This monitoring of doing and saying by the community is necessary to maintain accuracy. The harassed person is questioned for explicit details, the accused is asked to give his or her story, and reports by other people are used to ensure exactness of the reported events. Based on this inquiry, the community ensures reliable reports by victims and the punishment of sexual misconduct. Many aspects of legal trials involve procedures to check on and maintain correspondence between actions and recall.

There is evidence that expressing one's feelings, saying and doing, and recalling actions and events are aspects of verbal behavior (Skinner, 1957). One important function of verbal behavior involves formulating and following rules, maxims, or instructions (Skinner, 1969). Rules may be analyzed as verbal stimuli that alter the responses of a listener (Galizio, 1979). A doctor may state that "too much cholesterol increases the risk of heart attack," and the patient may follow this advice by reducing or eliminating foods with high cholesterol. Advice and other instructions regulate behavior because such rules usually guide effective action (i.e., health improves by selecting low-cholesterol foods). In this chapter, we will analyze the listener's actions as rule-governed behavior. The speaker's behavior in stating rules or describing contingencies is examined as verbal behavior in the next chapter of this book (see Chapter 12).

As you can see, correspondence relations are fundamental to an analysis of human behavior. This chapter emphasizes two types of correspondence contingencies—rule-governed behavior and observational learning. The effects of rules and instructions have already been mentioned, and further analysis is given at the end of this chapter.

Initially, this chapter describes the process of observational learning. Learning by observation involves doing what others do—in which the performance of an observer or learner is regulated by the actions of a model. Although modeling can produce a variety of effects (e.g., social facilitation, stimulus enhancement, and so on), **imitation** requires that the learner emit a novel response that could only occur by observing a model emit a similar response (Thorpe, 1963). This kind of social learning may arise from an innate capacity for imitation; there is some evidence that humans and other social animals show spontaneous imitation (suggesting that doing what others do may have an evolutionary basis). More complex forms of observational learning appear to build on this basic repertoire.

Correspondence and Observational Learning

Although doing what others do involves a large amount of social learning, this type of correspondence may have a biological basis. At the beginning of the 20th century, psychologists suggested that social organisms have an innate tendency to imitate the actions they see others perform (Baldwin, 1906; James, 1890; McDougall, 1908; Morgan, 1894). This

assumption was largely based on observations that young infants imitate the actions of an adult. McDougall (1908) indicated that, as early as 4 months of age, his child would stick out his tongue when an adult did the same.

Of course, 4-month-old infants already have a considerable history of interaction with their parents, and the observed behavior may simply be attributable to social conditioning. That is, people may smile and laugh when a young child imitates some adult movement. Presumably, these social consequences strengthen imitation by the child. Although social conditioning is a possibility, recent research with newborn infants and animals suggests that innate or spontaneous imitation occurs without reinforcement.

Spontaneous Imitation in Animals and Humans

Innate or **spontaneous imitation** is based on evolution and natural selection (a characteristic of the species) rather than experiences during the lifetime of the individual. That is, imitation of others may be an important form of adaptive behavior (Davis, 1973; Hutchinson, 1981; Millard, 1979; Porter, 1910; Thorpe, 1963). This behavior may range from a few instinctive actions to a more generalized set of responses, depending on the species. In addition, imitation may occur only when the model is present or it may be delayed for some time after the model has been removed. Such **delayed imitation** is often taken as a more complex form since it involves remembering the modeled stimulus, rather than direct stimulus control (see Courage & Howe, 2002, pp. 257–259 on cognitive development and delayed imitation).

There are ethnological reports of imitation by animals and birds (e.g., Alcock, 1969; Fisher & Hinde, 1949; Kawai, 1965). Fisher and Hinde (1949) described how birds in a southern English village obtained milk by spearing the foil tops of bottles left on doorsteps. Eventually, this behavior spread to several species of birds throughout England, Wales, Scotland, and Ireland. It stretches the imagination to suppose that so many birds learned the same response on their own. One conclusion is that the behavior was acquired and transmitted through observation and imitation (see also Dawson & Foss, 1965, for imitation of removal of container caps by budgerigars).

Japanese monkeys also seem to pass on novel behavior by observational learning. A report by Kawai (1965) describes the social transmission of an innovative way of feeding. The researchers had spread grains of wheat on a sandy beach that the troop often visited. Each monkey picked the grains from the sand and ate them one at a time. Then a young monkey learned to separate the sand from the wheat more efficiently by tossing a handful of mixture into the water. When this happened, the sand sank to the bottom and the wheat floated to the top. Using this technique, the monkey obtained more wheat with less effort. Other members of the troop observed this behavior and were soon imitating this new method of feeding. Kawai indicated that observational learning transmitted many other novel behaviors, including washing the sand off of sweet potatoes and swimming in the ocean (see Ball, 1938, and Breuggeman, 1973, for imitation by rhesus monkeys; Bering, Bjorklund, & Ragan, 2000, for delayed imitation by rhesus monkeys and orangutans; and Custance, Whiten, Sambrook, & Galdikas, 2001, for a failure to observe imitation in orangutans).

Although it seems likely that some birds, monkeys and a few other species (e.g., African gray parrots, Moore, 1992; dolphins, Taylor & Saayman, 1973) can imitate the novel responses of a model, these naturalistic studies are not sufficient to establish spontaneous imitation or to rule out alternative processes like social facilitation (Zajonc, 1965), stimulus enhancement, or copying (Galef, 1988, pp. 15–16; Galef, 1990). Social animals have many experiences that may contribute to doing what others do. Therefore, it is not possible to be sure that the imitation was spontaneous (based on species history) rather than acquired

(based on social learning). Only laboratory experiments can distinguish between acquired and spontaneous imitation.

Imitation in the Laboratory

Thorndike (1911) conducted the earliest experiment on spontaneous imitation. The experiment involved getting out of a puzzle box by observing the successful performance of others. A well-trained cat was placed in the box and an inexperienced cat was allowed to watch the performance from an adjacent cage. The experiment was a dismal failure. The cat that observed the successful performance was no better at getting out of the box than a naïve animal. There was no improvement in learning regardless of the number of observational trials. Thorndike obtained similar negative results with chicks, dogs, and monkeys and concluded that animals cannot learn by observation.

This conclusion stalled experiments on animal imitation for some time. Then Herbert and Harsh (1944) reported that cats could learn to solve manipulative problems by observation if they observed mistakes as well as successful performances. Cats that observed both mistakes and correct responses by a model did better at problems than ones that only watched skillful performance. When many alternative responses are available, seeing what does and does not work is necessary for observational learning (see Biederman & Vanayan, 1988, for a similar effect with pigeons).

At about this same time, Warden and his associates (Warden, Fjeld, & Koch, 1940; Warden & Jackson, 1935) showed imitation in rhesus monkeys. They trained monkeys by reinforcement to solve puzzles that opened doors to reveal hidden raisins. When this performance was well established, a naïve monkey watched a trained animal obtain raisins. Observation of the model produced instantaneous solutions on 76% of the test trials. However, only the first instance of imitation could be described as spontaneous since the discovery of the raisin would reinforce this behavior and increase its likelihood.

Spontaneous and Delayed Imitation in Pigeons

In fact, it is difficult to find an experiment that reliably demonstrates spontaneous imitation. This is because reinforcement of the observer's behavior always confounds the results. Based on this realization, Robert Epstein (Fig. 11.1) designed an experiment to show spontaneous imitation with pigeons (Epstein, 1984). The experimental procedures ensured that the observer was naïve, and there were no programmed sources of reinforcement for imitative responses.

Figure 11.2 shows the subjects and apparatus that Epstein used. Some birds served as models, and others were observers. Observers had never been in a laboratory experiment and none had ever eaten from a laboratory feeder. The model and observer pigeons could see one another through a clear partition that separated the chamber into two compartments, left and right. Each side had exactly the same configuration. Models were always placed in the left side of the chamber, where a feeder was filled with food. Observers were placed in the right side of the chamber, where the feeder never contained food. The modeled performance in various conditions was pecking or pushing a ball, pulling on a rope, or pecking a key. All models were trained by operant conditioning to emit the requisite performance for food reinforcement.

There were five conditions in the first experiment. During adaptation, a naïve-observer bird was placed in the right side of the chamber. One object, a ping-pong ball, rope, or key, was situated in the left compartment but not available to the bird in the right chamber. After three sessions, the same object was added to the right side and the naïve bird was placed

FIG. 11.1. *Robert Epstein. Reprinted with permission.*

alone in the chamber for three sessions of baseline. Next, the object was removed from the right chamber and the model bird was added. During exposure and adaptation to the model, the model engaged in the reinforced performance of pecking the ball, pulling the rope, or pecking the key, and the observer was exposed to this performance without the object for another three sessions. Following this phase, Epstein conducted a test for model-present imitation; he added the object to the observer's chamber while the model continued to demonstrate the performance. If the observer emitted the designated response at a higher rate than during baseline, this was evidence of direct spontaneous imitation. Finally, Epstein designed a test for model-absent imitation. The object remained present but the model was removed. If the observer responded to the object at a higher level than baseline, this was evidence of delayed spontaneous imitation.

Of the four observer pigeons tested, all showed more responses (key, ball, or rope) with the model present than during baseline. Two of the birds demonstrated strong spontaneous
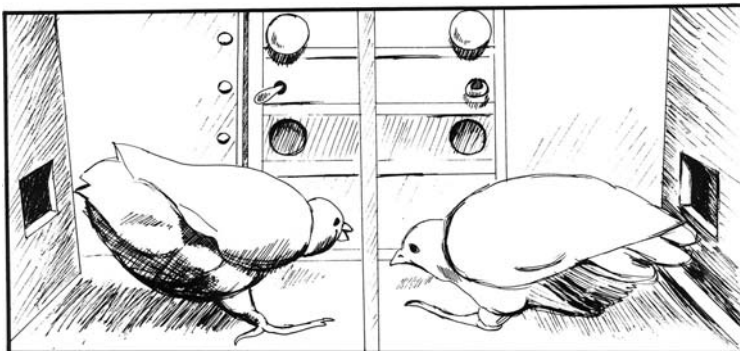
FIG. 11.2. *Subjects and apparatus used by Robert Epstein to study spontaneous imitation by pigeons. Adapted from "Spontaneous and Deferred Imitation in the Pigeon," by R. Epstein, 1984,* Behavioral Processes, 9, *pp. 347–352.*

imitation, but the effect was weaker for the other two pigeons. Birds that strongly imitated the model were found to continue this imitation even when the model was removed (i.e., model-absent imitation). The data suggested that delayed-spontaneous imitation can occur in laboratory pigeons, but the results were inconsistent over subjects.

Epstein (1984) ran a second experiment that specifically focused on delayed-spontaneous imitation. In this experiment, he used only "peck the ball" as the imitative response. The same conditions were used as in the first experiment, but the model-present phase was omitted. Thus, the birds never were able to match their responses immediately to those of the model. Results for three new birds were clear. In each case, pecking the ball was higher after exposure to and removal of the model than during baseline. Spontaneous imitation occurred even after 24 hr had elapsed between watching the model and the test for imitation.

Analysis of Epstein's Experiments

These experiments on direct and delayed spontaneous imitation are important. Experimental procedures ensured that the occurrence of imitation was not attributable to previous experience or current reinforcement. It therefore appears that spontaneous imitation is a real effect and is a form of phylogenetic behavior. That is, imitative behavior occurs because it has been important to the survival and reproduction of the species (i.e., contingencies of survival). In other words, organisms that imitated others were more likely to find food, avoid predators, and eventually produce offspring.

The phylogenetic basis of spontaneous imitation is a reasonable hypothesis. However, as Epstein notes, at least three aspects of the experiments suggest that some environmental experience is also necessary. The birds were raised in a colony and may have had social interactions that contributed to imitative performance. Pigeons who are isolated from birth may show smaller effects of exposure to a model (May & Dorr, 1968). In addition, the effects of food reinforcement may have contributed to the results. Although observers were never directly reinforced with food for imitation, they did see the models eat from the feeder. In fact, Epstein remarked that occasionally the naïve bird would thrust its head into the feeder hole when the model did, even though it did not receive food. Finally, only one object was present in the right and left sides of the chamber. If three objects were available, would the observer peck or pull the one the model did, without training? Each of these aspects opposes a strong conclusion about the biological basis of spontaneous imitation in Epstein's experiments.

There are other results, however, that point to an evolutionary basis for such behavior. The fact that pigeons showed imitation after a substantial delay is noteworthy. In discrimination experiments, birds often have trouble remembering events delayed by a few seconds. However, the birds in Epstein's second experiment showed imitation 24 hours after the model had pecked the ball. The extended retention of such behavior is in accord with a biological account, suggesting the preparedness of these animals to do what others have done.

The experimental research by Epstein (1984) on imitation and delayed imitation in pigeons remains controversial (imitation in rats is also in dispute due to possible odor cues on the manipulandum: Mitchell, Heyes, Gardner, & Dawson, 1999; see evidence against odor cues by Ray, Gardner, & Heyes, 2000). Thus, Pear (2001, p. 96) argues on the basis of related research that stimulus enhancement, or pairing of a conspecific (member of a species) with the ping-pong ball, accounts for the apparent direct and delayed imitation by pigeons (recall, however, that Epstein used a ball, rope, and key). On the other hand, recent research using a two-action method of pecking or pressing a treadle supports Epstein's claim of spontaneous imitation by pigeons (Kaiser, Zentall, & Galef, 1997; Zentall, Sutton, &

Sherburne, 1996). Although there is no further research evidence of delayed imitation by pigeons, new evidence indicates that pigeons can imitate a complex conditional discrimination (Dorrance, 2001), suggesting that delayed imitation is a possible interpretation of Epstein's results.

Spontaneous Imitation by Human Infants

There is evidence that spontaneous imitation occurs in human infants, almost from the moment of birth. Meltzoff and Moore (1977) were the first to report that 12- to 21-day-old infants can imitate the facial and hand movements of adult models. In these experiments, the imitative responses were tongue protrusion, mouth opening, lip protrusion, and sequential finger movement. The infants' facial gestures and modeled stimuli are illustrated in Figure 11.3.

Experiment 1 used three male and three female infants who ranged in age from 12 to 17 days. The experimenter presented a passive face for 90 s to the infant. Each infant was then shown four gestures (i.e., the modeled stimulus) in random order. The modeled stimulus was presented four times in a 15-s presentation period. An imitation-test period followed in which the experimenter resumed a passive face and the infant was monitored for imitative responses. Each new gesture was followed by 70 s of passive face.

The researchers made a videotape of the infants' behavior, and the segments were scored in random order by trained adult judges. For each segment, the judges were to order the four gestures from most likely to least likely in terms of imitation of the modeled stimulus. These judgments were collapsed to yes or no ratings of whether a particular gesture was the imitative response. In all cases, more yes judgments occurred when the gesture was imitative than when it was not.

FIG. 11.3. *Infants' facial gestures and modeled stimuli. From "Imitation of Facial and Manual Gestures by Human Neonates," by A. N. Meltzoff and M. K. Moore, 1977,* Science, 198, *pp. 75–78. Copyright 1977, the American Association for the Advancement of Science. Reprinted with permission.*
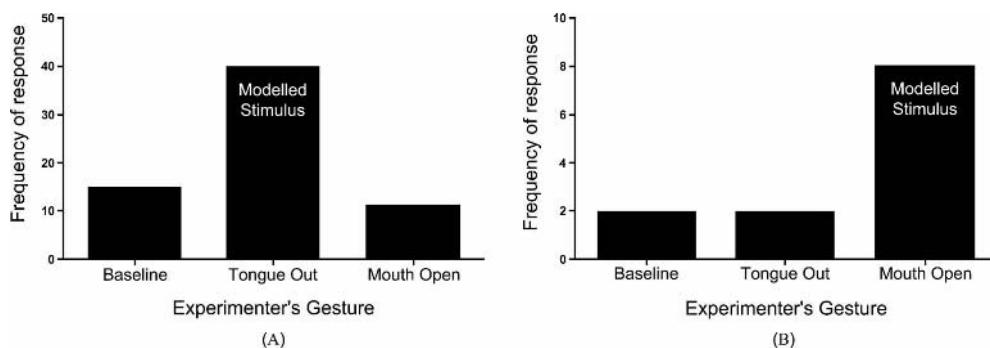
FIG. 11.4.   *Frequency of response during baseline and after exposure to the experimenter's gesture. In panel A the modeled stimulus is tongue out and the frequency response of tongue out responses by infants increases relative to baseline and the control response of mouth open. When the modeled stimulus is mouth open (panel B), the frequency of mouth open responses by the infant increases relative to the control conditions. Adapted from "Imitation of Facial and Manual Gestures by Human Neonates," by A. N. Meltzoff and M. K. Moore, 1977,* Science, 198, *pp. 75–78.*

Meltzoff and Moore (1977) designed a second experiment to correct some procedural problems with the first study. Six male and six female infants between 16 and 21 days old were used as subjects. The experiment began with the researcher inserting a pacifier into the infant's mouth and presenting a passive face for 30 s. A baseline period of 150 s followed in which the pacifier was removed, but the passive face continued to be presented. Next, the pacifier was reinserted in the infant's mouth and the researcher presented one of two gestures, mouth opening or lip protrusion. The modeled stimulus was presented until the infant had watched it for 15 seconds. The experimenter then stopped gesturing and resumed a passive face. At this point, the pacifier was removed and a 150-s response period or imitation test began, during which time the researcher maintained a passive face. Again, the pacifier was reinserted and the second gesture was presented in the same fashion.

The videotapes were scored in random order in terms of the frequency of tongue protrusion and mouth opening. Figure 11.4 shows the frequency of response during baseline and after exposure to the experimenter's gesture. When tongue protrusions were the modeled stimulus, the infant produced this response more frequently than during baseline. On the other hand, when mouth openings were the modeled stimulus, the infant frequently produced this response during the test period, but not tongue protrusions. These results suggest that babies are capable of spontaneous imitation of facial gestures (see Kuhl & Meltzoff, 1996, for imitation of vocal speech sounds).

In subsequent experiments, Meltzoff and Moore (1983) showed imitation of mouth opening and tongue protrusions in newborns that were 0.7 to 71 hr old. These results are in accord with Field, Woodson, Greenberg, and Cohen (1982), who reported imitation of mouth opening, mouth widening, and lip protrusion in infants who averaged 36 hr in age (see also Jacobson, 1979).

Difficulties with Infant Imitation Research

The results of Meltzoff and Moore's experiments remain controversial (for reviews, see Anisfeld, 1996; Bjorklund, 1987). Hayes and Watson (1981) were unable to produce infant imitation despite careful attempts to follow Meltzoff and Moore's (1977) procedures. In

their second experiment, Hayes and Watson found that the pacifier could evoke mouth movements and that this, rather than the experimenter's presentation of the modeled gesture, may have produced the responses. If this is the case, infant imitation may simply be an artifact of the experimental procedures. Furthermore, Jacobson (1979) found that the imitative responses of infants could be elicited by nonspecific events. For example, tongue protrusion occurred when a pen was moved toward the infant's face (see Anisfeld, 1996, on infant behavior and innate releasers; also Provine, 1989 on fixed-action patterns).

Other problems concern measurement, restricted range of responses, and infant attention to the modeled stimulus. Meltzoff and Moore (1977) noted that infants' responses are not discrete or well formed each time they occur. This means that the response class is not clearly defined and it is therefore difficult to obtain a reliable measure. Because the response class is unclear, coders who observe the modeled gesture may "see" the imitative response more frequently than other response forms (see Ullstadius, 2000, on variability in judgment of infant imitation). Additionally, there are few experimentally useful infant behaviors for imitation research (Meltzoff & Moore, 1983), and these responses may have several determinants. Thus, facial movements may be determined by general arousal, be elicited by nonspecific events, or be imitations of a model. Finally, it is difficult to keep the infant focused on the model. Because of this, researchers wait until the infant is "ready" before presenting the modeled stimulus. If experimenters match the model stimulus to infants' behavior, it may be that they are generating correspondence as an artifact (see also Jones, 1996, for oral exploration as an artifact). In other words, the experimenter accidentally imitates the infant instead of the infant imitating the experimenter's gesture (Field et al., 1982; Hayes & Watson, 1981; Jacobson, 1979).

Delayed Imitation by Human Infants

In 1988, Meltzoff reported on delayed imitation in 14-month-old infants (Meltzoff, 1988b). These infants were exposed to six modeled actions using different objects (e.g., an adult bending over and touching his or her head to an orange panel, causing a light to flash). One of the six actions had a zero probability of occurrence in spontaneous play. In the delayed imitation condition, infants observed the modeled behavior but were not permitted to touch the objects, thereby preventing direct imitation of the model. Following a delay of 1 week, infants returned to the experimental setting and their imitation of the model's actions was scored. Infants in the delayed imitation condition emitted more target actions than infants in control groups who were not exposed to the modeled actions. There was also evidence for delayed imitation of the novel action even though the infants had never directly imitated this behavior at the time it was presented, a finding replicated by Barr and Hayne (1996).

A series of studies by Meltzoff (1988a, 1988b, 1988c) indicate that infants ranging in age from 9 to 24 months will imitate significantly more modeled actions than a control group over delays ranging from 24 hr in the youngest infants to 4 months in the oldest infants. Additional research indicates that 14-month-old infants will show delayed imitation of behavior modeled on television after a 24-hr delay. In the same study, the researchers found delayed imitation by infants of behavior modeled by an "expert" toddler performing a novel response after a 48-hr delay and a change in context from the experimental situation to the home setting (Hanna & Meltzoff, 1993). The basic findings of the Meltzoff group have been replicated with 6- to 30-month old infants by other researchers (see Courage & Howe, 2002, for a review).

Analysis of Spontaneous and Delayed Imitation by Infants

Although spontaneous imitation by newborn infants is still open to question (as is the research with pigeons), the evidence is mounting that this is true imitation and not merely an artifact of experimental procedures or a more simple process such as innate releasers of fixed action patterns.

Spontaneous imitation in human newborns involves the infant observing a modeled gesture and responding with a set of muscle movements that correspond to the visual stimulus. The correspondence between the modeled stimulus and the form of response is a remarkable achievement because the infant is unable to see its own face when it reproduces the facial gestures of the adult model. Meltzoff and Moore (1999) refer to this process as "active intermodal mapping," where infants can monitor their facial movements through proprioception and compare this felt activity to what they see. At the present time, it is not possible to provide a detailed evolutionary account of the contingencies of survival and natural selection that favored active intermodal mapping and spontaneous imitation (see Meltzoff, 1999, for a speculative account).

Both pigeons and humans seem to engage in spontaneous imitation. The appearance of similar behavior does not necessarily imply identical functions. That is, the evolution of spontaneous imitation in pigeons, if real, probably resulted from biological contingencies different from those that led to this behavior in humans. For example, spontaneous imitation may be related to care taking in humans and to food gathering in birds. Only a detailed evolutionary analysis of behavior will provide an account that may be tested. Even with such experiments, it will be difficult to be certain about the adaptive advantage of spontaneous imitation for different species.

Although imitation by infants may have biological origins, later imitation is likely attributable to reinforcement and other ontogenetic experiences. Skinner (1984b, p. 220) noted that only the first instance of any behavior is entirely attributable to genetic history. Thus, delayed imitation by older human infants is probably not as much related to biology as to environmental experiences. Even so, there is no behavioral evidence showing what reinforcement history could account for delayed imitation by 6-week-old infants. Generalized imitation can be established by reinforcement, but no one has yet shown this in 6-week-old infants (see the section on generalized imitation in this chapter). Another aspect of delayed imitation by young infants is that they do not have to emit the novel actions of the model during the initial demonstration. That is, they merely observe the modeled stimulus and later show imitation in the absence of the model. Again, it is possible to provide an account of delayed imitation based on generalized imitation (see below), but whether this account can extend to very young infants is unknown. A good bet is that delayed imitation involves a capacity to reproduce the modeled actions in the absence of the model as well as a reinforcement history that substantially builds on this biological capacity.

Operant and Generalized Imitation

It is possible to train imitation as an operant in a social contingency of reinforcement. The discriminative stimulus is the behavior of the model (S^D_{model}), the operant is a response that matches the modeled stimulus (R_{match}), and reinforcement is verbal praise (S^r_{social}). Matching the model is reinforced, while noncorrespondent responses are extinguished. These social contingencies are similar to the discrimination experiments involving matching to sample for primary reinforcement (see Chapter 8).

In fact, Miller and Dollard (1941) proposed that observational learning was simply a special case of operant discrimination. If imitation is reinforced and nonimitation is extinguished, imitation of the model will increase. On the other hand, nonimitation will

occur if imitation is extinguished and nonimitation is reinforced. In one study, Miller and Dollard (1941) showed that children who were reinforced for imitation of a leader repeated these actions more than children who did not receive reinforcement. This kind of leader–follower behavior has also been reported for rats and other animals (Hake, Donaldson, & Hyten, 1983).

Although **operant imitation** provides a straightforward account of observational learning, Bandura (1969) noted that the operant account may be limited to situations in which the observer sees the model, an imitative response immediately occurs, and reinforcement follows. In everyday life, there are occasions when imitation does not conform to this sequence. For example, a young child is seated in front of a television set watching *Sesame Street*, and she observes Kermit the Frog sing "It's not easy being green" for the first time. After watching Kermit's performance, the child turns off the television and goes to help her parent in the kitchen. The next day, the girl begins to sing Kermit's song. The child's performance approximates the puppet's song; although she may not remember every word, she has the basic tune. Notice that the girl has never before performed this sequence of responses. Because of this, reinforcement could not have strengthened her performance. Also, the child's imitative sequence occurred in the absence of the model; Kermit was not present when she imitated him. Finally, the girl's imitative performance was delayed; she sang the song the next day, not immediately after Kermit's demonstration.

The Kermit the Frog song is typical of observational learning in everyday life, but it seems to defy an S^D: R → S^r interpretation. The imitative response is novel and reinforcement for the song is missing. In addition, the girl sings the song 1 day later with the model or S^D absent. Finally, Bandura (1969) noted that there is no account of the long delay between modeled performance and later imitation.

Although Bandura (1969, 1977, 1986) has argued against an operant account based on these difficulties, Donald Baer (see Fig. 11.5) and his associates provided a behavior analysis of imitation that handles each of the apparent challenges to the operant paradigm (Baer, Peterson, & Sherman, 1967; Baer & Sherman, 1964). The approach is called **generalized imitation** and is based on operant principles of discrimination and generalization (see Glossary for complete definition).

The procedures of generalized imitation begin with simple reinforcement of correspondence between the modeled performance (S^D model) and the imitative operant (R_{match}). The contingency requires the observer to perform the same action as the model.

FIG. 11.5. *Donald Baer. Reprinted with permission.*
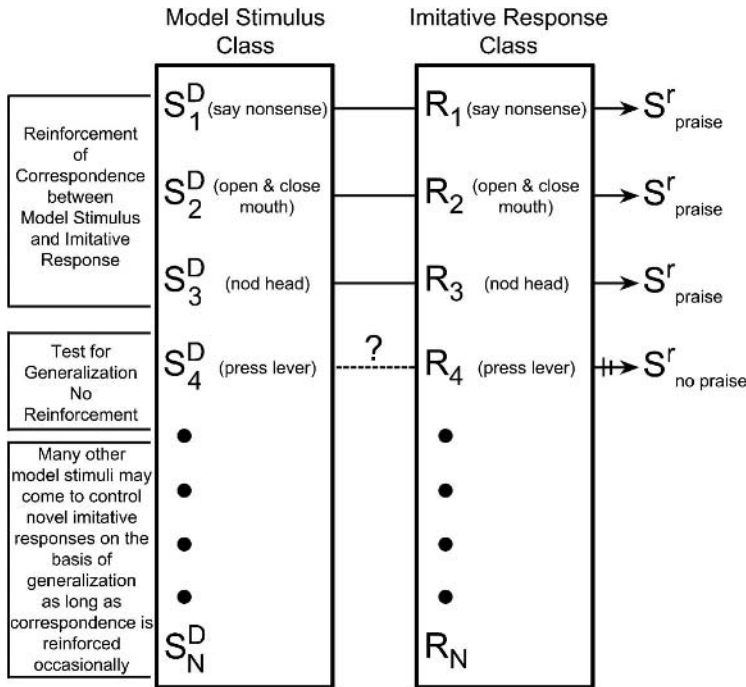
FIG. 11.6. *Discrimination procedures used by Baer and Sherman to establish generalized imitation. After several imitative responses are trained, a test for generalization is given without reinforcement. Generalized stimulus (model) and response (imitation) classes eventually are formed on the basis of training the model-imitation exemplars. Based on a description of the contingencies in "Reinforcement Control of Generalized Imitation in Young Children," by D. M. Baer and J. A. Sherman, 1964,* Journal of Experimental Child Psychology, 1, *pp. 37–49.*

Reinforcement increases imitative behavior, while extinction makes it decrease. If a child is reinforced with praise for imitation of nonsense syllables by a puppet, this response will increase. When praise is withheld, imitation of the puppet declines (Baer & Sherman, 1964).

The actual discrimination procedures are shown in Figure 11.6 and involve several modeled stimuli (S^Ds) and multiple operants (R_{match}). The puppet's head nodding is an S^D for the child to nod her head and an S^Δ for saying nonsense syllables or opening and closing her mouth. When the puppet opens and closes its mouth, this is an S^D for similar behavior by the child and an S^Δ for the other two responses. In each case, what the model does sets the occasion for reinforcement of a similar response by the child; all other responses are extinguished. This training results in a stimulus class of modeled actions and an imitative response class. The child now imitates whichever of the three responses that the model performs.

The next step is to test for generalization of the stimulus and response classes. Baer and Sherman (1964) showed that a new-modeled stimulus would set the occasion for a novel imitative response, without any further reinforcement. If the puppet began pressing a lever, the child also imitated this performance even though this response was never reinforced with praise. Thus, generalized imitation accounted for the appearance of novel imitative acts in children—even when these responses were never reinforced.

What about the absence of the discriminative stimulus and long delays? It is important to note that all instances of modeling and imitation involve the absence of the S^D

before the imitative response occurs. That is, the model demonstrates the action (S^D presented), and after the demonstration (S^D removed), the imitative response is emitted. A contingency may be established that requires a delay of some time between the presentation of the discriminative stimulus and the imitative response. This is the same as when a pigeon pecks a key that matches the sample, but reinforcement depends on delaying the matching response by a few seconds. The delay between the offset of the sample stimulus and the occurrence of the matching response may be lengthened by successive approximation. Eventually, the pigeon may be accurate even after 20 seconds without seeing the sample.

Similarly, children may learn to delay their imitative responses. Adults may reinforce newborn infants when the babies mimic their behavior. As the child gets older, reinforcement of imitation depends on increasing delays between the modeled performance and the imitative response. If you tell a joke to someone, the person seldom repeats it in your presence. Immediate repetition of the joke does not reinforce the listener. Later the joke is told to another audience, whose laughter reinforces the imitative performance. In this way, social contingencies generate extensive delays between the model stimulus and the imitative response.

It is important to account for the maintenance of generalized imitation. One interpretation involves conditioned reinforcement. Baer and Sherman (1964) suggest that similarity becomes a conditioned reinforcer. When a child is taught to imitate, reinforcement occurs only if there is correspondence between the model's actions and the learner's performance. Since reinforcement depends on similarity, imitating others becomes a conditioned reinforcer. Thus, when it occurs, imitation is automatically reinforced.

Alternatively, generalized imitation may be maintained by intermittent reinforcement. Gerwitz (1971) indicated that there was no need to postulate similarity as a conditioned reinforcer. He noted that there is no way of separating similarity from the imitative behavior it is said to explain. Intermittent reinforcement for imitation may account for the persistence of generalized imitation. If there were occasional reinforcement of imitation, this would maintain the stimulus–response relationships. That is, occasionally imitating others pays off, as when a person learns to operate a computer by watching others.

ON THE APPLIED SIDE: TRAINING GENERALIZED IMITATION

Dr. Donald Baer conducted the early research on generalized imitation and pioneered its application. Don was born in Chicago in 1931 and attended the University of Chicago where, in 1957, he received his Ph.D. in psychology under the supervision of Jacob L. Gewirtz. With Sidney W. Bijou at the University of Washington (1957–1965), Don established the behavior analysis approach to child development and contributed to the experimental analysis of child behavior. Together with Montrose M. Wolf and Todd R. Risley at the University of Kansas (1965–2002), he founded the discipline of applied behavior analysis. Don had more than 200 research and related publications and contributed to a number of literatures including early education, social development, language development, self-regulation, and imitation. Don received numerous awards from the American Psychological Association and the Society for the Experimental Analysis of Behavior, served as an international distinguished professor, and held the Roy A. Roberts Distinguished Professor Chair of Human Development at the University of Kansas. Don Baer died on April 29, 2002 while having lunch. He was known for his wit, intellectual brilliance, and advocacy on behalf of

individuals with behavioral disabilities. In this section we learn about Baer's use of generalized imitation principles to teach imitation to a child with severe disabilities.

Marilla was a profoundly retarded child who had never shown signs of imitating others. At 12 years old, she had a limited repertoire of responses that included grunting sounds; following simple commands like "sit down"; dressing and feeding herself; going to the washroom; and responses such as turning a knob or opening a door. Although the staff at Firecrest School had tried their best with Marilla, they were now convinced that the child was "just too dumb to learn anything."

Donald Baer and his students (Baer et al., 1967) wondered if Marilla's lack of imitation had contributed to her slow behavioral development. Most normal children learn much of their behavior by observation and imitation, but Marilla could not do this. For a child who has learned to imitate, it is rather easy to teach a game like "pat-a-cake." You simply say the words to each line (pat-a-cake, pat-a-cake, baker's man) and model the accompanying gestures (clapping hands). Eventually, the child engages in this performance without any special prompts.

Although it is easy to teach rhymes and games to children who can imitate, Marilla had no imitative skills. For Marilla, the only hope would be to train such a performance by reinforcing successive approximation or shaping. Even if this could be accomplished, it is likely that the teacher would give up long before success was obtained. Because of this, Baer and his associates used operant principles to teach generalized imitation to Marilla.

About an hour before lunch, Marilla was brought to a room with a table and chairs in it. The training began when the teacher said, "Do this," and raised his arm (S^D). Marilla simply stared at him and did not imitate the response. The same sequence was tried several times without success. On the next attempt, the teacher raised his arm and assisted Marilla in doing the same. After this sequence, Marilla received a spoonful of her lunch and at the same time the teacher said, "Good." After several assisted trials, Marilla needed less and less help and reinforcement only occurred when she lifted her arm by herself. Sometimes Marilla raised her arm when the performance was not modeled (S^Δ); these responses were not reinforced. With this training, Marilla acquired a simple response of raising her hand when the teacher said, "Do this," and demonstrated the action.

Other imitative responses, such as tapping a table and parts of the body with the left hand, were established by shaping and differential reinforcement. After seven examples were taught, the teacher said, "Do this," and tapped the arm of a chair. Marilla immediately made the same response although she had never been reinforced for doing so. This was the first instance of generalized imitation; a novel modeling stimulus (tapping the arm of the chair) resulted in a new imitative response (Marilla tapping the arm of her chair).

Although Marilla had shown generalized imitation, she did not imitate the next novel example. Training had proceeded too quickly and earlier imitative responses had to be reinforced. When this was done, Marilla eventually showed another instance of generalized imitation. At this point, novel imitations were maintained without reinforcement as long as they were interspersed with cases of reinforced imitation.

As more instances of reinforced imitation were added to Marilla's repertoire, the percentage of novel imitations were increased. Some of the responses were more important in everyday life, such as scribbling on paper, placing geometric forms in order, crawling under a table, and burping a doll. After 120 examples of reinforced imitation, the girl would immediately imitate new examples of modeled performance.

The basic idea of generalized imitation is that reinforcement of some members of the stimulus and response classes maintains the strength of all members—including novel imitations that never have been reinforced. To show the importance of reinforcement for Marilla's novel imitations, the contingency of reinforcement was changed.

The teacher continued to model various actions, but Marilla was no longer reinforced for imitating. However, when she did anything except imitate, reinforcement occurred every 30 seconds. This differential reinforcement of other behavior (DRO) maintains the reinforcer in the setting, places imitation on extinction, and increases behavior that is incompatible with imitation. In less than 20 sessions, both reinforced and novel imitations declined to near zero responses for each session. Clearly, generalized imitation was maintained by reinforcement.

Next, reinforcement for imitation was reinstated and generalized imitation was acquired again. At this point, the researcher began to teach sequences or chains of imitative performance to Marilla. For example, the teacher would raise his hand and stand up; reinforcement depended on Marilla imitating this two-response sequence. With small steps, the teacher was able to add more and more responses until Marilla could follow a seven-response sequence. Many of the sequences included novel imitative responses that had never been reinforced.

In the final phase of this project, Baer and his associates decided to add vocal responses to the imitative sequences. Since Marilla mad grunting sounds, the teacher said, "Do this," rose from his chair, walked to the middle of the room, and said, "Ah." Marilla followed the sequence, but when it came to the vocal response she only made mouth movements. The facial expression was, however, a good first approximation and was reinforced. Over time, closer and closer approximations occurred until Marilla completed the sequence with a well expressed "Ah." Using fading, the teacher was able to get the girl to say, "Ah," whenever he said, "Do this," and demonstrated the vocal response.

Once the imitation of various sounds was well established, the teacher combined the sounds into words and, after about 20 hr of vocal imitation, Marilla could imitate words like "hi," "okay," "Marilla," and the names of familiar objects. Once generalized imitation of motor and vocal responses was well established, new male and female experimenters were used to extend the performance to new models. Now, any teacher could work with Marilla to broaden her skills and add to her behavioral repertoire.

The operant procedures of fading, shaping, differential reinforcement, and so on can be used to establish generalized imitation in other disabled people. Once a sizable imitative repertoire is available, further learning occurs much more rapidly. Rather than teach separate responses, a person can be shown what to do. This rapid learning of complex skills is necessary for getting along in the world.

The work of Baer et al. (1967) has important practical implications for learning-delayed people. What is less obvious is the theoretical value of this work. This research shows that complex human behavior may arise from relatively simple behavior principles operating in combination. One implication is that these same principles, when added to a possible cross-modal matching capacity (Meltzoff & Moore, 1999), account for the development of observational learning in everyday life.

Complex Observational Learning

Dr. Albert Bandura (Figure 11.7) has worked on complex observational learning and self-regulatory processes for about 50 years and is one of the most cited researchers in psychology. He was born in 1925 and raised in Mundare, a small town in northern Alberta, Canada. His elementary and high school years were spent in the only school in town, where two teachers handled the entire school curriculum. Following high school, Bandura went westward to attend the University of British Colombia and graduated in 1949 with the Bolocan Award
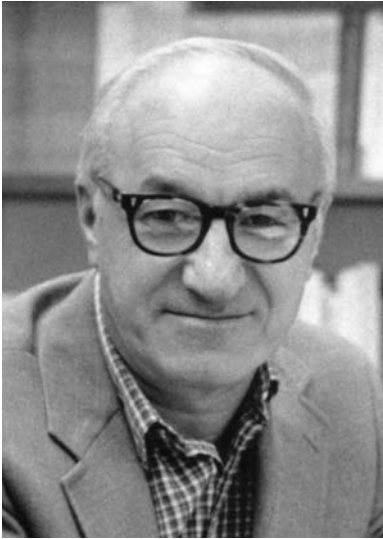
FIG. 11.7.   *Albert Bandura.*

in psychology. He decided to do graduate study at the University of Iowa in part due to the writings of the well-known learning theorist Kenneth Spence. At Iowa, in the Department of Psychology, Bandura confronted the fundamental problems of learning, investigated alternative theories of learning and performance, and followed the work of Neal Miller on social learning. In 1952 he graduated with his Ph.D. and joined the faculty at Stanford University, where he became a full professor in 1964. Currently, Dr. Bandura is David Starr Jordan Professor of Social Sciences in Psychology at Stanford University. His work on imitation and aggression is discussed in the following section.

The Bobo Doll Experiment

Albert Bandura (1965) designed an experiment to show a form of learning by observation more complex than generalized imitation. Children participated in this experiment on the imitation of aggressive behavior. As shown in Figure 11.8, each child watched a short film in which an adult demonstrated four distinctive aggressive actions toward an inflated Bobo doll (cf. Bandura, Ross, & Ross, 1963). Every aggressive action was accompanied by a unique verbal response. While sitting on the Bobo doll, the adult punched it in the face and said, "Pow, right in the nose, boom, boom." In another sequence, the adult hit the doll with a mallet saying "Sockeroo, stay down." Also, the model kicked the Bobo doll and said, "Fly away," and threw rubber balls at the doll while saying, "Bang."

Some of the children saw the model rewarded by another adult, who supplied soda, snack, and candies while saying, "strong champion." Other children saw the model receive negative consequences. The adult scolded and spanked the model for "picking on that clown" and warned him or her not to act that way again. A third group saw the modeled aggression, but no consequences for the aggressive behavior were portrayed.

When the film ended, a child was taken to a room that contained many toys, including a Bobo doll. The child was encouraged to play with the toys and then was left alone. The researchers watched through a one-way mirror and recorded instances of aggression and imitative aggression directed at the Bobo doll. Generally, there was a high frequency of imitative aggressive behavior toward the Bobo, and boys were more aggressive than girls.

FIG. 11.8. *Imitation of modeled aggression against a Bobo doll. After viewing a model hit, jump on, and verbally insult a Bobo doll, male and female children also showed these imitative aggressive responses. From "Imitation of Film-Mediated Aggressive Models," by A. Bandura, D. Ross, and S. A. Ross, 1969,* Journal of Abnormal and Social Psychology, 66, *pp. 3–11. Copyright 1969, Albert Bandura. Reprinted with permission.*

Bandura (1965) also found that reward and punishment of the model's actions affected the imitation of aggression. Children who saw the model punished were less likely to imitate aggression than those who saw the model rewarded. Children who saw the model rewarded did not differ in imitative aggression from those who watched the model perform the actions without receiving social consequences. Importantly, this means that just seeing modeled aggression (no consequences) had about as much impact on imitation as observing violence being rewarded. Finally, Bandura offered an incentive to all the children if they could remember the actions of the model in the film. With this incentive, all three groups recalled the modeled aggression at about the same level. It seemed that all children had learned equally from the modeled aggression, but those who witnessed punishment of the model were less inclined to perform the aggressive sequences.

Social Cognitive Interpretation

Bandura (1986) argued that the difference between learning and performing modeled aggression requires a cognitive theory of **observational learning**. The observer pays attention to the modeled sequence, noting the arrangement of each action. The general information in the sequence must be coded and rehearsed as when the child says, "First sit on the Bobo, and then say the words 'pow.'" Once this abstract information is retained in memory, imitation is a matter of reproducing the component responses in the correct sequences.

Complex behavior patterns, however, cannot be learned by observation until the component skills have been mastered. It is impossible to fly a plane or do an inward one-and-a-half dive by mere observation. When the separate skills have been acquired, observing others

can provide information on how to sequence complex performances, especially with corrective feedback. The golf instructor may show a person how to stand, hold the golf club, and swing at the ball. This demonstration could produce a sequencing of these responses, but the person may still not hit the ball well. It takes corrective feedback from the instructor and the trajectory of the ball to improve performance. Finally, the anticipated consequences of imitation determine whether an imitative response will occur. People who expect positive outcomes are likely to perform actions they have witnessed, and those who expect negative consequences are less likely to imitate such actions.

Behavioral Interpretation

A behavioral interpretation for complex observational learning is that it may build on the processes of generalized imitation. As we have noted, generalized imitation provides an account of novel instances of imitation. From an operant perspective, imitation is most likely to occur in situations in which it was reinforced previously. Such behavior is unlikely in situations in which it was extinguished, or in settings in which it was punished.

Doug witnesses his brother, Barry, raid the cookie jar before dinner. Barry is caught by his mother and sent to his room. Later, Doug steals a cookie, is also caught, and is sent to his room. Over time, such experiences teach the child "what happens to others can happen to me." Based on such a learning history children show differential imitation based on modeled consequences. Doug avoids activities in which Barry has been punished and imitates the rewarded actions of his brother. This kind of conditioning history provides a plausible account of Bandura's results concerning complex observational learning.

The learning and performance differences of the Bobo doll research may also be due to previous conditioning. When Bandura offered an incentive for recalling the modeled action, he presented a discriminative stimulus that increased in probability of this verbal behavior. For most children, it is likely that being promised a reward for recalling some action is a situation that has accompanied reinforcement in the past. That is, a child may be told, "Mommy and Daddy will be proud of you if you can remember the alphabet," and the child is reinforced for reciting the ABCs. Many such instances result in a generalized tendency to recall events and actions when promised a reward. Given such a history and the incentive conditions that Bandura used, children in all three groups would show a high frequency of recalling what they have observed.

FOCUS ON ISSUES: RULES, OBSERVATIONAL LEARNING, AND SELF-EFFICACY

Recently, Bandura has noted that observational learning in humans involves the discovery and use of abstract rules. In a dialogue with Richard Evans (1989), he stated:

> I began to develop the notion of modeling as a broad phenomenon that serves several functions. This conceptualization of modeling is concerned more with the observers' *extracting the rules* and structure of behavior, rather than copying particular examples they had observed. For example, in language learning, children are extracting the rules of how to speak grammatically rather than imitating particular sentences. Once they acquire the structure and the rules, they can use that knowledge to generate new patterns of behavior that go beyond what they've seen or heard. As they acquire the rules of language, they can generate sentences they have never heard. So modeling is a much more complex abstract process than a simple process of response mimicry. (Evans, 1989, p. 5)

From a behavioral perspective, "extracting the rules" is verbal operant behavior that describes the contingencies of reinforcement (Skinner, 1957, 1969). Both Skinner and Bandura agree about the importance of rules for human behavior, but they differ in terms of interpretation and philosophy.

Bandura (in Evans, 1989) talks about rules as cognitive events, and Skinner (1969) views them as verbal descriptions. For Skinner, following rules is behavior under the control of verbal stimuli. That is, statements of rules, advice, maxims, or laws are discriminative stimuli that set the occasion for behavior. Rules, as verbal descriptions, may affect observational learning. In this regard, Bandura's modeling experiments involve a number of distinct behavioral processes—including generalized imitation, descriptions of contingencies, and rule-governed behavior. Behavior analysts study each of these processes to understand how they may combine in complex forms of human behavior, including observational learning.

One kind of rule or description of contingency involves statements about oneself such as "I am a competent person who can cope with this situation." This self-description can be contrasted with statements such as "I am an incompetent person who is unable to cope with this situation." Bandura (1997) refers to these kinds of responses as beliefs in self-efficacy, and provides evidence that these "cognitions" have a large impact on human behavior.

From a behavior analysis view, statements of self-efficacy, as a class of verbal stimuli, can affect subsequent behavior (see next section on Rule-Governed Behavior). For example, when confronted with speaking to a large audience, John thinks (or states out loud) that he doesn't have the verbal skills to succeed and estimates that his chances are only 40% for giving a well-organized, interesting, and clear presentation. Subsequently, John gives the talk and, as expected, performs at a low level. In this example, John's statement of self-efficacy describes a past history of behavior at speaking engagements (a rule). As a rule, the verbal stimulus sets up compliance as reinforcement (e.g., establishing operation). That is, for most people, stating and following rules (compliance) have resulted in generalized social reinforcement from a verbal community. Based on social conditioning for compliance, statements of self-efficacy often predict how a person will act in subsequent (similar) situations.

Rule-Governed Behavior

A large part of human behavior is regulated by verbal stimuli. Verbal stimuli are the products of speaking, writing, signing, and other forms of verbal behavior (see Chapter 12). Rules, instructions, advice, and laws are verbal stimuli that affect a wide range of human action. The common property of these kinds of stimuli is that they describe the operating contingencies of reinforcement. The instruction "turn on the computer and use the mouse to click the desired program in the menu" is a description of the behavior that must be executed to get a program running. Formally, rules, instructions, advice, and laws are **contingency-specifying stimuli**, describing the $S^D: R \rightarrow S^r$ relations of everyday life (Skinner, 1969).

The term **rule-governed behavior** is used when the listener's (reader's) performance is regulated by contingency-specifying stimuli. According to this definition, a scientist shows rule-governed behavior when following specified procedures to make observations. People, as listeners, may generate their own rules when they speak. Travelers who read a map to

get to the cabin may say to themselves, "Take Interstate 5 and turn left at the first exit." The self-directions are verbal rules that describe the contingencies of reinforcement that result in getting to the cabin. In a classroom, a student may solve a set of mathematical problems by following the square-root rule. Rule-governed behavior is seen when a client follows the advice given by a counselor. When people obey the laws as expressed by posted speed limits, signs that say NO SMOKING, and proscriptions not to steal, the behavior is rule-governed.

Constructing and Following Rules

In solving a problem, people often make up or construct their own discriminative stimuli. A person who has an important, early morning appointment may set an alarm clock for six o'clock a.m. Technically, setting the alarm is **precurrent behavior**, or an operant that precedes some other response. This behavior produces a discriminative stimulus that sets the occasion for getting up and going to the meeting. Thus, a major function of *precurrent behavior* is the **construction of S^Ds** that regulate subsequent action.

As shown in Figure 11.9, people also may construct discriminative stimuli through written words or spoken sounds. For example, a person may make a shopping list before going to the supermarket. Making a list is precurrent behavior, and the list is a discriminative stimulus for choosing groceries. Similarly, economical shoppers may say to themselves, "Only buy products that are on sale." This verbal stimulus acts something like the grocery list in the previous example. As a rule, the verbal expression points to the relation between the stimuli, behavior, and reinforcement in the marketplace (see Taylor & O'Reilly, 1997, for use of self-instruction in shopping by people with mild learning disabilities). The words *on sale* identify a property of products that is correlated with saving money (reinforcement). The rule makes it easier to discriminate a good deal from a bad one, is easily recalled, and may be executed in any relevant situation.

Constructing discriminative stimuli and rules is important for a technological society. To improve mail delivery, ZIP codes are added to letters. When a person puts a ZIP code on a letter, the code is an S^D that regulates sorting by postal employees. Letters are directed electronically throughout the postal system and arrive at an address specified by the code. Without such codes, mail is sorted at a much slower rate, and many letters get misdirected, lost, or returned.
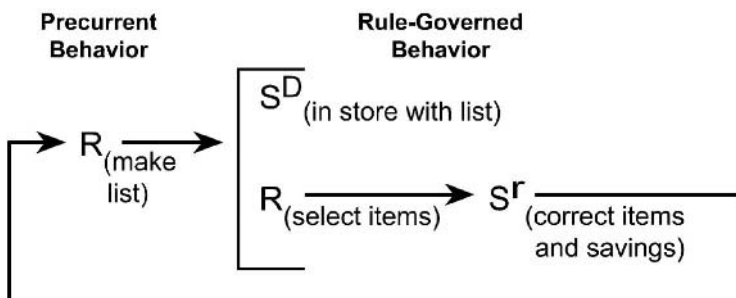
FIG. 11.9.   *Illustration of how precurrent verbal behavior (or rules) functions as a discriminative stimulus regulating subsequent behavior (rule-governed behavior).*

Folk wisdom represents another example of constructing and following rules. People who constructed the golden rule "Do unto others . . ." presumably did better in social relationships. When others transcribed the rule, it provided a guideline for successful interpersonal relationships to all who read it. Thus, a statement of wisdom is precurrent behavior that results in a discriminative stimulus. The rule as an S^D regulates the subsequent behavior of the person. Once the rule is made public, it affects others as it did the originator.

Formal laws of government or religion may also involve constructing and following verbal discriminative stimuli (e.g., Norton, 2001). Laws of property rights likely developed from social contingencies. When someone stole another person's property, the victim and family usually retaliated. Eventually, the contingencies were described by rules like, "Thou shall not steal." Descriptions of the contingencies made it easier for people to avoid stealing. Once formulated and codified, the laws were stated by authorities and backed up by religious and legal sanctions. In this way, members of the group or culture conformed to the codified rules without risking exposure to the actual contingencies.

Although much human behavior is based on constructing and following rules, some contingencies seem to defy reliable description. An elite athlete may execute a skillful gold medal performance, but be unable to say exactly how it happened. A scientist may make an important discovery, yet be unable to advise others on how to be inventive. Creative artists and musicians produce interesting visual and auditory effects in ways that cannot be stated. In all such cases, the interrelations of stimuli, responses, and reinforcements are so subtle that rules have not yet been described. In these situations, behavior is governed by exposure to the contingencies of reinforcement rather than regulated by rules.

Rule-Governed and Contingency-Shaped Behavior

People are said to solve problems either by discovery or by instruction. From a behavioral perspective, the difference is between the direct effects of contingencies (discovery) and the indirect effects of rules (instruction). When performance is attributed to direct exposure to reinforcement contingencies, behavior is said to be **contingency-shaped**. As previously noted, performance set up by constructing and following instructions (and other verbal stimuli) is termed *rule-governed behavior* (Catania, Matthews, & Shimoff, 1990; Hayes, 1989b).

Skinner (1969) illustrated the differences between contingency-shaped and rule-governed behavior in his analysis of a baseball player "catching the ball" and a naval commander "catching a satellite":

> The behavior of a baseball outfielder catching a fly ball bears certain resemblances to the behavior of the commander of a ship taking part in the recovery of a re-entering satellite. Both (the outfielder and commander) move about on a surface in a direction and with a speed designed to bring them, if possible, under a falling object at the moment it reaches the surface. Both respond to recent stimulation from the position, direction, and speed of the object, and they both take into account effects of gravity and friction. The behavior of the baseball player, however, has been almost entirely shaped by contingencies of reinforcement, whereas the commander is simply obeying rules derived from the available information and from analogous situations. (Skinner, 1969, p. 146)

Although behavior attributed to rules and contingencies occasionally may look the same, the variables that affect performance are in fact quite different. One difference is motivational—reinforcement determines the rate of response (probability) for a given setting, while rules only affect how the response is executed (topography). Recall that a rule is a special kind of discriminative stimulus and that S^Ds affect behavior because they set the

occasion for reinforcement. This means that rule-following itself must arise from contingencies of reinforcement. The advice of a friend is taken only because such directions have been useful in the past. For example, a friend may have recommended a certain restaurant and you found it enjoyable. Based on these consequences, you are now more likely to follow your friend's advice, especially for dining.

Reinforcement for following the advice of others in various situations may establish a general tendency to do what others recommend. This kind of reinforcement history may underlie generalized susceptibility to social influence (Orne & Evans, 1965). You probably know someone who is a sucker for a sales pitch. Many sales pitches are presented as advice, in the sense that a salesperson describes the benefits of owning a product. Often, however, the purchase results in more benefits to the seller than to the buyer. The television evangelist does not have a material product, but uses advice, promises, and threats of retribution to get people to send in money.

When directions are backed up with social punishment rather than natural consequences, they are called orders and commands (see Zettle & Hayes, 1982, on generalized compliance or *pliance* versus *tracking*). Individuals follow orders because they have been punished for disobedience. Of course, obedience often results in avoiding aversive consequences, as when a child is told, "don't play in the street," by a parent who has punished disobedience. Generalized obedience, however, may be a problem. Governments can induce blind obedience in which a person harms another without regard for moral consequences. In many countries, Amnesty International has documented the torture of political prisoners by guards and police. In these cases, obedience to authority is unquestioned and obviously results in serious harm or death to the victims (Milgram, 1974). Figure 11.10 shows Dr. Stanley Milgram (left) with a shock panel that subjects were ordered to use. The right-hand photograph shows an elderly gentleman who was given the supposed shocks. Participants in the experiment delivered bogus shocks that they considered real. Many participants delivered
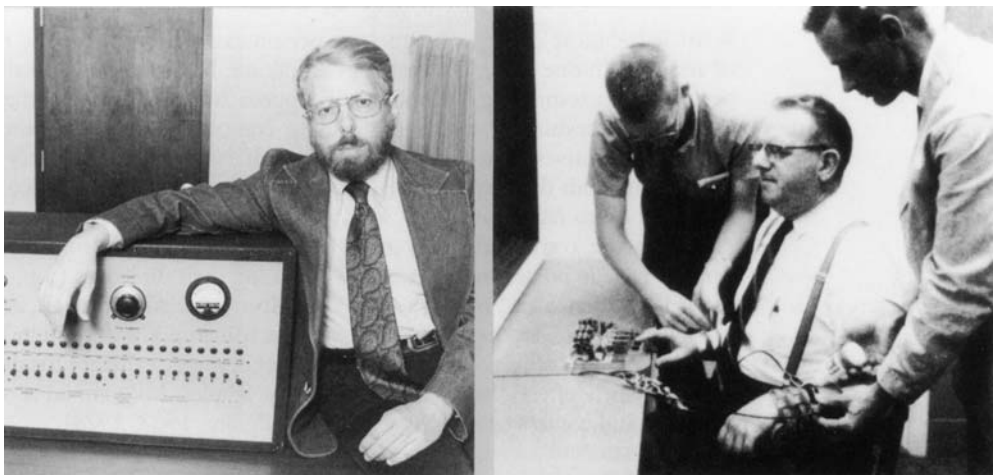
FIG. 11.10. *Stanley Milgram's famous study of obedience to authority illustrates the impact of orders and commands on human behavior. Based on the experimenter's orders, subjects administered what they thought were increasingly severe electric shocks to a 59-year-old man who complained of a heart condition. Photograph of Stanley Milgram (left) with the shock generator used in the obedience experiment. Photograph of learner (right) being strapped into chair is from the film* Obedience © 1965 by Stanley Milgram and distributed by Penn State Media Sales. Both reproduced with permission of Alexandra Milgram.*

the shocks even though the man complained of a heart problem. The tendency to obey the commands of the authority (experimenter) outweighed the signs and sounds of distress from the elderly victim.

The importance of reinforcement contingencies in establishing and maintaining rule-following is clearly seen with ineffective rules and instructions. One kind of rule that is likely to be weak is based on statistical analysis of contingencies. For example, it is unlikely that a person will give up smoking merely based on the directive, "Stop smoking—smoking causes cancer." The actual consequences are too remote and the statistical chances of getting cancer too unlikely. Of course, smoking usually declines when a person gets cancer, but at this point it is too late. When rules describe delayed and improbable events, it is necessary to find other reasons to follow them.

Recently, government reports of second-hand smoke and its effects have led some communities to classify public smoking as illegal. Towns and cities arrange fines and other penalties for failing to obey the no-smoking bylaw. In this case, smokers follow the anti-smoking rule for reasons unrelated to smoking itself (i.e., social punishment). A similar effect is obtained when smoking is called sinful or shameful and religious sanctions are used to promote compliance. Generally, social contingencies may be used to establish rule-following when natural contingencies are too remote or improbable to affect behavior.

Baum (1995) emphasizes the importance of rules in terms of long-term contingencies between behavior and fitness. As a discriminative stimulus, the rule strengthens listeners' behavior that is reinforced in the short run by social contingencies, but the rule also enters into the long-term contingencies that enhance the listeners' fitness. For example, in following the rule "Do not smoke" the listener is reinforced by the speaker's consequences in the short run, but this behavior is also related to better health and longer reproductive years. When the rule is said to be "internalized," the listener's behavior has switched from short- to long-term control. The fitness-enhancing consequences of long-term contingencies are health, resources, relationships, or reproduction. Baum's analysis of fitness and rule-governed behavior, therefore, integrates behavior analysis explanations of human behavior with evolutionary theory and natural selection.

FOCUS ON RESEARCH: INSTRUCTIONS AND CONTINGENCIES

In his discussion of rule-governed and contingency-shaped behavior, Skinner (1969) speculated that instructions may affect performance differently than the actual contingencies of reinforcement. One way to test this idea is to expose humans to reinforcement procedures that are accurately or inaccurately described by the experimenter's instructions. If behavior varies with the instructions while the actual contingencies remain the same, this would be evidence for Skinner's assertion (see Hackenberg & Joker, 1994 on correspondence between instructions and contingencies).

An early study by Lippman and Meyer (1967) showed that human performance on a fixed-interval schedule varied with instructions. When subjects were told that points (exchanged for money) became available after a specific amount of time, their performance was characterized by a low rate of response, appropriate to the fixed interval. In contrast, subjects told that points depended on a certain number of responses produced a high and steady rate of response. In a similar study, Kaufman, Baron, and Kopp (1966) placed subjects on a variable-interval (VI) schedule of reinforcement and told them that points were available on either a fixed-interval or variable-ratio basis. Performance was more in accord with the experimental instructions than with the actual VI contingencies.

FIG. 11.11.   *Mark Galizio. Reprinted with permission.*

The fact that instructions, in these experiments, seem to override the actual contingencies has been used to argue against a reinforcement analysis of human behavior. Bandura (1971, 1974) linked instructions to modeling and argued that both of these procedures activate subjects' expectancies which, in turn, affect subsequent behavior. This means that expected reinforcement, rather than actual contingencies, is the stronger determinant of human behavior. In addition, Spielberger and Denike (1966) disputed the claim that instructions were complex discriminative stimuli. They argued that there was no evidence to show that instructions gain (or lose) control over behavior because of selective reinforcement.

Both objections were addressed by Mark Galizio (Figure 11.11), who showed that following instructions is, in fact, a discriminative operant (Galizio, 1979). In a series of important experiments, human subjects responded to avoid the loss of money. Subjects received a payment to attend experimental sessions, and they could turn a handle to avoid a loss of five cents from their earnings. When they turned the handle to the right, the onset of a red light and loss of money were postponed. Subjects were exposed to four different contingencies during a session. A change in the contingency was signaled by one of four amber lights. One condition had no losses, but the other three had costs scheduled every 10 s. For the conditions in which costs occurred, each response delayed the next loss for either 10, 30, or 60 s.

To vary instructional control, labels were placed above the amber lights that signaled each condition. When instructions were accurate, there were no discrepancies between labels and the contingencies. Thus, the component in which each response postponed the loss for 10 s was labeled correctly as "10 sec," as were the "30 sec," "60 sec," and "no loss" components.

Galizio also created conditions of inaccurate instructions in which the labels did not match the actual contingencies. In a no-contact condition, all the components were changed to no losses, but the labels incorrectly described different response requirements. If subjects behaved in accord with the instructions, they made unnecessary responses, but there was no monetary loss. As you might expect, people followed the rules. For example, subjects turned the handle more when the label said "10 sec" then when it said "60 sec."

At this point, a contact condition was implemented in which losses occurred every 10 s in all components. The signs still read 10, 20, 60 s, and no loss. In this situation, responding

to the instructions produced considerable loss of earnings. Consider a person who turned the handle every 60 s but lost money every 10 s. Subjects quickly stopped following the instructions and responded in terms of the actual contingencies of reinforcement. Galizio (1979) explained the significance of these findings as follows:

> [In] the CONTACT condition, when instruction-following led to exposure to the loss contingency, instructional control was rapidly eliminated. The elimination of instruction-following persisted when the NO CONTACT condition was reinstated. This last finding is particularly important, since it shows that subject reactions to the instructions were irreversibly altered after exposure to the CONTACT condition. Subjects now "disbelieve" the instructions and the schedule assumes control of behavior. But contact with schedule–instruction discrepancies is necessary for the elimination of instruction-following, not simply the existence of such a discrepancy. *Instruction-following is controlled by its consequences*. (p. 62)

Overall, the results of Galizio's experiments provide strong support for the view that instructional control is a form of rule-governed behavior (see also Buskist & Miller, 1986; Hayes, Brownstein, Haas, & Greenway, 1986; Horne & Lowe, 1993; Ribes & Martinez, 1998; Ribes & Rodriguez, 2001; see Hayes & Ju, 1997; Plaud & Newberry, 1996 for applied implications of rule-governed behavior). In accord with numerous other experiments, subjects were found to acquire rapidly appropriate responses to the contingencies when instructed about how to behave. Importantly, the influence of instructions depended on the consequences of following these rules (see Svartdal, 1992). When the costs of rule-following increased, people no longer followed the rules. Additional evidence showed that following instructions could be brought under stimulus control. Thus, people follow instructions in situations that lead to reinforcement, but not in situations that signal extinction or aversive consequence. Finally, Galizio showed that accurate instructions have reinforcing properties, a characteristic shared by simple discriminative stimuli. People not only respond to instructions but seek out reliable descriptions of the contingencies.

Instructions about interval (or ratio) contingencies often occur in everyday life (see Luciano, 2000; Poppen, 1982). Students are given timetables, calendars, and outlines for lectures, due dates, examination periods, and official holidays. When instructions accurately describe contingencies, behavior is highly efficient. A professor who shows up at the stated time will have students who are punctual. And, as we have noted, reliable instructions are reinforcing; people seek out information about scheduled events, such as television programs and arrival–departure times of airlines.

Inaccurate instructions lead to several different effects. People will continue to follow misleading instructions when there is some benefit and little cost. Buses may never arrive as scheduled, but people continue to follow the listed times because the buses eventually show up. People may continue to follow inaccurate instructions because of social reinforcement. Students follow the rule, "Go to class to get good grades." A few students who get satisfactory grades do not pay attention to the lectures, but they "put in time" in going to class. They follow the rule because their friends go to class, even though it has no effect on their grades. Unreliable instructions, however, are not followed if the rules lead to extinction or aversive consequences. When this occurs, people ignore the rule and act on the basis of the actual contingencies. Instructions to spend during periods of economic recession may be ignored as consumers contact the costs of buying (e.g., increasing debt, threats to basic essentials). Loss of consumer confidence may reflect the weakening of rule-governed behavior because of contact with the actual contingencies of the market (see Cullen, 1998, on the problems with rules).

Rules as Function-Altering Events

Altering Discriminative Relations

Although the discriminative function (S^D) of rules is well established, several researchers (Malott, 1988; Michael, 1982a, 1984; Schlinger & Blakely, 1987) have argued that contingency-specifying stimuli have additional, and perhaps even more crucial, effects. Rules can act as **function-altering events**, altering the function of other stimuli and, thereby, the strength of relations among these stimuli and behavior (Schlinger & Blakely, 1987). A passenger on an airplane is instructed to respond to a drop in cabin pressure by "placing the yellow oxygen mask over your mouth and breathing normally." The instruction is a *function-altering event* that sets up the "dangling yellow mask" as a discriminative stimulus for placing the mask on the face. In the absence of the rule, the dangling mask might occasion looking at it or asking for the stewardess (see Schmitt, 2001, for rule following after a delay). The function-altering effects of the airline rule is shown when the passengers put on their masks only at the appropriate moment. Also, the probability of placing masks on faces is higher for those who are given the instruction.

Rules may alter the discriminative functions of stimuli in more complex ways, as when a person is given detailed instructions. A person may be told, "See George about buying the car, but if Craig is there don't make an offer." As a result of this verbal description, the listener emits a conditional discrimination: George is an S^D for making an offer and Craig is an S^Δ for this behavior. Notice that without the detailed instruction or rule, George and Craig may have no discriminative functions when buying a car.

In this chapter we have learned about correspondence relations, focusing on imitation and rule-governed behavior. Rule-governed behavior concerns the effects of verbal stimuli on the behavior of the listener. That is, instructions (and other verbal stimuli) are products of the behavior of the speaker that regulate the behavior of the listener. In the next chapter, we examine contingencies of reinforcement that regulate the behavior of the speaker or what Skinner (1957) called the analysis of verbal behavior.

KEY WORDS

Construction of S^D	Correspondence relations	Operant imitation
Contingency-shaped behavior	Delayed imitation	Precurrent behavior
Contingency-specifying stimuli	Function-altering event	Rule-governed behavior
	Generalized imitation	Spontaneous imitation

ON THE WEB

http://www.pigeon.psy.tufts.edu/avc/zentall/default.htm The issue of imitation in animals, evidence, function and mechanisms is addressed by Zentall and Akins at this Web addresss. The distinction between apparent imitation and "true" imitation is one topic of interest.

http://jom-emit.cfpm.org/1998/vol2/blackmore_s.html Susan Blackmore's thesis is that the basic unit of cultural transmission is the meme (after Richard Dawkins), and this Web site shows how social learning and imitation are the basis for transmission of memes.

STUDY QUESTIONS

1. Technically, what is a correspondence relation? (295) Give several examples of correspondence training and human behavior. In your answer, refer to doing what others do, saying and doing, reports of private events, doing and saying, and giving rules and advice. (295)

2. What are two kinds of correspondence contingencies emphasized in this chapter? (296) Define imitation according to Thorpe (1963). (296)

3. At the beginning of the century, what did psychologists believe about imitation? (296) What is delayed imitation? (297) Describe two studies of spontaneous imitation by birds and monkeys. (297) Why are these studies inadequate to tell spontaneous from acquired imitation? (297)

5. What were the results of Thorndike's (1911) attempts at imitation? (298) How did Herbert and Harsh (1944) clarify the conditions necessary for imitation by cats? How does reinforcement confound a spontaneous imitation account of monkeys solving the hidden raisin problem? (298)

6. Describe the subjects and apparatus used by Epstein (1984). (298) Outline the experimental procedures used by Epstein (1984) to study spontaneous imitation in pigeons. Outline the five conditions of the first experiment and the results. What were the results of Epstein's (1984) second experiment on delayed spontaneous imitation? (300) Analyze these experiments in terms of the phylogenetic basis of spontaneous imitation. Why do Epstein's results remain controversial? (300)

7. Summarize Meltzoff and Moore's (1977) initial experiment on spontaneous imitation on newborn infants. (301) Next, describe their second experiment. (302) What were the results? Describe the difficulties with infant imitation research. (302) Outline the research on delayed imitation by infants. (303). Give an analysis of spontaneous and delayed imitation according to the textbook. (304)

8. Show how operant-discrimination procedures can result in imitation of a model's performance. (305) How does a child watching *Sesame Street* and later singing Kermit's song suggest behavior more complex than operant discrimination? (305)

9. Describe generalized imitation in terms of procedures. (306) How does generalized imitation account for the performance of the child who imitates Kermit's song after watching *Sesame Street?* (306) What maintains a repertoire of generalized imitation? (307)

10. **ON THE APPLIED SIDE**: Who is Don Baer? (307) Be able to recount the use of generalized imitation by Baer et al. (1967) to modify the behavior of Marilla, a profoundly retarded child. (308) How did the researchers show that generalized imitation was maintained by reinforcement? Describe the final phase of Marilla's training. (308) What are the advantages of teaching generalized imitation rather than only using successive approximation or shaping? (309)

11. Who is Albert Bandura? (309) Recount the Bobo doll experiments by Bandura and his associates. (309) What were the experimental conditions of Bandura (1965)? How did Bandura test for aggressive imitation and what did he find? (311) What was the effect of adding an incentive to remember the modeled aggression? (311)

12. How is the Bobo doll experiment understood from a cognitive perspective? (311) Provide a behavioral interpretation of the same experiment. (312)

13. **FOCUS ON**: Describe the difference between Bandura and Skinner in terms of rules and complex human behavior. (313) How do behavior analysts deal with the effects of self-efficacy on subsequent performance? (313)

14. Provide a technical definition of rules. (313) What is rule-governed behavior? (313) Give some common examples of rule-governed behavior. (314)

15. Describe from Fig. 11.9 how people construct stimuli that regulate their behavior. (314) How do spoken and written words play a role in self-management, as in economical shopping? (314) Show how constructing verbal and nonverbal S^Ds is important for society. (315) It is sometimes difficult to describe the operating contingencies by rules; give some examples. (315)

16. Distinguish between rule-governed and contingency-shaped behavior. (315) Analyze catching a satellite and a fly ball in terms of rules versus contingencies. (315) Although performances attributed to rules and contingencies may look the same, the regulating conditions are different—discuss this. (315)

17. Provide a behavior analysis of susceptibility to social influence and obedience. (316) How does this behavior ultimately rely on reinforcement contingencies? (316) What did Baum (1995) say about rules, behavior and fitness? (317)

18. **FOCUS ON**: Outline the results of early experiment on control by instructions and contingencies. What conclusions were drawn for these early studies? (317) Describe Galizio's (1979) experiment on instructions and contingencies. (318) What were the major results? How do Galizio's findings support a behavioral perspective of rule-following? (319) Discuss accurate and inaccurate instructions in everyday life. (319)

21. Discuss rules as function-altering events. Rules may alter discriminative functions of stimuli. How? Give examples. (320)

BRIEF QUIZ

1. The relationship between saying and doing is formally a _____ relation.
   - (a) cognitive consistency
   - (b) correspondence
   - (c) synergistic
   - (d) dose response

2. Imitation requires that the learner emit a _____ response that could only occur by observing a _____ emit a similar response.
   - (a) significant; peer
   - (b) operant; organism
   - (c) novel; model
   - (d) similar; conspecific

3. What did Thorndike (1911) conclude from imitation experiments with animals?
   - (a) animals show amazing intelligence
   - (b) animals can easily imitate another member of their species
   - (c) animals do not show a capacity for intelligence
   - (d) animals cannot learn by observation

4. Epstein's (1984) second experiment concerned _____ _____ and showed that spontaneous imitation in pigeons occurred after _____ had elapsed.
   - (a) delayed imitation; 24 hours
   - (b) deferred matching; 48 hours
   - (c) delayed sampling; 24 hours
   - (d) deferred equivalence; 48 hours

5. In the Meltzoff and Moore (1977) study (Experiment 1) of infant imitation, the researchers
   (a) used 12- to 21-day-old infants
   (b) presented a passive face for 90 seconds
   (c) presented four gestures in random order
   (d) all of the above
6. Both humans and pigeons seem to engage in spontaneous imitation. The appearance of similar behavior
   (a) shows that humans and pigeons share much in common
   (b) shows identical functions of the behavior
   (c) shows that structure and function go together
   (d) none of the above
7. In terms of generalized imitation, which of the following are true?
   (a) generalized imitation is based on principles of social cognition
   (b) generalized imitation provides an account of imitation after a delay
   (c) generalized imitation is part of Bandura's cognitive theory
   (d) all of the above
8. To show the important of _____ for Marilla's _____ imitations, Don Baer changed the _____ of reinforcement.
   (a) stimulus control; immediate; contingency
   (b) stimulus control; spontaneous; quality
   (c) reinforcement; novel; contingency
   (d) reinforcement; immediate; quality
9. Rule-governed behavior involves
   (a) control by contingency-specifying stimuli (verbal stimuli)
   (b) the effects of instructions on the behavior of the listener
   (c) the effects of advice given by a counselor
   (d) all of the above
10. Rule-following is _____ regulated by _____ of reinforcement.
   (a) behavior; contingencies
   (b) cognitively; expectancies
   (c) mentally; contingencies
   (d) socially; expectancies

Answers to brief quiz (*page*): b(295); c(296); d(298); a(300); d(301); d(304); b(304); c(308); d(313); a(315)

Verbal Behavior

IN THIS CHAPTER

1. Find out the difference between language and verbal behavior.
2. Discover the operant functions of verbal behavior.
3. Investigate complex behavior in the laboratory and communication between pigeons.
4. See how reinforcement contingencies can result in pigeons reporting on their internal states on drugs.
5. Learn why the flag is a symbol of America by investigating research on stimulus equivalence.

Humans are social animals. Most of the daily life of people takes place in the company of others. An important aspect of human social behavior involves what we do with words, as in speaking, writing, signing, and gesturing. Behavior analysts use the term verbal behavior to refer to this kind of human activity. In this chapter, verbal behavior is analyzed according to the same principles of behavior that have been used throughout this book. The analysis explores the role of contingencies of reinforcement in the regulation of verbal behavior.

In terms of behavior analysis, Lee (1981a) notes that language tends to obscure environment–behavior relationships. Language usually directs research attention to grammar, syntax, and unobservable mental representations and processes (structure), rather than to the objective conditions that influence the behavior of a speaker or writer (function). Catania (1998a) also has noted that the "language of reference" implicitly proceeds from words to objects in the world. The possibility that environmental contingencies regulate our speaking and writing is usually not considered. Catania (1998a) states:

> We also speak of language as if it were directed toward events or objects. We say that words or sentences refer to, deal with, speak of, call attention to, or are about things. The language of reference implicitly includes the direction from verbal behavior to environment. Everyday language doesn't include words that emphasize the opposite direction. What if our everyday language has prejudiced us about the ways in which our verbal behavior works? We hardly ever say that we utter nouns in the presence of relevant objects or that sentences are occasioned by relevant events. Instead, we say that words refer to objects or that sentences are about events. There are good reasons for these usages; . . . [but] they may be misleading in an analysis of the behavior of speakers and listeners or readers and writers. (pp. 239–240)

Language and Verbal Behavior

People usually use the term language when they talk about speaking and other forms of communication. Although some researchers argue that language is behavior (Baer & Guess, 1971), others use the term to refer to a set of linguistic habits (Hockett, 1958, 1968), while

still others point to the underlying mental rules that are presumed to organize spoken and written words (e.g., Chomsky, 1957). Some view language as a cultural phenomenon that does not depend on individual behavior and mental rules (Sanders, 1974). Finally, language is said to consist of three main features involving vocabulary, syntax and meaning (Erlich, 2000, p. 140). As you can see, there is little agreement on the definition of language. The most important implication of this confusion is that language may not be a useful concept for a natural-science approach to speaking (and other forms of verbal behavior).

To rectify these problems, Skinner (1957) introduced the term verbal behavior. The term helps to redirect attention to the operating contingencies. In contrast with the term language, **verbal behavior** deals with the performance of a speaker and the environmental conditions that establish and maintain such performance. That is, verbal behavior concerns the *function* of what we do with words that are spoken, written or signed. Some of the functions of verbal behavior that have been researched include (a) how we learn to talk about things and events in the world, (b) how we learn to communicate our feelings and emotions, and (c) how the listener's response to what we say shapes what we talk about.

Verbal Behavior: Some Basic Distinctions

Verbal behavior refers to the vocal, written, gestural and signed behavior of a speaker, writer, or communicator. This behavior operates on the listener, reader, or observer, who arranges for reinforcement of the verbal performance in a particular setting. A woman who is hungry may ask a waiter for "the tossed green salad with the egg sandwich." The speaker's behavior affects the listener, who in turn supplies reinforcement (i.e., placing the meal on the table). A similar effect is produced if the woman writes her order on a piece of paper. In this case, the written words function like the spoken ones; the waiter reads the order and brings the meal. Verbal behavior therefore expands the ways that humans can produce effects on the world.

Verbal behavior allows us to affect the environment *indirectly* (Vargas, 1998). This contrasts with nonverbal behavior, which often results in direct and automatic consequences. When you walk toward an object, you come closer to it. If you lift a glass, there is a direct and automatic change in its position. Verbal behavior, on the other hand, only works through its effects on other people. To change the position of a lamp, the speaker says, "Lift the blue lamp at the back of the room" to a listener who is inclined to respond. Notice that reinforcement of the verbal response is not automatic, since many conditions may affect what the listener does. The listener may not hear you, may be distracted, or may not understand (e.g., picking up the red lamp rather than the blue one). Generally, the social contingencies that regulate verbal behavior are complex, subtle, and highly flexible.

The Range of Verbal Behavior

Although verbal behavior is usually equated with speaking, vocal responses are only one of its forms. In addition to talking, a person emits gestures and body movements (signs) that indirectly operate on the environment through their effects on others. In most cultures, a frown sets the occasion for others to remove some aversive event, while a smile may signal the observer to behave in ways that produce positive reinforcement. In fact, frowns and smiles have such consistent and pervasive effects on others that some researchers have considered these gestures as universal symbols (Ekman & Friesen, 1975; Rosenberg & Ekman, 1995).
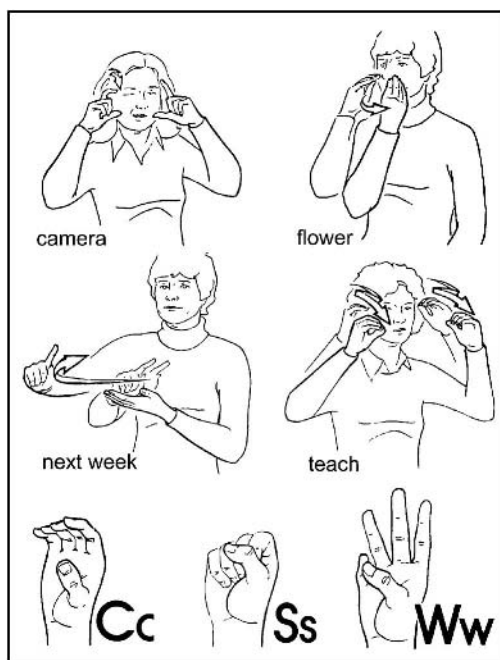
FIG. 12.1. *Examples of American Sign Language (ASL) and finger-spelled letters. From A Basic Vocabulary: American Sign Language for Parents and Children, 1978, by T. J. O'Rourke, T. J. Publishers.* Copyright 1978, T. J. Publishers, Inc., Silver Spring, MD. Reprinted with permission.

Another kind of verbal behavior involves manual signing rather than speech sounds. In American Sign Language (ASL), the speaker produces arm and hand movements that are functionally similar to speech sounds. In this case, regulation of the listener's behavior is along a visual dimension. Deaf speakers may also acquire complex finger movements known as "finger spelling" that function like letters in the English alphabet. Figure 12.1 illustrates some of the basic manual movements of ASL and digital positions for finger spelling.

In the behavioral view, writing is verbal behavior that functions to regulate the behavior of a reader. Although written words and sentences have little formal similarity to spoken ones, the two modes of communication have equivalent functions. Recall that behavior analysts classify behavior in terms of its functions, and for this reason both writing and speaking are commonly categorized as *verbal operants*.

Speaking, Listening, and the Verbal Community

The behavior of the speaker (or writer) is functionally different from the behavior of the listener (or reader). That is, the conditions that regulate speaking are distinct from those that affect listening. In the field of psycholinguistics, the distinction between speaking and listening is often blurred by talking about language encoding and decoding. Since both are treated as aspects of language (i.e., the transmission of meaning), there is little attempt to analyze the separate functions of such behavior. In fact, Skinner (1969) used the term *rule-governed behavior* to describe the behavior of the listener and *verbal behavior* to specify the performance of the speaker.

Rule-governed behavior refers to the effects of instructions, advice, maxims, and laws on the listener's behavior (see Chapter 11). In this view, rules are seen as complex discriminative stimuli, and the principles that govern stimulus control also regulate the behavior of the listener. While many behavior analysts have accepted this perspective, others have suggested

that rule-governed behavior involves additional processes (see Parrott, 1987, for a discussion of these issues).

Regardless of one's view about the behavior of the listener, verbal behavior requires special attention because the consequences of verbal behavior are mediated by the actions of others (Vargas, 1998). The way a person speaks is shaped by the consequences supplied by the listener. A busy mother may not respond to the polite response of "milk, please" by her child. However, a change in form to "Give me milk!" may induce compliance. Inadvertently, the mother is teaching her child to give commands in a loud voice. Subtle contingencies of reinforcement shape the style, dialect, tonal quality, and other properties of speaking.

The contingencies that regulate verbal behavior arise from the practices of people in the **verbal community**. These practices are part of the culture of the group and they have evolved over time (Skinner, 1953). The practices of the verbal community therefore refer to the customary ways that people reinforce the behavior of a speaker. In an English-speaking community, the speaker who substitutes "also" for "in addition" or "besides" is likely to be reinforced, especially if repetition is bothersome to the listener. When linguists analyze the grammar of a language, they state rules that describe the reinforcing practices of the verbal community. For example, the grammatical rule "i before e except after c" describes a requirement for reinforcement set by the community; the written word *received* is reinforced while *recieved* is not. Thus, verbal behavior is established and maintained by the reinforcing practices of the community or culture.

Operant Functions of Verbal Behavior

In his book *Verbal Behavior*, Skinner (1957) presented a preliminary analysis of this kind of human activity. Although some linguists have treated Skinner's work as a behavioral theory of language, it is more likely that the book represents a set of testable hypotheses about verbal behavior (MacCorquodale, 1970). Skinner described verbal behavior in terms of the principles found in the operant laboratory. Such an analysis must ultimately be judged in terms of its adequacy. That is, it must deal with the facts of the speaker's behavior in natural settings and the experimental and observational evidence that supports or refutes such an account. In this section, the basic verbal classes are outlined using Skinner's (1957) distinctions as well as clarifications made by others (e.g., Michael, 1982b; Oah & Dickinson, 1989).

Manding and Tacting

Verbal behavior may be separated into two broad operant classes, manding and tacting, based on the regulating conditions. When you say "Give me the book," "Don't do that," "Stop," and so on, your words are regulated by motivational conditions—deprivation for the book, or another person doing something unpleasant. In behavior analysis, this verbal behavior is called manding. **Manding** refers to a class of verbal operants whose form is regulated by establishing operations (e.g., deprivation, aversive stimulation, etc.). The word manding comes from the common English word *commanding*, but commanding is only a small part of this operant class.

Everyday examples of manding include asking someone for a glass of water when thirsty, or requesting directions from a stranger when lost. Notice that specific reinforcement for manding is made effective by some establishing operation. A glass of water reinforces asking for it when you are deprived of water, and directions are reinforcement for requesting them

when you are lost. Common forms of manding include speaking or writing orders, asking questions, requesting objects or things, giving flattering comments to others, and promoting commercial products (i.e., "buy this detergent").

There is another major class of verbal operants. **Tacting** is defined as a class of verbal operants whose form is regulated by nonverbal discriminative stimuli (nonverbal S^D) and maintained by generalized conditioned reinforcement from the verbal community. A child is tacting when she says "The sun is orange" in the presence of the midday sun on a beach with her mother. In this example, the presence of the sun in the sky (and the relevant property of color) is a nonverbal S^D for the verbal tacting by the child. The operant class of tacting is maintained by generalized conditioned reinforcement from the verbal community (e.g., mother, father, teacher, and others) usually in the form of corrective feedback such as "yes," "right," and so on. The word tacting comes from the more familiar term *contacting* and refers to verbal behavior that makes contact with events in the world (nonverbal S^Ds). Everyday examples of tacting include describing a scene, identifying objects, providing information about things or issues, and reporting on your own behavior and that of others.

Occasionally, it is difficult to distinguish between manding and tacting. A person who says "I believe you have the sports page" may be tacting the nonverbal stimulus (the sports page) or manding specific reinforcement (getting the sports page). The issue is often resolved by the listener saying "Yes, I do" and returning to read the paper. If the original response was manding, the listener's reply will not function as reinforcement (the sports page is not given). In this case, the speaker is likely to clarify the disguised manding by stating, "May I please have the sports page!" In a different example, a man who picks up his girl friend for a date may say "Darling, you look beautiful tonight." Again, the form of response cannot distinguish manding from tacting. If the man's verbal response is regulated by abstract properties of "beauty" (nonverbal S^D) he is tacting. On the other hand, the verbal response could be regulated by deprivation for sexual reinforcement and, if so, the man is manding. Only an analysis of the relevant contingencies can distinguish between manding and tacting behavior.

Many advertisements and television commercials are disguised manding, in the sense that the verbal responses of an announcer seem to describe the benefits of the product (tacting), but are in fact requests to buy it (manding). A television actor dressed in a doctor's white coat states that "Xprin relieves pain and muscle ache" and is available at your local drugstore. The verbal description of the product (relieves pain) suggests tacting by the speaker (actor) but there are manding (profit) aspects to the verbal behavior. Given these contingencies, listeners learn how to reveal the disguised manding of a speaker (testing the controlling variables), and speakers learn to conceal their obvious manding of a listener (making the verbal description of the product appear as tacting its benefits). Persuasion and attitude change may be analyzed therefore in terms of manding, tacting, and the interaction of speakers and listeners (Bem, 1965).

ADVANCED ISSUE: A FORMAL ANALYSIS OF MANDING AND TACTING

In his book *Verbal Behavior*, Skinner (1957) discusses the formal differences in behavior regulation between manding and tacting. In this section on advanced issues, we explore the social contingencies that establish and maintain these two classes of verbal behavior. The contingencies are somewhat complex and diagrams of the interrelationship of the speaker and listener help to depicted the controlling variables.

The Manding Relation

Figure 12.2 is a formal analysis of the manding relation. A **social episode** involves the social interaction of speaker and listener. The line through the middle of the diagram separates the speaker's events and actions from those of the listener (check this out). Each person completes a behavioral sequence or chain ($S^D : R \rightarrow S^r + S^D : R \rightarrow S^r \ldots$), and social interaction involves the intermingling of these chains or the **interlocking contingencies** (examine this in Figure 12.2). In the diagram of a social episode, an arrow ($\rightarrow$ horizontal or vertical) means "produces or causes"; thus, a verbal response by the one person may cause an event, condition, or stimulus for the behavior of the other person (vertical arrow). That is, the verbal behavior of one person functions as a stimulus and/or consequence in the behavior chain of the other person. Also, within the behavioral sequences of each individual, the verbal operants produce effects or consequences (horizontal arrow) supplied by the behavior of the other person (check this out).

In the example of Figure 12.2, we assume that two people are seated at a counter in a cafeteria. Dinner is placed in front of the speaker, but the ketchup is out of reach and situated near the other person or listener. In this context, the presence of food on the table is an *establishing operation (EO)* for behavior that has produced ketchup in the past (see Michael, 1982a; 1993; also Chapter 2). The establishing operation also makes getting ketchup a reinforcing event in this situation.

In addition to the EO, the speaker's manding response ("pass the ketchup") in Figure 12.2 is regulated by the presence of ketchup near the listener (S^D_1 for speaker). The causal effect of the presence of the listener is shown by the first vertical arrow passing from the listener's side of the interaction (operant chain) to the speaker's side. If there were no other people in the restaurant, it is likely that the speaker would get out of his or her seat and get the ketchup. The presence of a listener increases the probability that the
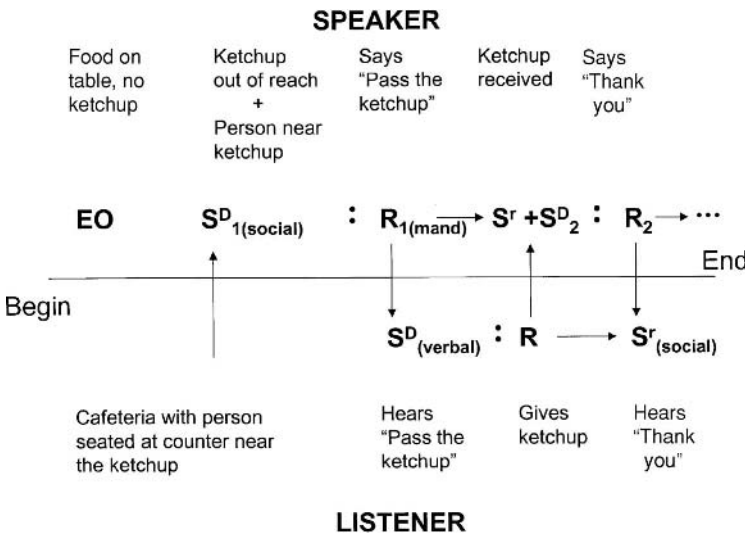
FIG. 12.2. *Analysis of the manding relation between speaker and listener based on Skinner (1957). EO = establishing operation; S^D = discriminative stimulus; R = operant; S^r = reinforcement. See text for a description of the verbal contingencies.*

speaker will say "pass the ketchup" rather than get it himself or herself. This means that the listener functions as part of the discriminative stimulus (S_1^D) in this social episode. Together, the out-of-reach ketchup and the presence of the listener (S_1^D) set the occasion for (:) a verbal response (R_1) by the speaker (check this out).

The speaker's verbal response (R_1) of "pass the ketchup" affects the listener as a stimulus. The causal effect of the speaker's behavior on the listener is shown as a vertical downward arrow from R_1 (speaker) to the listener's side of the interaction (operant chain). The words "pass the ketchup" by the speaker are a verbal stimulus for the listener (S_1^D) that sets the occasion for (:) the listener to pass the ketchup (R_1 for listener). In this social episode, the listener's response of passing the ketchup (R_1 for listener) is reinforcement for the speaker's verbal operant (S_1^r for speaker). Because the speaker's verbal response ("pass the ketchup") produces specific reinforcement (getting ketchup) from the listener, the verbal operant is formally manding. As previously stated, *manding* is a verbal behavior that is set up by an establishing operation (out-of-reach ketchup) and maintained by specific reinforcement (getting ketchup) mediated by the listener's behavior.

In this situation, the listener's response of passing the ketchup has **multiple functions** for the speaker's behavior ($S_1^r + S_2^D$ for speaker). Passing the ketchup not only functions as reinforcement for manding, but also functions as a discriminative stimulus for the next response by the speaker. That is, the same event (listener giving ketchup) can have several causal effects on the speaker. Based on the discriminative function of the listener's behavior (S_2^D for speaker), getting the ketchup sets the occasion for (:) the speaker saying "thank you," a verbal response (R_2 for speaker) that serves as generalized conditioned reinforcement for the listener's behavior (S_1^r for listener). The "thank you" response also serves as the ending point for this social episode, releasing the listener from obligations with respect to the speaker.

The Tacting Relation

Figure 12.3 is a formal analysis of the tacting relation. As with the manding relation, the verbal episode involves the interlocking contingencies of a speaker and listener. In this example, the speaker is a student and the listener is a teacher. The social episode begins in a classroom with the teacher showing pictures of objects to a young student.

When a picture of a red ball is displayed, this event causes (horizontal arrow) the teacher to say, "What color?" (examine Figure 12.3) The teacher's question (R_1) produces a verbal stimulus to the student (vertical arrow upward). In this situation, the student's answer depends on *both* the nonverbal stimulus of the red ball ($S_{1\,speaker}^D$) and the teacher's question ($S_{2\,speaker}^D$). Notice that the student will give a different answer if the question is, "What shape?"

The student's answer of "red" is formally tacting ($R_{1\,speaker}$) because the operant is regulated by the nonverbal stimulus (redness of ball). In this example, the student's tacting produces a verbal stimulus ($S_{1\,listener}^D$) for the teacher that may or may not *correspond* to the specified physical property of the ball ($S_{2\,listener}^D$). If the student's answer of "red" corresponds to color of the ball, the teacher's question of "what color" is reinforced ($S_{1\,listener}^r$). Notice how the speaker and listener complete individual operant chains (e.g., $S^D : R \rightarrow S^r + S^D : R \rightarrow S^r \ldots$) that are *interlocking*, in the sense that the behavior of each person causes stimulation and reinforcement for the behavior of the other.
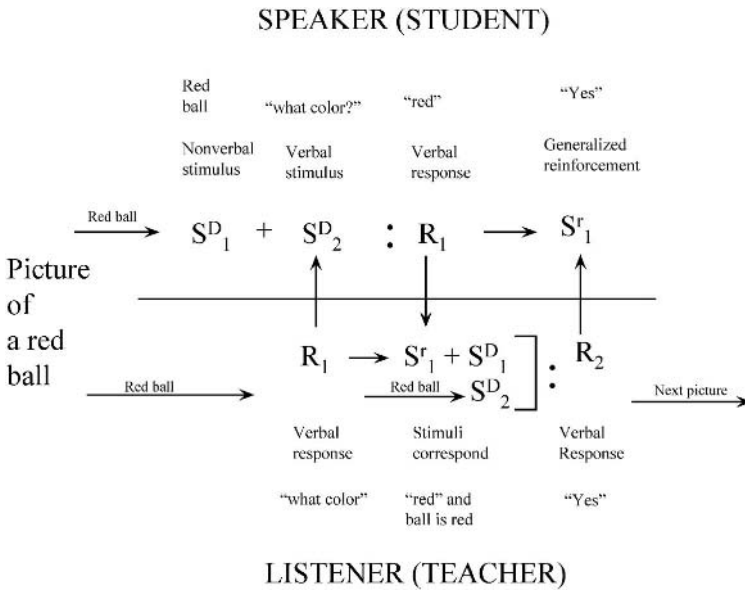
FIG. 12.3. *Analysis of the tacting relation between speaker and listener. S^D = discriminative stimulus; R = operant; S^r = reinforcement. See text for a description of the verbal contingencies.*

In terms of analysis, the teacher's question, "What color is the ball?" is manding. This verbal response is reinforced by correspondence between the student's tacting and the actual color of the object. When correspondence occurs, this condition sets the occasion for the teacher saying ($R_{2\,listener}$) "Yes" and turning to the next picture (noncorrespondence may lead to repeating the question, perhaps in a different way). The teacher's verbal response ("Yes") produces generalized conditioned reinforcement ($S^r_{1\,speaker}$) for the student's tacting and functions to maintain the operant class.

Finally, it is useful to compare the tacting and manding relations. As we have seen in the teacher–student example, the form or topography of tacting depends on an appropriate nonverbal stimulus. The redness of the ball regulated the student's verbal response. In contrast, manding depends on an establishing operation (EO) such as deprivation. The dinner without ketchup regulated asking for it. Generalized conditioned reinforcement (acceptance, praise, etc.) serves to maintain the operant class of tacting. In contrast, specific reinforcement related to an establishing operation (getting ketchup) maintains the operant class of manding.

Research on Verbal Behavior

Training of Verbal Operants: Manding and Tacting

According to Skinner (1957), the basic classes of verbal behavior are functionally independent in the sense that the relations involved in manding are distinct from those that define tacting. This functional independence means that it is possible to teach manding

and tacting as separate operant classes. It also implies that there is no basic ordering of the verbal repertoire; that is, it is not necessary to train manding in order to train tacting, or vice versa. In this section, research on basic verbal relations will be outlined and assessed in terms of **functional independence** of the response classes.

Training Manding Relations

Recall that the manding relation is defined by an establishing operation (EO) and specific reinforcement. An establishing procedure regulates the topography or form of manding behavior and sets up a specific consequence as reinforcement. To train manding, the most direct procedure is to manipulate an EO and reinforce the verbal response with the specified consequence. In the laboratory, establishing operations usually involve a history of deprivation for some event that functions as primary reinforcement (e.g., food).

Most human behavior, however, is regulated by conditioned reinforcement. To investigate the manding of conditioned reinforcement, Michael (1988) suggested the use of a **conditioned establishing operation (CEO)**. The procedure is called the blocked-response CEO, in which a response that usually occurs is blocked because of the temporary absence of a specific condition, stimulus, or event. For example, you may leave your seminar notes at home as you rush to the university. Because you cannot complete the behavioral sequence of giving a seminar presentation, obtaining the notes would function as reinforcement for making a telephone call to get them. The notes would not have a reinforcement function during a casual lunch with an old friend, because they are not necessary to this behavioral sequence. Whenever an event or stimulus is required to complete a behavior chain, withholding the event will establish it as reinforcement for operant behavior (see Michael, 2000, for a more extensive analysis).

Hall and Sundberg (1987) used the blocked-response CEO to train manding by deaf subjects. The first step was to teach a sequence or chain of responses. For example, a subject was taught to open a can of fruit with a can opener, to pour the contents into a bowl, and to eat it with a spoon. When the sequence was trained, the subject was given the items to complete the chain, except that one was missing. In this situation, a previously trained verbal response that specified the missing item (manding) was reinforced by the teacher supplying the object. Since subjects came to emit such verbal responses, it appears that CEO and specific reinforcement are regulating conditions for manding behavior (see also Carroll & Hesse, 1987; Yamamoto & Mochizuki, 1988).

There are other studies of mand training that did not manipulate an establishing operation (Hung, 1980; Rogers-Warren & Warren, 1980; Savage-Rumbaugh, 1984; Simic & Bucher, 1980; Sundberg, 1985). In these studies, humans, apes, and pigeons were required to produce a response that specified a particular object (food items or toys). The objects were shown to the subject to evoke an appropriate manding response (EO). When the verbal response occurred, the object was given and this functioned as specific reinforcement.

For example, in the study by Savage-Rumbaugh (1984), chimpanzees were shown a number of food items. If the animal pointed to the corresponding symbol on a communication panel, the item was given as reinforcement. Chimpanzees readily acquired this kind of verbal behavior and even more complex symbolic communication (Savage-Rumbaugh, 1986; Savage-Rumbaugh & Lewin, 1994; Savage-Rumbaugh, Shanker, & Taylor, 1998). However, there is some question as to the exact regulating conditions. The food items may have functioned as discriminative stimuli that set the occasion for selecting the corresponding symbol key, in which case the chimpanzee was tacting rather than manding. Because the sources of control were complex, the behavior is best described as *impure manding* (i.e., it is

attributable to the control exerted by the food items as discriminative stimuli and specific reinforcement).

In chimpanzee studies, pointing to a food symbol is taken as manding since it results in getting the item. Pointing at something is a type of manding in which the response topography or form (index finger extended) remains constant but the response is directed at different stimuli (banana, apple, etc.). This contrasts with human speech, in which the topography of the vocal response varies with the establishing operation and specific reinforcement (i.e., "give food" versus "give water"). Vocal manding facilitates discrimination by a listener (the form of response varies) and may therefore produce more rapid and precise compliance to manding . Although pointing to what you want is formally manding, saying what you want is much more effective—especially if the listener is in another room, or the object is out of sight.

Training Tact Relations

To train tact responses, a speaker must come to emit a verbal operant whose form depends on a nonverbal discriminative stimulus. A second requirement is that the operant class be acquired and maintained by *nonspecific reinforcement*. Reinforcement is nonspecific if the reinforcer for one response exerts no stimulus control over the form of the next response. In animal studies, a response may qualify as a tact even if it is reinforced with food, as long as food reinforcement does not set the occasion for a subsequent verbal response or the selection of the next symbol. For example, a chimpanzee may be offered an apple, and when it selects the symbol key for apple it is given a piece of banana. The presentation of the banana cannot set the occasion for pressing the symbol for apple on the next trial.

Tact relations have been investigated with chimpanzees. Savage-Rumbaugh (1984) used pointing to symbol keys as the verbal response. When the experimenter displayed an item of food (apple), a response to the corresponding symbol resulted in praise and the delivery of a different item of food (banana). That is, the item of food used as reinforcement always differed from the one on display.

In this situation, the display of an item of food was a nonverbal S^D that set the occasion for a response to the appropriate symbol key (tacting). Since reinforcement was nonspecific, the consequences of behavior could not regulate pointing to a particular symbol. That is, because the chimpanzee points to the apple symbol (in the presence of an apple) and is reinforced with a banana, we can be sure that the verbal response is tacting rather than manding.

Chimpanzees' symbol pointing came under the control of the displayed food items and therefore qualified as tacting. In this experiment, the *topography of the tact was the same* (i.e., pointing with finger), but its location changed. In contrast, vocal tacting in human speech involves *changes in topography depending on the nonverbal stimulus* (i.e., "that's a chair" or "there's a table"). Finally, the delivery a food item is probably not necessary and generalized conditioned reinforcement (e.g., praise, acceptance, etc) alone could be used to train tacting in both apes and human children (see Savage-Rumbaugh et al., Rumbaugh, 1993; Savage-Rumbaugh, Shanker, & Taylor, 1998; see also Sundberg, 1996 for a behavioral analysis).

Researcher have also used pigeons to investigate tacting relations. Michael, Whitley, and Hesse (1983) attempted to train tacting based on changes in response topography. Pigeons received nonspecific reinforcement (food) that depended on a bird emitting a particular form of response in the presence of a nonverbal discriminative stimulus. For example, a thrust of the head was reinforced when a red ball was presented, and turning in a circle produced reinforcement when a blue ball was the discriminative stimulus. Functionally,

this is equivalent to a child who says, "That's a red coat" and "This is a brown coat" and is reinforced by acceptance of the description by the listener. Tacting in the pigeons was successfully established even though the contingencies required correspondence between the nonverbal stimulus and the form of the bird's response. A question that is left unanswered by this research is whether pigeons (or chimps) can show generalization of a tact relation. That is, without further training, would the respective responses for blue and red occur when the objects were triangles or squares rather than balls?

In terms of application, there are behavioral experiments with language-delayed humans that trained tacting as part of a more general program of language acquisition (Carroll & Hesse, 1987; Guess, 1969; Guess & Baer, 1973; Guess, Sailor, Rutherford, & Baer, 1968; Lamarre & Holland, 1985; Lee, 1981a). Carroll and Hesse (1987) investigated the effects of alternating between mand and tact training. During mand training, a response to an object produced the item. When tacting was trained, the experimenter presented the objects as discriminative stimuli and provided praise as reinforcement for correct responses. Results indicated that subjects responded appropriately to the verbal contingencies, and that *mand training facilitated the acquisition of tacting.* That is, manding "give cup" increased the acquisition of tacting "that's a cup." This latter finding is interesting because it suggests that under some conditions, manding and tacting are not independent classes of behavior (e.g., Sigafoos, Doss, & Reichle, 1989; Sigafoos, Reichle, Doss, Hall, & Pettitt, 1990). Apparently, these verbal operant relations may interrelate as when parts of the response forms are shared (i.e., both involve the word "cup").

Experiments by LaMarre and Holland (1985) and Lee (1981b) also concerned the acquisition of tacting by language-delayed humans (see also Partington, Sundberg, Newhouse, & Spengler, 1994, for tact training of an autistic child). In these experiments, one object was placed on the left and another on the right. The tact response was saying "on the right" or "on the left" depending on the position of the object. For example, the experimenter would prompt "Where is the dog?" The subject who answered "on the right" when the dog was on the right of a flower was reinforced with social praise. This type of training successfully established verbal responses that contacted the position of an object. In another version of tact training, Guess (1969), Guess and Baer (1973), and Guess et al. (1968) trained verbal responses that contacted the quantity of an object. Subjects with language deficits were taught to emit the singular form of a noun when a single object was shown and to emit the plural form if two identical items were presented.

In these experiments, correct responses produced food, rather than praise. Thus, the subject was presented with a single cup and saying "cup" rather than "cups" was reinforced with food. Food may be defined as nonspecific reinforcement in such studies because it does not exert any stimulus control over the next verbal response, "cup." In humans, both generalized conditioned reinforcement (e.g., praise) and nonspecific reinforcement (e.g., food in the preceding example) may be used to establish tacting to various features of the nonverbal environment (e.g., position of objects, quantity, etc.).

Overall, Skinner's (1957) description of the controlling variables for manding and tacting has been verified by research on a variety of animals including primates, young children, and language-delayed humans. This research shows that manding is verbal behavior under the control of an establishing operation (EO) and specific reinforcement. In contrast, tacting is verbal behavior controlled by nonverbal discriminative stimuli and generalized reinforcement (or nonspecific reinforcement). The experimental analysis of manding and tacting has resulted in a technology of training verbal behavior in humans that do not show basic verbal skills (Sundberg & Michael, 2001). Although manding and tacting may be established as independent verbal operant classes (LaMarre & Holland, 1985), the evidence from applied research suggests that the verbal contingencies are interrelated so that training mand relations may aid in the acquisition of tact relations and vice versa.

Additional Verbal Relations: Intraverbals, Echoics, and Textuals

Intraverbal Relations

Other verbal responses also depend on discriminative stimuli. **Intraverbal behavior** is a class of verbal operants regulated by verbal discriminative stimuli. Verbal stimuli arise from verbal behavior; a verbal response by a speaker ("one, two, three, . . .") may be a stimulus for a subsequent verbal operant by the same speaker ("four"). When a verbal response ("Mary") exactly replicates the verbal stimulus (say "Mary"), we may say there is correspondence between them. In this case, the verbal behavior is defined as echoic (see below). Intraverbal behavior, however, has no point-to-point correspondence between the verbal stimulus ("jack, queen, . . .") and the response ("king").

In everyday language, thematically related words (or sentences) are examples of intraverbal behavior. For example, the verbal response "fish" to the spoken words "rod and reel" is an intraverbal operant; saying "water" to the written word "lake" is also intraverbal behavior. On the other hand, the person who says "water" to the spoken sound "water" is not showing intraverbal regulation; in this case, there is exact correspondence between the response and the stimulus, and the response is echoic.

The technique of free association (Galton, 1879) seems to depend on intraverbal regulation. Free association has been used in psychoanalysis. The psychiatrist begins by saying neutral words like "soap," "cup," and "book," and the client is asked to say the first word that comes to mind. As the session continues, the therapist introduces words that may have thematic and emotional relevance in terms of the client's problem. For example, the words dominant, overbearing, and punitive may evoke the common response "father"—suggesting a special history of aversive conditioning.

An individual who says sexual words to noncorresponding verbal stimuli also shows a particularly strong history of reinforcement. This is because the immediate consequences of free associations are not obvious and the verbal stimulus (e.g., "Regina") may set the occasion for a variety of different responses (e.g., "Canada," "Saskatchewan," "city,". . .) that have a higher probability of occurrence than a sexual word (e.g., "vagina"). Skinner (1957) analyzed free association as intraverbal behavior in the following passage:

> One verbal response supplies the stimulus for another in a long series. The net effect is revealed in the classical word-association experiment. Here the subject is simply asked to respond verbally to a verbal stimulus, or to report out loud any responses he may "think of"—that is, find himself making silently. . . . Such an experiment, repeated on many subjects or on one subject many times, produces a fair sample of the responses under the control of a standard stimulus in a given verbal community. . . . Many different responses are brought under the control of a given stimulus word, and many different stimulus words are placed in control of a single response. For example, educational reinforcement sets up many different intraverbal operants involving the cardinal numbers. *Four* is part of the occasion for five in learning to count, for six in learning to count by twos, for *one* in learning the value of π, and so on. On the other hand, many different verbal stimuli come to control the response *four*, e.g., *one, two, three, . . .* or *two times two makes.* . . . Many different connections between verbal responses and verbal stimuli are established when different passages are memorized and different "facts" acquired. The word-association experiment shows the results. (pp. 73–74)

As you can see, intraverbal relations are an important part of human behavior. This class of verbal behavior has been studied in the laboratory for many years, and it was called "verbal learning" (e.g., Ebbinghaus, 1964 [originally]) published 1885. From the behavioral

perspective, verbal learning experiments using nonsense syllables are studies of intraverbal behavior. The use of nonsense syllables enables researchers to control for previous experience and allows for the regulation of verbal responses by arbitrary combinations of stimuli.

A nonsense syllable is usually a three-letter sequence of consonant–vowel–consonant. For example, subjects are instructed to say "BEF" in the presence of the stimulus BEF, "JAH" in the presence of JAH, "PUC" for PUC, and so on. In serial learning, a list of nonsense words is presented and the subject has to remember the list. For instance, in learning the list BEF–JAH–PUC, saying "BEF" must come to occasion the response "JAH," which in turn regulates the spoken word "PUC." Notice that this problem concerns the acquisition of intraverbal behavior. The occurrence of the verbal stimulus BEF regulates the verbal response "JAH," which is acoustically different from the verbal stimulus (the verbal stimulus and verbal response do not correspond). Similarly, the occurrence of the verbal stimulus JAH sets the occasion for "PUC"—the noncorresponding verbal response.

Intraverbal training is part of our educational curriculum. In elementary school, students are taught to say the multiplication table, as in "5 × 5 equals 25" and so on. In this example, the verbal stimulus "5 × 5" exerts direct stimulus control over the response "25" and the relation is intraverbal. In contrast, a student who derives the answer "25" by adding five 5s, counting by 5s, or counting the cells in a 5-by-5 matrix is tacting the number or set of elements rather than emitting an intraverbal response. As you can see, the training of academic behavior in young children involves several verbal relations including tacting and intraverbal behavior (see DeBaryshe & Whitehurst, 1986; Partington & Bailey, 1993). Children and adults with language defects may also benefit from intraverbal training (eg., Sundberg, Endicott, & Eigenheer, 2000; Sundberg & Michael, 2001)

Echoic Relations

When there is point-to-point correspondence between the stimulus and response, verbal behavior may be classified as either echoic or textual, depending on the criterion of formal similarity. The contingencies of echoic behavior require formal similarity while the contingencies of textual behavior do not (see below). **Formal similarity** requires that the verbal stimulus and the product of the response be in the same mode (auditory, visual, etc.) and have exact physical resemblance (e.g., same sound pattern). An **echoic** is a class of verbal operants regulated by a verbal stimulus in which there is *correspondence and formal similarity* between the stimulus and response. Saying "this is a dog" to the spoken stimulus "this is a dog" is an example of an echoic response in human speech. Generally, *echoic behavior is generalized imitation along a vocal dimension* (see Chapter 11 and Poulson, Kymissis, Reeve, Andreatos, & Reeve, 1991).

Echoic behavior occurs at an early age in an infant's acquisition of speech. The child who repeats "dada" or "mama" to the same words uttered by a parent is showing echoic operant behavior. In this situation, any product of behavior (sound pattern of child) that closely replicates the verbal stimulus (modeled sound pattern) is reinforced.

Although reinforcement appears to occur along a dimension of acoustical correspondence, the contingencies of echoic behavior are probably based more on the matching of phonetic units. Catania (1998a) indicates that the learning of echoic behavior begins with the basic units of speech called phonemes. He explains:

> The significant dimensions of the units of speech called phonemes are more easily defined by articulations (position of the tongue, etc.) than by acoustic properties. . . . The interactions of articulation and sounds are complex; for example, many English consonants (e.g., *p, b, d*) can't be produced unless accompanied by a vowel, and their acoustic properties vary as a function of

context (e.g., the sounds of *l* and *k* are different in *lick* than in *kill*). Echoic behavior isn't defined by acoustic correspondence; it's defined by correspondences of the phonetic units. (p. 241)

Coordinated movements of the child's larynx, tongue, and lips results in phonemes (e.g., "ma") that replicate parts of adult speech ("ma…ma"). When articulations by the child correspond to those of the adult, the acoustical patterns also overlap. Adults that hear speech-relevant sounds ("ma") often provide social consequences (e.g., tickling, poking, etc.) that are paired with these acoustical patterns. On this basis, the duplication of speech sounds itself comes to function as automatic reinforcement for speech relevant articulations by the child (Yoon & Bennett, 2000).

It is important to emphasize that echoic behavior is not simply the duplication of sounds. As a verbal operant, echoic performance is regulated by specific reinforcement contingencies based on articulation. Echoic contingencies in humans involve reinforcement by listeners of correspondence of basic speech units rather than the mere reproduction of sounds. These units begin as phonemes (i.e., smallest sound units to which listeners react), expand to words, and eventually may include full phrases and sentences. In contrast, parrots and other birds duplicate the sounds they hear (Pepperberg, 1981) but their behavior is not necessarily verbal in Skinner's (1957) sense. Parrots will reproduce sounds or noises even when these responses produce no change in the behavior of the listener. For this reason an infant's speech is echoic behavior, but a parrot's "speech" is not.

Echoic contingencies are most prevalent during language acquisition. This means that an infant's vocalizations will have more echoic components than the speech of an adult. It also implies that adult speech will become more echoic when a person is learning to speak a second language. Thus, a Spanish teacher may demonstrate word pronunciation to a student who initially makes many errors in articulation. The teacher gives repeated examples, and the student is reinforced for correct pronunciation. After some practice and correction, the student's pronunciation is close to that of the teacher's. Only when the speech units correspond is the student said to show competence in pronunciation of Spanish.

Textual Relations

Verbal behavior is textual when there is no formal similarity between the stimulus and response. **Textual behavior** is defined as a class of verbal operants regulated by verbal stimuli where there is correspondence between the stimulus and response, but no formal similarity. The most common example of textual behavior is reading out loud. The child looks at the text, See Dick see Jane and emits the spoken words "See … Dick, … see … Jane." In adult reading, the behavior is also textual but the "out loud" aspect is no longer emitted—the person reads silently so that the response is now a private event. Textual behavior is also observed when a secretary *takes dictation* from his or her boss. In this case, hearing the words "Dear Mr. Smith …" spoken by the boss sets the occasion for writing these words by the secretary. Again, correspondence between the stimulus and response occurs but there is no formal similarity.

Analysis of Complex Behavior in the Laboratory

Faced with the complexity of verbal behavior, many people find it hard to believe that basic behavior principles, such as stimulus control, shaping, and schedules of reinforcement, can eventually account for this kind of human activity. It is useful therefore to step back and

consider the contingencies of complex behavior. Analysis of these contingencies convinced Skinner (1957) that operant principles could eventually provide a natural science account of human language. [Note: Chomsky (1957, 1959) argued against behavior principles and for a system of mental rules underlying the speaker's performance; interestingly, Schoneberger (2000) proposes that Chomsky's second revolution now rejects the mental rules account of language and his former ties to cognitivism.]

Although there are many distinctions between the verbal behavior of humans and the complex behavior generated in pigeons, the laboratory analog identifies some of the basic contingencies that play a role in human language acquisition. In this section, we consider experimental procedures that result in pigeons showing conditional discriminations, symbolic communication, and communication of internal and private events. Many of these behaviors, if observed in humans, would be attributed to "higher mental processes" rather than the contingencies of reinforcement that were known to produce them.

Let's begin with a fairly complex set of contingencies for pigeons. Consider a conditional-discrimination experiment described by Catania (1980), in which a pigeon is placed in an operant chamber with left and right keys (Figure 12.4). Stimuli can be projected on the keys, and a light is situated in one corner of the response panel, allowing general illumination of the chamber (i.e., a houselight). The stimuli consist of circles with horizontal or vertical lines and triangles with similar angled lines (see matrix of Figure 12.4). Centered below the keys is a feeder that provides food reinforcement depending on the prevailing conditions. When the houselight is ON, pecks to the left or right keys are reinforced according to line angle, horizontal or vertical (ON = peck by line angle). If the houselight is OFF, pecks to the keys produce food on the basis of form, circle or triangle (OFF = peck by form). There are four possible arrangements of the two keys by line angle when the houselight is ON and four other arrangements by form when the houselight is OFF. For each session the houselight is illuminated or not, and the four arrangements by line angle (or form) are presented in random order.

Figure 12.4 portrays the contingencies based on whether the houselight is ON or OFF. During sessions when the houselight is ON, pecks to the left key are reinforced if the line angle projected on the two keys is horizontal (HORIZONTAL = peck left key) and pecking the right key is on extinction. When the line angle on the two keys is vertical, pecks to the right key produce food (VERTICAL = peck right key) and pecking the left key is on extinction. Notice that the form of the stimuli (triangles or circles) has no function when the houselight is ON or illuminated.

In contrast, when the houselight is OFF, key pecks are reinforced depending on form, and line angle no longer has a stimulus function. If circles are presented on the two keys, pecks to the left key are reinforced (CIRCLES = peck left key) and pecking the right key is on extinction. When triangles are projected on the keys, pecks to the right key produce food (TRIANGLES = peck right key) and pecking the left key is on extinction. Notice that the line angle (horizontal or vertical) has no function when the houselight is OFF.

Assuming that the bird's pecking is regulated by the appropriate stimuli, we may say that the performance demonstrates a **conditional discrimination**. Pecking the keys depends on line angle or form conditional on the illumination of the houselight. These conditional relations among stimuli and responses are also observed in verbal behavior. A child provides the answer of "five" when presented with a picture of five dimes and the question, "How many coins?" When asked "What kind of coins are these?" the child will respond "dimes." This kind of verbal performance involves contingencies similar to the ones that produce conditional discrimination in the laboratory.

This does not mean that the pigeon's performance should be called verbal. The laboratory procedure shows that nonverbal processes (conditional discrimination) may play a role in
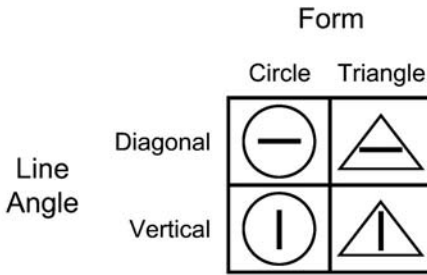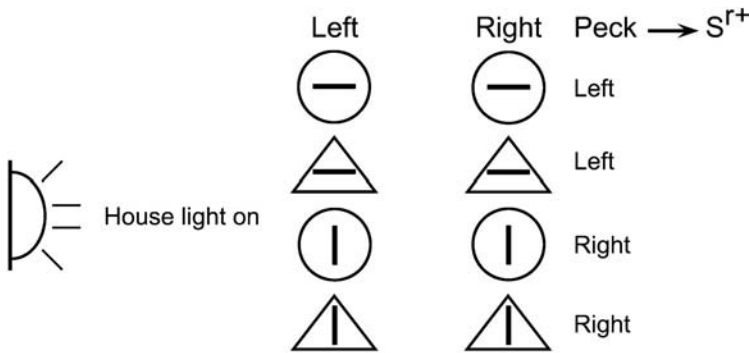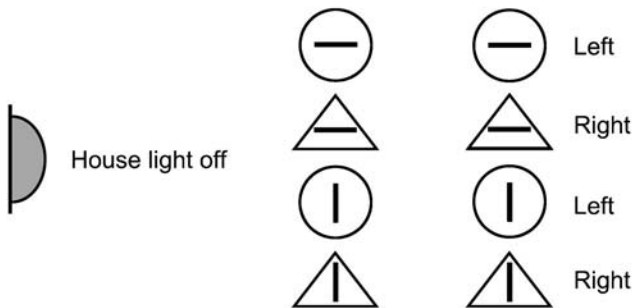
FIG. 12.4. *A conditional discrimination experiment as described in the text (based on the hypothetical experiment described by Catania, 1984). A matrix of possible shapes and line angles is shown. When the houselight is ON reinforcement is based on line angle; the pigeon pecks left if the line angle is horizontal and pecks right if it is vertical. When the houselight is OFF reinforcement is based on geometric form; the bird pecks left when the shape is a circle and pecks right when it is a triangle.*

verbal behavior. In the pigeon experiments, the bird responded to color and form only within the narrow context of the operant chamber. Verbal behavior in humans is not limited to specific situations or circumstances. You may also have noted that the bird's performance was maintained by food, and this is seldom the case with human verbal behavior. Additionally, no audience responded to the performance and mediated reinforcement. In each of these respects, and perhaps others, the pigeon's behavior may be distinguished from human verbal

performance. The point, however, is that conditional control by stimuli (e.g., four-term contingencies) are important in an analysis of human behavior, and this is especially so for verbal behavior.

Symbolic Communication in Animals

One implication of complex stimulus control in the laboratory is that animals exposed to such contingencies often acquire behavior that in humans is said to reflect mental or cognitive processes. That is, human communication is said to be caused by our expanded brain capacity and cognitive abilities. Behavior analysts offer an alternative to the mental capacity approach, arguing that symbolic communication is caused by special contingencies of reinforcement. To test this assumption, nonhuman organisms have been trained to emit verbal responses. In this research, one subject is designated the speaker and the other the listener. The roles of speaker and listener are used here to suggest the verbal exchange between two organisms, one who asks for and uses information (listener) and the other who supplies it (speaker).

The Jack and Jill Experiment

 Communication in pigeons was first reported by Epstein, Lanza, and Skinner (1980). [Note: the original experiment used discrimination procedures based on color; the illustrations in this textbook are in black and white and for clarity we will substitute procedures based on geometric form (e.g., triangles) rather than color.] The pigeons, called Jack and Jill, were placed in separate chambers with a clear Plexiglas partition between them (see Figure 12.5). In the original procedure, Jack was the listener and Jill was the speaker (see Epstein & Skinner, 1981, for implications of training both birds as speaker and listener). Following basic training for both birds to establishing the respective operant chains, the interaction began when Jack pecked a key in his chamber with the words *What form?* projected on it. When this happened, one of three forms—triangle, circle, or square—was illuminated in Jill's chamber. Importantly, the form was hidden by a curtain and could not be seen by Jack (check this out in Figure 12.5).

The speaker, Jill, thrust her head behind the curtain and looked at the geometric form projected on a disk. Following this, she pecked one of three symbol or letter keys, labeled with the letters T, C, or S (T = triangle; C = circle; S = square), that matched the form she had observed behind the curtain. When Jack looked into Jill's chamber, he saw which symbol key she had pecked; he then pecked his *Thank you* key that in turn operated Jill's feeder for a few seconds. Following this, Jack pecked one of three form keys in his chamber (e.g., triangle, circle, or square) that corresponded to the symbol (T, C , or S) selected by Jill. If Jack matched his form key to the symbol pecked by Jill (e.g., pecked his triangle key when Jill had pecked her T symbol key), this response operated Jack's feeder for a few seconds. An incorrect response resulted in a short time out. After 5 days of this interaction, the pigeons were accurate on more than 90% of the trials.

Formally, the experiment involved training pigeons in manding and tacting. The role of listener (Jack) required manding, *What form?* His "question" is manding that is reinforced by Jill reporting the form she had observed behind the curtain. Jill "reports" her observation by pecking one of the three symbol or letter keys. This "report" by the speaker (Jill) allows the listener (Jack) to peck the corresponding geometric form on his panel. Because pecking the correct form is part of a sequence that leads to food, hiding the geometric shape from the listener may be viewed as a *conditioned establishing operation* (blocked-response procedure) in this experiment.
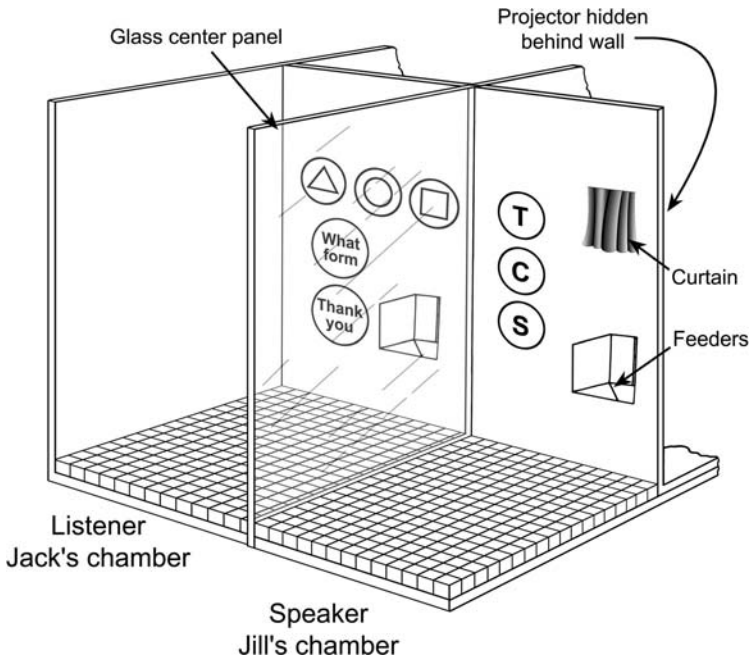
FIG. 12.5. *Based on the chambers and key arrangement for the Jack and Jill experiment as described in "Symbolic Communication Between Two Pigeons (Columbia livia domestica)," by R. Epstein, R. P. Lanza, and B. F. Skinner, 1980, Science, 207, pp. 543–545. For clarity, we have substituted line angles for color stimuli. The experiment involved communication between two pigeons. The curtain in Jill's chamber hides a projected geometric form (triangle, circle, or square). The letter or symbols correspond to the geometric forms (T = triangle, C = circle, and S = square). Jack matches geometric form (triangle, circle, or square) to the symbol key (T, C, or S) pecked by Jill. See text for a description of the contingencies.*

The speaker's sequence also is initiated when the listener pecks *What form?* In the presence of this verbal stimulus, the speaker must look at the form behind the curtain and "report" on the shape she has seen. Pecking the correct symbol key is formally tacting in Skinner's (1957) classification of verbal behavior. The symbolic response qualifies as tacting because it is controlled by a nonverbal aspect of the environment (the hidden color) and results in nonspecific reinforcement (i.e., the food supplied when the listener pecks *Thank you*). A nonspecific reinforcer is one that does not specify the topography of a subsequent tacting response. The speaker pecks T, C, or S and is reinforced with grain. The presentation of grain at the end of the listener–speaker interaction does not control which symbol the speaker pecks on the next trial.

Communication and Generalized Reinforcement

In human communication, tacting emitted by a speaker almost never result in food reinforcement. It is therefore important to know whether pigeons will continue to tact when this behavior is supported by generalized conditioned reinforcement. An experiment by Lubinski and MacCorquodale (1984) was designed to answer such a question.

These researchers established a generalized conditioned reinforcer for the speaker by pairing a flashing light with the presentation of both food and water. On some days the
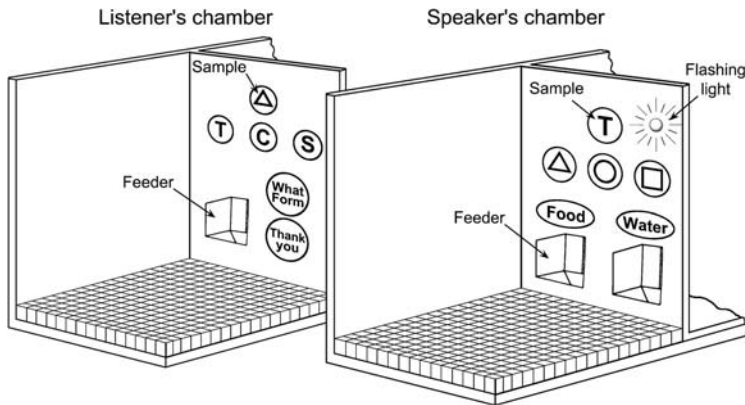
FIG. 12.6. *Based on the chambers and key arrangements for speaker and listener as described in "'Symbolic Communication' Between Two Pigeons* (Columbia livia) *Without Unconditioned Reinforcement," by D. Lubinski and K. MacCorquodale, 1984,* Journal of Comparative Psychology, *98, pp. 372–380. For clarity, we have substituted geometric forms for color stimuli. The experiment concerned tacting in a pigeon maintained by generalized conditioned reinforcement (the flashing light). Following a response of "What form" by the listener bird, the sample key in the speaker's chamber presented a symbol T, C, or S. Depending on the sample, the speaker pecked one of three geometric forms (T = peck triangle; C = peck circle; S = peck square). This response activated the sample key in the listener's chamber with a corresponding geometric form. Next, the listener pecked the "Thank you" key that activated a flashing light in the speaker's chamber (and provided the choice of food or water). The listener then pecked one of three symbol keys (T, C, or S) and a response that matched to the sample resulted in food reinforcement for the listener. See text for a description of the contingencies.*

pigeon was food-deprived, and on other days it was deprived of water. Occasionally, the bird was deprived of both food and water. When food-deprived, the pigeon could peck a key that operated a feeder. When the bird was thirsty, it could peck a different key to produce water. Importantly, responses for food or water were only effective when a light was flashing in the chamber. The flashing light became a *generalized conditioned reinforcer* because it was associated with more than one source of primary reinforcement (food and water).

After extensive training of the requisite operant chains, the interaction of the pigeons was similar to the performances of Jack and Jill (Epstein et al., 1980). This occurred even though the keys, procedures, and chambers were different (see Figure 12.6). As in the Jack and Jill experiment, one bird (the listener) started the interaction by pecking the key with *What form?* projected on it. This response produced a letter (T, C, or S) that was projected on the other bird's (the speaker's) sample disk. The speaker then pecked one of three form keys—triangle, circle or square—that corresponded to the letter (T, C , or S) on the sample disk. Notice that in this experiment by Lubinski and MacCorquodale (1984), the speaker is presented with a letter or symbol sample and "reports" its observation by pecking the matching form key; in the Jack and Jill experiment, the bird observes the hidden form and "reports" by pecking a letter or symbol. Both experiments involve the *interlocking contingencies* between a speaker and a listener.

When the speaker pecked one of the form keys, the listener pecked a *Thank you* key that activated the flashing light (generalized conditioned reinforcement) in the speaker's chamber. When the light started flashing, the speaker could produce reinforcement by pecking either the food or water keys. The *Thank you* response also turned on a sample disk in the listener's chamber. A geometric shape was projected on the listener's sample disk that

corresponded to the form pecked earlier by the speaker. Finally, the listener was reinforced with food if the bird pecked one of the three letter keys that matched the form presented on its sample disk. Overall, the birds were highly successful at mastering this kind of symbolic communication.

As the experiment progressed, the researchers tested whether the speaker would continue to emit tact responses (i.e., pecking the form key corresponding to a sample letter) when satiated on primary reinforcement. On some days the pigeon was satiated on both food and water, so that the only consequence of tacting was the flashing light (generalized conditioned reinforcement). Under these conditions, accurate tacting was maintained but the frequency of tacting responses decreased substantially. Apparently, for pigeons, some level of deprivation is required on at least one reinforcement dimension to maintain the effectiveness of generalized conditioned reinforcement and a high probability of tacting responses. On the other hand, *the experiment showed that tacting in the pigeon would occur even when the only consequence was reinforcement from the "flashing light."*

Research on nonhuman communication plays an important role in behavior analysis (see Lubinski & Thompson, 1993, for a review). In such experiments, the researcher must guess about the kind of experiences that allow for "language-like" verbal interactions. To do this, the behavior analyst must consider the principles of behavior and how they might apply to such a complex problem. Notice that communication in these experiments depends on one organism manding (What form?) and the other tacting (e.g., pecking the form key corresponding to the symbol on the sample). The behavior of the speaker supplies reinforcement (i.e., reporting the form) for the listener's manding ("What form?"). The subsequent response by the listener, *Thank you,* provides generalized conditioned reinforcement (flashing light) for the speaker's tacting. These sources of reinforcement maintain the *interlocking contingencies* that compose a social episode.

Although human communication involves far more than the manding and tacting of symbols and forms, these nonhuman experiments point to the *basic elements* that underlie symbolic communication. This research also suggests that *human communication may arise from the simultaneous interplay of relatively simple principles of behavior*—in this case, shaping, fading, chaining, and discrimination procedures.

FOCUS ON: REPORTS OF PRIVATE EVENTS BY PIGEONS

One of the actions that is said to separate humans from other animals is the ability to report on internal states and feelings. Behaviorists have maintained that humans do not have special capabilities that give them knowledge of themselves. Rather, behavior analysts suggest that self-description is something a person learns by interacting with others who ask questions about the person (e.g., "How do you feel?"). *It is only because of special verbal contingencies that a person acquires a repertoire of self-description* (Bem, 1965; Skinner, 1957).

As we have seen in earlier chapters, behavior analysts treat the internal and external happenings of an organism as *physical* events. The only difference between the external environment and the one inside of us is that internal events are private. This privacy means that *internal events are less accessible* to others and, as a result, it is more difficult for the verbal community to teach a person to describe internal events accurately.

When a verbal response is controlled by a nonverbal discriminative stimulus, this response is functionally defined as tacting. A person who has learned to describe the up-and-down flight of a butterfly may say "I have butterflies in my stomach" when upset or nervous. This response is analyzed as extended or *generalized tacting*—the person describes

an upset stomach the same as a person describing the motion of a butterfly. This suggests that self-description is, in part, based on the verbal relations involved in tacting.

To set up a report on a private event (tacting), it is necessary to have a public event that is well correlated with this private happening. For example, a bump on the head and crying usually accompany painful private stimulation. A child who bumps her head and cries may occasion the response "Oh, you're hurt" by the parent. In this situation, the child is asked where it hurts and how she feels. The youngster is reinforced when she accurately reports "I hurt my head" and "it hurts a lot." Although parents use public events (bumps and crying) to train self-description, *the public cues are usually well correlated with private stimulation* (physical damage). Because of this correspondence, private stimulation eventually comes to regulate self-descriptive responses (e.g., "I am hurt") even in the absence of public signs like crying.

The verbal relations that are presumed to set up a self-descriptive repertoire may be arranged in a laboratory (see Lubinski & Thompson, 1993, for an overview). A pigeon is a useful organism to test these ideas because pigeons are not usually able to describe themselves. Lubinski and Thompson (1987) therefore used pigeons that were trained to discriminate among the private stimulation produced by different drugs (S^Ds) and to "report" how they felt in each condition ($R_{tacting}$) for generalized conditioned reinforcement (S^r). *This is another example of communication in nonhuman organisms, but the experiment involves reporting on internal (private) drug effects rather than external events (S^Ds) like triangles, circles or squares.* Again, the internal effects of the drugs are treated as physical events that pigeons can discriminate, just as pigeons can discriminate among shapes projected on a key. Presumably, humans also discriminate among internal stimulations and are trained by the verbal community to report on these (physical) events. The basic point is that describing one's feelings and emotions is behavior controlled by the *interlocking contingencies* among speakers and listerners (the verbal community).

In Lubinski & Thompson's (1987) experiment, two pigeons were placed in separate chambers, as shown in Figure 12.7. One bird was the "mander" or listener and the other
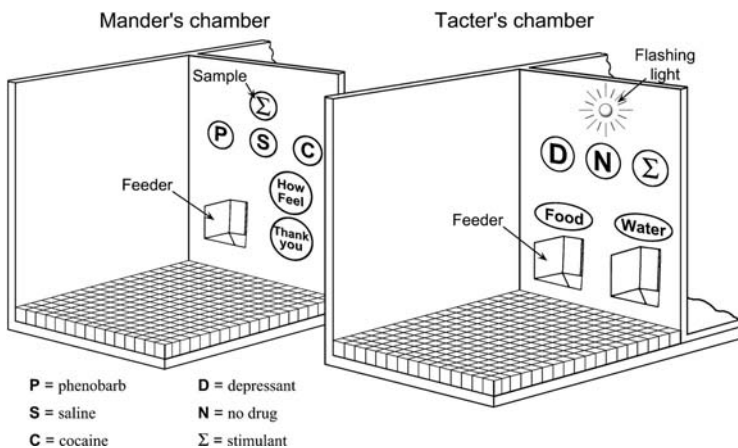
FIG. 12.7. *The chambers and key arrangements for speaker and listener in the experiment on communication of internal states by pigeons, as described in "An Animal Model of the Interpersonal Communication of Introceptive (Private) States," by D. Lubinski and T. Thompson, 1987,* Journal of the Experimental Analysis of Behavior, 48, *1–15. The symbols D, N, and Σ are equivalent to depressant, no drug, and stimulant. The other symbols P, S, or C are equivalent to phenobarbital, saline, and cocaine. The flashing light functions as generalized conditioned reinforcement for the behavior of the tacter bird. See text for a description of the contingencies.*

was the "tacter" or speaker, as in other studies of communication in pigeons described in this chapter. The first step was to develop a generalized reinforcer for the tacter. That is, pecking a key for food or a key for water was reinforced only when a blue light was flashing (cf. Lubinski & MacCorquodale, 1984). After this training, the tacter bird was given a drug that was either a depressant, a stimulant, or a saline solution (salt water). Private stimulation consisted of the introceptive effects produced by the different kinds of drugs or chemicals.

Again after extensive training to establish the behavioral sequences, the interaction began with the mander (listener) pecking a *How do you feel?* key in its chamber. This response illuminated three keys in the tacter's (speaker's) chamber. Each key had a symbol, D for depressant, N for no drug, and Σ (sigma) for stimulant. The tacter had to peck a symbol key that corresponded to the drug it had received (D after an injection of phenobarbital; N after saline; Σ after cocaine) . When this occurred, a sample disk illuminated in the mander's chamber with the symbol reported by the tacter (e.g., Σ), and at the same time a *Thank you* key was illuminated. Pecks to the *Thank you* key by the manding bird activated a flashing blue light in the tacter's chamber. The tacting bird could then receive food or water by pecking the corresponding keys.

The interaction ended with the mander pecking one of three comparison keys that matched the sample (D, N, or Σ) reported by the tacter bird. The mander's three keys had the letters P, S, or C on them: P for phenobarbital, S for saline, and C for cocaine. If the symbol N (no drug) was the sample (the tacter had pecked the N key), pecking the S key for saline resulted in food reinforcement for the mander. Reinforcement also occurred if the mander pecked its P key for pentobarbital when D (depressant) was the sample, or pecked the C key for cocaine when Σ (stimulant) was the sample. Notice that this experiment is similar to the experiments in which pigeons reported on a hidden forms or symbols. The interesting twist on the procedure is that the tacting bird reports an internal and private drug state ("I am on a stimulant" = Σ). The mander, on the other hand, indicates her "understanding the feeling" by matching the symbol for the drug to the sample (pecking the C key for cocaine).

Although these complex behavioral sequences took a long time to train, eventually the tacter's "reports" and the mander's "comprehensions" were highly accurate—exceeding 90% reliability. At this point, Lubinski and Thompson (1987) conducted additional experiments on the communication of internal events, in order to extend the findings to human behavior. In a test for generalization, the researchers substituted the drug Dexedrine (*d*-amphetamine) for cocaine and Librium (chlordiazepoxide) for pentobarbital. Although the Dexedrine and Librium differ chemically and pharmacologically from cocaine and pentobarbital, both share pharmacological properties with these agents. *The generalization tests showed that accurate reporting of drug effects occurred even when the same bird was given a different depressant and stimulant.* This finding suggested that the tacting response (i.e., pecking the symbol key that corresponded to the drug effect) had generalized to a class of drugs with common chemical effects. In addition, the experiments showed that *accurate tacting of the drug effects could be maintained by generalized conditioned reinforcement* (as would be the case in human reports of internal states). In this case, the tacting bird was satiated on food and water, and the only result of the report was the blue flashing light. Even though the number of tacts declined, the pigeon was still highly reliable at reporting on the internal effects of the drugs.

The research on private events by Lubinski and Thompson (1987) is an important step in the analysis of verbal behavior and self-description. The contingencies arranged by the researchers resulted in a complex sequence of behavior between two pigeons. *When birds are exposed to verbal contingencies that are presumed to operate in human behavior, they begin to act something like humans—reporting on how they feel to one another* (cf. Lubinski & Thompson, 1993).

Self-reference in humans is also trained through the socialization practices of the community (Bem, 1965). People in different parts of the world (e.g., India) are able to contact and describe internal events that are usually unavailable to North Americans. These people receive religious and educational training that make them more "aware" of themselves. Although mystical explanations have been given for such abilities, contingencies of reinforcement provide a scientific account of this kind of human behavior.

Symbolic Behavior and Stimulus Equivalence

For most Americans, the flag is a significant symbol. When we see the flag, we may think of the United States, mother, and apple pie. This suggests that symbolic behavior involves the training of **stimulus equivalence**. The presentation of one class of stimuli (e.g., flags) occasions responses made to other stimulus classes (e.g., countries). This seems to be what we mean when we say that the flag stands for, represents, or signifies our country. Equivalence relations such as these are an important aspect of human behavior. For example, in teaching a child to read, spoken words (names of animals) are trained to visual stimuli (pictures of animals) and then to written symbols (written words for animals). Eventually, the written word is then said to stand for the actual object, in the same sense that a flag stands for a country. In this section, we will examine the behavior analysis of equivalent relations as an account of symbolic activity and meaning.

Recall that symbolic communication in pigeons is based on a procedure known as matching to sample. In the Jack and Jill experiment by Epstein et al. (1980), the listener, Jill, looked behind a curtain at a color projected on a plate (red, green, or yellow) and then pecked and illuminated one of three symbol keys with black on white letters (R, G, or Y). Although this performance seems to involve symbolic behavior, this is not the only possibility. Jill may simply have learned a stimulus–response chain, or a conditional (if red, peck R) relation.

If the stimuli were functioning as symbols for Jill, then each letter would stand for a color, and each color would stand for its corresponding letter. The stimuli would be equivalent—the colors would substitute for letters, and vice versa. In the communication experiments, Jill was taught to match a set of colors to a set of letters. This may be called an A to B relation (A = B). Given a member of Set A (e.g., red), the pigeon is reinforced for pecking the corresponding member of Set B (e.g., R). If the A class of stimuli is equivalent to the B class, it follows that Jill should be able to do the reverse, *without any further training*. That is, if Jill is presented with a member of Set B (e.g., Y), she should peck the corresponding stimulus in Set B (yellow). In this case, a B to A relation (B = A) would have emerged from the initial A to B training. Unfortunately, Epstein et al. (1980) did not test for this emergent performance, and we cannot be sure that Jill's communication involved stimulus-equivalence relations.

Basic Equivalence Relations

When stimulus class A is shown to be interchangeable with stimulus class B (if A = B then B = A), we may say that the organism shows **symmetry** between the stimulus classes. Symmetry is only one form of equivalence relation. A more elementary form of equivalence is called **reflexivity**. In this case, an A to A relation (A = A) is established so that given the color red on a sample key, the organism responds to the comparison key with the identical

color (red). A child who is given a picture of a cat and then finds a similar picture in a set of photographs is showing reflexivity.

Reflexivity and symmetry are basic logical relations of mathematics. A child who is presented with the number 1 shows reflexivity when she points to 1 in an array of numbers {2,3,1,4,5}. The same child shows symmetry if, when given the number 2, she selects the set {X,X} rather than {X} or {X,X,X}, and when given {X,X} she selects 2 from the array {3,2,1,5,4}.

There is one other equivalence relation in mathematics. This is the relation of **transitivity**. If the written numbers one, two, three are equivalent to the arithmetic numbers 1, 2, and 3, and these arithmetic numbers are equivalent to the sets {X}, {X,X}, and {X,X,X}, it logically follows that one, two, and three are equivalent to the sets {X}, {X,X}, and {X,X,X}. That is, if A = B and B = C, then A = C (transitivity).

Experimental Analysis of Equivalence Relations

Although equivalences are logically required by mathematics, it is another thing to show that the behavior of organisms is governed by such relations. In terms of behavior, three stimulus classes (A, B, and C) are called equivalent when an organism has passed tests for reflexivity, symmetry, and transitivity.

A complete experiment for stimulus equivalence consists of both identity and symbolic matching procedures. In **identity matching**, the researcher presents a sample stimulus (e.g., triangle) and two options (e.g., triangle or circle). The organism is reinforced for choosing the triangle option that corresponds to the triangle sample (i.e., matching to sample). **Symbolic matching** involves presenting one class of stimuli as the sample (e.g., geometrical forms) and another set of stimuli (e.g., different line angles) as the options. Reinforcement depends on an arbitrary relation (e.g., triangle = horizontal). After the reinforced relations are trained, tests are made for each kind of equivalence relation. *The question is whether reflexivity, symmetry, and transitivity occur without further training.* To make this clear, identity and symbolic matching are training procedures that allow for stimulus equivalence, but the procedures do not guarantee it. We will describe such an experiment in a step-by-step manner.

Figure 12.8 presents the identity-matching procedures used to show reflexivity. The training involves identity matching for line angles or geometric forms by a pigeon. The bird is presented with three keys that may be illuminated as shown in the two displays (Display A or B). For each display, two sets alternate on the three keys. A set includes a sample key and two option keys. For the sake of clarity, in our example the option (side key) that matches the sample is always shown on the left of the displays, and the nonmatching option is on the right. *In real experiments, of course, the position of the matching stimulus varies from trial to trial, eliminating any left or right bias.* A peck on the sample key illuminates the option keys, and pecks to the matching key produce food and the next sample. Pecks to the nonmatching key are not reinforced and lead to the next trial (i.e., the next sample).

Reflexivity

Reflexivity or generalized identity matching may be shown using this identity-matching procedure. In the Display A (angle match) of Figure 12.8, the sample key presents a line angle (horizontal). When the pigeon pecks the sample key, horizontal and vertical stimuli are presented on the side keys (matching and nonmatching) . Pecks to the horizontal matching key are reinforced with food, while pecks to the vertical nonmatching key are not. The next trial may present Display B (angle match). Now the sample is a vertical line.
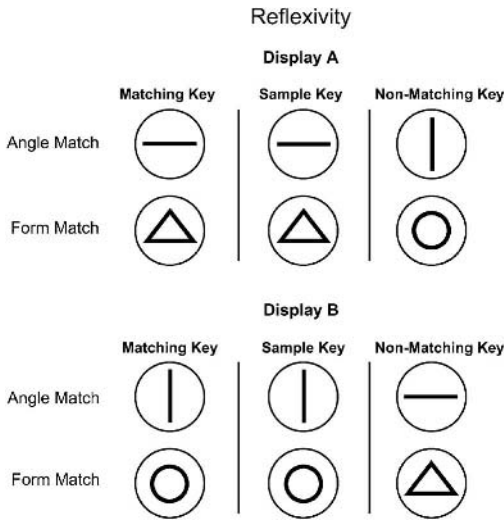
FIG. 12.8. *The identity matching proce-dures that would be used to establish reflexiv-ity in pigeons as described by Catania (1984). First, train matching to angles using the an-gle match arrangements in Displays A and B (top). Next, train matching to form using the form match arrangements in Displays A and B (bottom). Finally, test for reflexivity or gener-alized identity matching using color match-ing displays (not shown). See text for a de-scription of the contingencies.*

If the bird pecks the vertical line matching key, it receives food, but pecks to the horizontal line nonmatching key are extinguished. Based on this training and many more matching to sample trials, the bird learns to identify line angles (identity matching).

Similar procedures may be used to train identity matching based on geometric form. In Figure 12.8 Display A (form match), the form display is based on triangles and circles. When Display A is in effect, the sample key is illuminated with a triangle. Pecks to the sample produce the two options—triangle and circle. Pecks to the key that matches the sample are reinforced, while pecks to the nonmatching geometric form are placed on extinction. A new trial may result in Display B (form match). In this case, the sample is a circle. When the bird pecks the sample two options are presented on the side keys (circle and triangle). Pecks to the key with a circle produce food, but pecks to the triangle are extinguished. Using these procedures, the pigeon learns to identify geometric forms.

Reflexivity is shown by a test for generalization of identity matching. A test for reflexivity would involve testing for generalization of identity matching based on the training of matching to sample based on angle and form. For example, a bird trained to identity match to angle and form could be tested with colors (green or red) as the sample and comparison stimuli. A bird that pecks to the color that matches the sample, without specific training on colors, shows reflexivity or generalized identity matching.

Symmetry

Figure 12.9 shows the procedures used to train symbolic matching and the tests for symmetry. These procedures are implemented only after a bird has shown identity matching. For example, symbolic matching occurs if the bird is trained to discriminate geometric shapes on the basis of angles (angle-to-form discrimination). **Symmetry** occurs if the bird can pass a test for *reversal* (form-to-angle discrimination) without further training.

This procedure is shown by the angle-to-form display of Figure 12.9 (Display A). Pecks to the horizontal sample illuminate the side options—triangle or circle. In the presence of the horizontal-line sample, pecks to the triangle are reinforced while pecks to the circle are not. When Display B is presented, the sample is the vertical line and pecks to the circle are reinforced while pecking the triangle is on extinction.
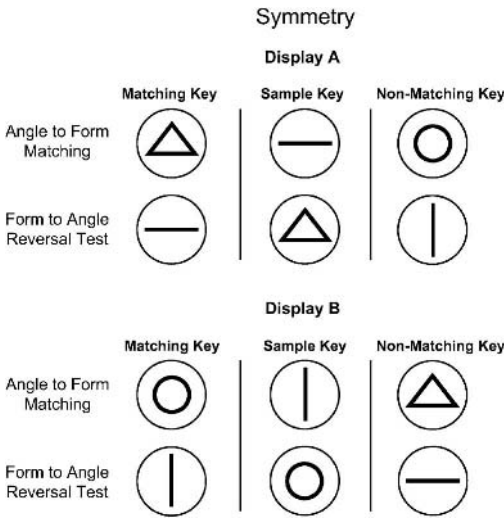
FIG. 12.9. *The symbolic matching procedures that would be used to train and test for symmetry in pigeons, as described by Catania (1984). First, train angle-to-form matching (Angle = Form) using the arrangements of Displays A and B (top). Next, test for reversal or symmetry (Form = Angle) using the form-to-angle arrangements of Displays A and B (bottom). See text for a description of the contingencies.*

Once the matching of angle to geometric form is well established, a **reversal test** (form to angle) is conducted without any further reinforcement. In reversal test of Display A, the bird is presented with a triangle as the sample and the question is whether it pecks the side key with the horizontal line. Because horizontal = triangle was trained, the bird shows symmetry if it pecks the horizontal comparison key when presented with a triangle sample (triangle = horizontal). Similarly, because vertical = circle was trained, symmetry is shown if the bird pecks the vertical side key of Display B when the circle is presented as the sample (circle = vertical). In everyday language, the bird responds as if the horizontal line stands for triangle and as if the vertical line means circle. The percentage of "correct" responses during the test (without reinforcement) is the usual measure of symbolic performance on this symmetry task.

Transitivity

Figure 12.10 illustrates the procedures that may be used to train and test a pigeon for transitivity. These procedures would be used only if a bird had passed the tests for reflexivity and symmetry. Rows 1 and 5 (Display A and Display B) of the figure present the angle-to-form (symbolic matching) procedures for symmetry that were described earlier (horizontal = triangle; vertical = circle). To test for transitivity, the pigeon is trained to produce an additional discrimination. Rows 2 and 6 of Displays A and B illustrate this training. The pigeon is reinforced for matching a geometric form to intensity of illumination on the option keys—darker or lighter key. For example, in row 2 Display A, pecking the lighter option key is reinforced when a triangle is the sample (triangle = lighter) and pecking the darker key is not reinforced; also, row 6 of Display B shows that pecking the darker key produces food when a circle is the sample (circle = darker) while pecking the lighter option is on extinction.

Notice that the bird is trained that horizontal = triangle and vertical = circle (rows 1 and 5) and has shown the reversal on tests of symmetry. Given this performance, if triangle = lighter and circle = darker (rows 2 and 6), then the following relations could occur without explicit training on transitivity tests: horizontal = lighter, and lighter = horizontal (rows 3 and 4), also vertical = darker, and darker = vertical (rows 7 and 8). These tests would establish transitivity in the pigeon, showing that the bird responds to the set of line angles as
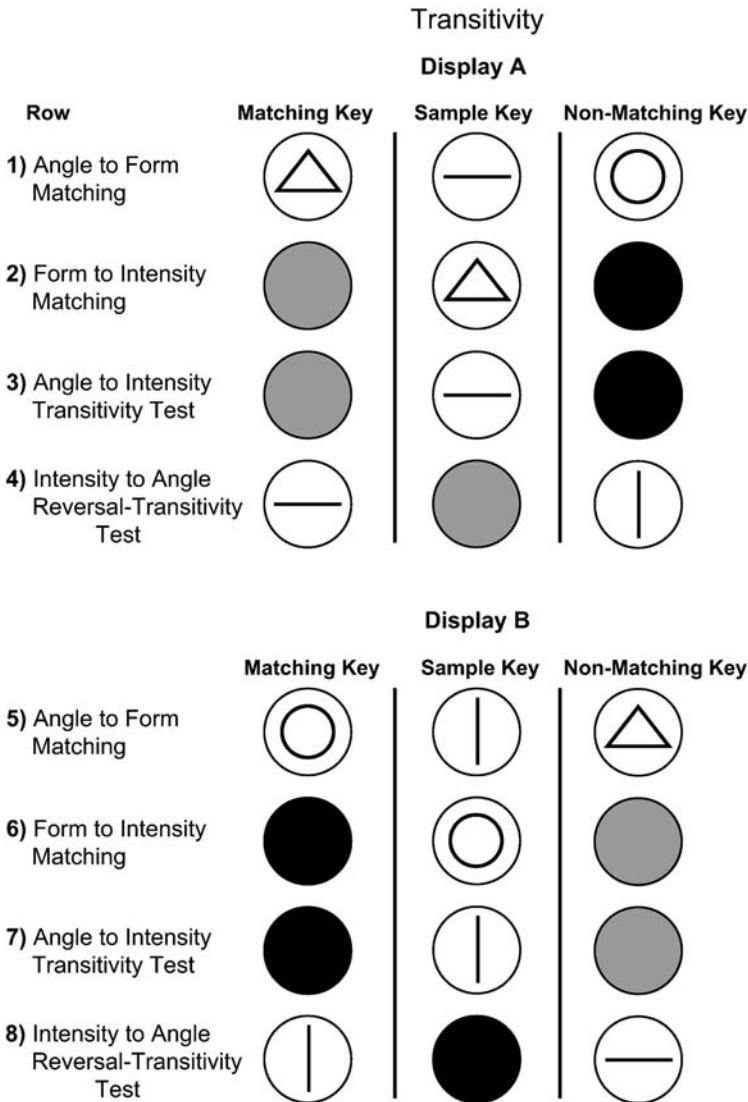
FIG. 12.10. *The symbolic matching procedures that could be used to establish and test for transitivity in pigeons, as described by Catania (1984). First, train angle-to-form matching (Angle = Form) using the arrangements in rows 1 and 5 of Displays A and B. Next, train form-to-intensity matching (Form = Intensity) using the arrangements in rows 2 and 6 of Displays A and B. Following training, conduct a transitivity test (Angle = Intensity) using the arrangements in rows 3 and 7 of Displays A and B. Finally, conduct reversal-transitivity tests (Intensity = Angle) using the arrangements in rows 4 and 8 of Displays A and B. See text for a description of the contingencies.*

it does to the set of geometric forms, and responds to the set of geometric forms as it does to the set of light intensities (A = B = C). This performance would be similar to a person who responds to the written word dog in the same way as to a picture of a dog or the spoken word "dog." The stimuli are said to be equivalent because they regulate the same operant class.

Although stimulus-equivalence training has been given to both human and nonhuman subjects, only a limited number of nonhuman studies have claimed that animals can pass tests

for reflexivity, symmetry, and transitivity (McIntire, Cleary, & Thompson, 1987; Vaughn, 1988) or symmetry and transitivity (D'Amato, Salmon, Loukas, & Tomie, 1985; Richards, 1988). These studies are controversial since some researchers assert that the animals did not demonstrate generalized relations—all the relations were directly trained (e.g., Hayes, 1989a; Saunders, 1989). Also, in nonhuman research there is some question as to whether the pigeon (or ape) is picking out the key that matches the sample or is merely doing *exclusion*, or rejecting the nonmatching option (Carrigan & Sidman, 1992). These concerns are well taken because, in humans, equivalence relations are easily trained and demonstrated, even in people who are behaviorally retarded.

Another issue is whether equivalent relations are stimulus classes that form on the basis of elementary principles of discrimination and generalization, or whether equivalence itself depends on even higher order operant classes. These higher order classes have been postulated because stimulus equivalence is seemingly unique to human behavior, depending on higher order language categories. Two higher order verbal classes have been proposed: naming and relational concepts or frames. It is beyond the scope of this textbook to elaborate the theories of naming (see Horne & Lowe, 1996) and relational frames (Hayes, 1991; Hayes, Barnes-Holmes, & Roche, 2001). At this point, however, it is useful to understand what is meant by higher order operant classes. Catania (1998b) states that a higher order class is

> a class that includes within it other classes that can themselves function as operant classes [as generalized imitation includes all component imitations that could be separately reinforced as a subclass, *Chapter 11 of this textbook*]. A higher order class, in the sense that contingencies arranged for some subclasses within it generalize to all the others. . . .Higher order classes may be a source of novel behavior (e.g., as in generalized imitation of behavior the imitator had not seen before). [Higher order classes] also have the property that contingencies may operate differently on the higher order class than on its component subclasses. For example, if all instances of imitation are reinforced except those within one subclass (e.g., jumping whenever the model jumps), that subclass may not become differentiated from the higher order class and so may change with the higher order class rather than with the contingencies arranged for it (i.e., the imitation of jumping may not extinguish even though it is no longer reinforced). Control by contingencies arranged for the higher order class rather than by those arranged for the subclasses defines these [higher order] classes; the subclasses may then be said to be insensitive to the contingencies arranged for them. Higher order classes of behavior are held together by the common consequences of their members. (p. 416)

All the features of higher order classes of behavior seem to be part of the naming and relational frame accounts of stimulus equivalence. The existence and relevance of these higher order classes is a much disputed area of behavior analysis and learning (see for example the set commentaries in the 1996 issue of the *Journal of the Experimental Analysis of Behavior*, 65, 243–353).

At the applied level, stimulus equivalence training has been helpful to those who lack reading skills. Researchers have used developmentally delayed people who could pass a reflexivity test (identity matching) but, before training, failed to show symmetry or transitivity (Sidman & Cresson, 1973; Sidman, Cresson, & Wilson-Morris, 1974; see also Lazar, 1977). These subjects were given training in symbolic matching. They were presented with one of 20 spoken names and asked to select the corresponding picture from a comparison set (A = B training). Next, the subjects were trained to select printed words from a set when given one of the 20 names (A = C training). After both training procedures, subjects displayed four untrained relations without further training—two symmetry and two transitivity

relations. Subjects showed B to A and C to A reversals—given a picture they emitted the corresponding name, and given a printed word they said it. In addition, subjects showed two transitivity relations. When given a picture (e.g., car, boy, dog, etc.), subjects selected the corresponding printed word (B = C), and when given the printed word, they selected the corresponding picture (C = B).

During training the subjects were presented with three stimulus classes that contained 20 elements in each class (spoken words, pictures, and written words). Forty instances of symbolic matching were reinforced (spoken words = pictures, and spoken words = written words). Tests revealed that 80 new instances of correspondence were established indirectly from training (B = A; C = A; B = C; and C = B).

As you can see, the reinforcement of symbolic matching resulted in a preliminary form of reading by these individuals. The limits on this training have not been established, but it seems obvious that equivalence relations make up a large part of human education (mathematics, science, reading, etc.). Equivalence classes are not the same as discriminative stimuli because S^Ds cannot be exchanged for the responses they occasion. Clearly, equivalence relations define symbolic performance and are an important part of the experimental analysis of verbal behavior (see Sidman, 1994).

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ON THE APPLIED SIDE: THREE-TERM CONTINGENCIES AND NATURAL SPEECH

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At the most basic level, behavior analysts suggest that the acquisition of verbal behavior is governed by contingencies of reinforcement. We have already discussed some of the elementary contingencies that contribute to human speaking and writing. When different responses by a speaker produce specific reinforcements, the speaker learns a repertoire of manding. The speaker usually learns a generalized response such as "Give me [something]"— where the thing specified depends on the motivational conditions. If the contingencies are changed, the speaker may acquire a repertoire of tacting responses. In this case, a nonverbal S^D is presented and the speaker must emit a response with respect to a discriminative stimulus. Correspondence between the verbal response and the stimulus conditions results in generalized (or nonspecific) reinforcement arranged by a listener. The tact contingency seems to contribute to humans' ability to identify features of the environment and describe the world in which they live.

An important question is whether humans arrange similar verbal contingencies in their everyday interactions. Evidence of operant contingencies in casual speech is important for a comprehensive account of verbal behavior. When observational research shows natural dependencies between speakers and listeners, we can be more confident that our understanding of speaking (and writing) is not an artifact of laboratory procedures. Also, evidence of verbal contingencies without explicit control by an experimenter suggests that laboratory findings may eventually have general applicability. For both of these reasons, Moerk's (1990) analysis of contingency patterns in mother–child verbal episodes is an important contribution to the analysis of verbal behavior.

One interesting aspect of this study is that Ernst Moerk is not a behaviorist, although he has always been interested in language training and learning (Moerk, 2000). His research program goes back almost 20 years and builds on Harvard psychologist, Roger Brown's (1958; Brown & Bellugi, 1964; Brown & Fraser, 1963) empirical approach to first language

acquisition. In his article that appeared in *the Journal of the Experimental Analysis of Behavior*, Moerk (1990) states that

> from the beginning . . . [my] program borrowed eclectically from the behavioral, observational learning, system theoretical, and functional/ecological tradition, while retaining cognitive and linguistic perspectives where they seemed most useful. With more detailed focus on interactional data, it appeared increasingly necessary to adopt learning theoretical concepts and principles in order to explain the training and learning of language skills [italics added]. . . . [The] stream of verbal behavior (as it unfolds in the interactions between mother/adult and child), the contingencies between successive utterances, and the functional relationships were central to the analyses. (p. 294)

Although Moerk has numerous publications on language training and learning his work on three-term contingency patterns in the acquisition of human speech (Moerk, 1990) is of specific interest. The data are based on a reanalysis of the verbal interactions between a child named Eve and her mother. The original observations were collected by Roger Brown (1973) as part of a larger study of mother–child interaction. Eve and her mother were observed in their home during everyday activities. When the study began, Eve was 18 months old, and she was 28 months old at the end of the research. Brown collected numerous samples of verbal interaction between Eve and her mother over this 10-month period. Moerk selected all odd-numbered samples and analyzed 2 hr of transcribed audio recoding for each of these samples.

Transcripts were coded by Moerk and two trained research assistants. Observational categories included verbal behavior emitted by both mother and child (Eve). For example, sentence *expansion* involved the mother adding syntactic elements to her child's utterance (Eve says "see boy" and her mother says "You see the boy"), while sentence *reduction* occurred when Eve omitted elements that were originally present in her mother's speech (mother says "give the toy to mommy" and Eve says "give toy mum"). The research focuses on the arrangement of such verbal utterances in mother–child–mother interactions.

Moerk (1990) found that many different mother–child–mother verbal sequences ended with maternal reinforcement. Reinforcement was defined as feedback from the mother that confirmed that Eve's utterance was linguistically acceptable (e.g., "yes," "right," "ok," and so on). A sequence that often occurred was the mother saying a new or rare word (model) that was repeated by Eve (imitation) and followed by her acceptance by the mother (reinforcement). Another three-term pattern involved the mother repeating what she had just said, Eve emitting an approximation to this utterance, and her mother ending the sequence with words of acceptance.

Moerk found that a three-term contingency (maternal verbal stimulus, child verbal imitation, and maternal reinforcement) characterized many of the verbal episodes of early language learning. He suggested that

> . . . the general dynamics, as well as the specific training/learning principles, are apparent. . . . Many linguistic skills are first modeled by the mother; they are more or less directly imitated by the child and rewarded by a maternal "yes" or a closely equivalent reinforcing response. In accordance with the age and early stages of Eve's language acquisition, vocabulary training is still predominant, but many grammatical exercises are also encountered, with a strong emphasis on basic syntactic training. (Moerk, 1990, p. 298)

Moerk also described other three-term sequences that characterized mother–child interactions. These sequences had the common feature of ending with maternal expansion. Expansion involved the mother repeating Eve's utterance and adding syntactic elements that were omitted by the child. For example, in one common sequence the mother might introduce the word "cup" (vocabulary preservation), Eve responds "kuh" (vocabulary

preservation), and her mother repeats "cup" (expansion). From a behavioral perspective, expansion appears to involve two separate functions: The repetition of Eve's utterance functions as reinforcement for her approximation "kuh," and the insertion of omitted elements exerts stimulus control over Eve's next attempt at the word (see Moerk, 1994, for the importance of corrective feedback).

Overall, Moerk's (1990) research on the three-term contingency and human speech is an important contribution to behavioral science. In terms of behavior analysis, this research suggests that contingencies of reinforcement are fundamental to the acquisition of speaking (see also Moerk, 1999). In addition, this research indicates that natural contingencies are arranged by the verbal community (e.g., parents, teacher) that govern when, where, and how a person speaks. Although Moerk's research is not based on functional analysis, it seems apparent that his response categories are compatible with Skinner's functional analysis of verbal behavior.

KEY WORDS

Conditional discrimination	Formal similarity	Stimulus equivalence
Conditioned establishing	Identity matching	Symmetry
operation (CEO)	Manding	Symbolic matching
Echoic behavior	Multiple functions	Tacting
Intraverbal behavior	Reflexivity	Textual behavior
Interlocking	Reversal test	Transitivity
contingencies	Social episode	Verbal behavior
Functional independence		Verbal community

ON THE WEB

http://www.aba.wmich.edu/avbjournal/ The Web address for *The Analysis of Verbal Behavior*, a journal published by the Association for Behavior Analysis. You can see the current and past issues of the journal.

http://psyc.csustan.edu/verbalbehavior/ The Verbal Behavior Special Interest Group is found at this address. Students can find out about membership, meetings, the archives, discussions, job postings, and other links about verbal behavior.

http://www.behavior.org/vb/indexm The Cambridge Center for Behavioral Studies provides an introduction to the analysis of verbal behavior by Charles Catania. The importance of language experiences in the acquistion of vocabulary by children is discussed by Janet Twyman.

STUDY QUESTIONS

1. How do behavior analysts use the term verbal behavior? Why do Lee (1981a) and Catania (1998a) argue against the use of the term language in behavior analysis? (324) What are some of the meanings of the term language? (324) According to Skinner (1957), what is the study of verbal behavior? (325)
2. Discuss the verbal interaction of speaker and listener, using a waiter and customer as an example. How does verbal behavior operate *indirectly* on the environment? (325)

3. Describe the range of verbal behavior as outlined in this textbook. (325)
4. Distinguish between speaking and listening in terms of function. (326) What is the term used to describe the behavior of the listener? (326)
5. Why does verbal behavior require special attention? (327) What is the verbal community, and how does grammatical form depend on this community? (327)
6. What is the name of Skinner's book on verbal behavior? (327) Why is Skinner's analysis of verbal behavior better viewed as a set of testable hypotheses? (327)
7. Provide a functional definition of manding and indicate the English word that the term is based on. (327) Give examples of manding in everyday life. Define tacting and the English word the term is based on. (328) Give everyday examples of tacting. Discuss the problem of distinguishing between manding and tacting. (328) Extend manding and tacting to television commercials. (328)
8. **ADVANCED ISSUE**: Be able to diagram (as in Figure 12.2) and describe a simple social episode involving the manding relation. In your discussion refer to the interlocking contingencies between speaker and listener. (329) What is meant by multiple functions of events? (330) Be able to diagram (Figure 12.3) and describe a simple social episode involving the tacting relation. (331) Compare manding and tacting in terms of the controlling variables. (331)
9. What is meant by the functional independence of verbal response classes? (331) How do researchers train mand relations? (332) What is a blocked-response conditioned establishing operation, or CEO, and how did Hall and Sundberg (1987) use it? (332)
10. Discuss other forms of mand training as used with chimpanzees. (332) Compare the teaching of mands by pointing and speaking. (333)
11. How is tacting trained? What procedural cautions must be used to ensure tacting rather than manding? (333) Outline Savage-Rumbaugh's (1984) training of tacting by chimpanzees. (333) How did Michael, Whitley, and Hesse (1983) train pigeons to tact based on changes in response topography? (333)
12. Describe behavioral experiments on tact training with language-delayed humans. (334) How does this research relate to the question of functional independence of verbal response classes? (334) Cite further evidence of tact training in humans involving positions and quantity of objects. (334) Overall, what does the research on the training of manding and tacting indicate? (334)
13. Define intraverbal behavior. (335) Give some common examples of intraverbals. (335) How does intraverbal behavior relate to free association? (335) Show that a serial learning of nonsense syllables tests for intraverbal relations. (335) Give examples of intraverbal training in education. (336)
14. Define an echoic response. (336) Give an example of echoic behavior involving an infant and parents. (337) Compare echoic behavior with the mere duplication of sound by some organisms. (337) When is echoic behavior most prevalent in human speech? (337)
15. What is a textual behavior? (337) Give an example of textual behavior. (337)
16. Be able to describe a conditional discrimination experiment with pigeons, using circles with vertical and horizontal lines and triangles with similar line angles. Refer to Figure 12.4 in your answer. (338–339)
17. Extend the conditional discrimination experiment to a child's behavior of naming the number and type of coins. (338) Why is it inappropriate to call the conditional-discrimination performance of a pigeon verbal behavior? (338)
18. Describe the Jack and Jill experiment concerning communication by pigeons. (340) Be able to distinguish the interlocking contingencies regulating the behavior of speaker and listener. (340)

19. Outline the Lubinski and MacCorquodale (1984) experiment on communication and generalized conditioned reinforcement. (341). What were the findings? (342) What is the value of experiments on communication by pigeons? (343)

20. **FOCUS ON**: How are humans able to report on themselves? (343) Describe Lubinski and Thompson's (1987) experiment on the reporting of private stimulation by pigeons. (344) What did additional experiments show? (345) Why is this research important? (345)

21. Give some common examples of symbolic behavior. (346) Analyze the Jack and Jill experiment in terms of symbolic behavior and equivalence relations. (346)

22. Define three basic equivalence relations. (346) How are these relations examined in the laboratory (refer to identity and symbolic matching procedures)? (347) Describe how identity matching is used to obtain reflexivity to colors, based on the identity matching of angles or forms by pigeons. (347)

23. Outline how symbolic matching is used to train and test for symmetry. Refer to the training of a angle-to-form discrimination and the reversal test for additional untrained relations. (348)

24. Building on the symmetry relation, how can transitivity be established? (349) What tests are necessary to show transitivity? (349)

25. What is the evidence that nonhuman subjects can pass tests for reflexivity, symmetry, and transitivity? (351) Discuss equivalence and higher order stimulus classes. (351) What happens when retarded children who pass a test for reflexivity are reinforced for symbolic matching involving symmetry and transitivity? (352)

26. At the most basic level, what do behavior analysts claim about verbal behavior. (352) How does natural observation of human speech relate to claims about verbal behavior? (352) Describe Moerk's program of research. (352) In terms of three-term sequences (e.g., mother-child-mother), what did Moerk's results show? (353)

27. What are the functions of contingencies ending with maternal expansion? (353) Overall, what is the importance of Moerk's research? (354)

BRIEF QUIZ

1. _____ introduced the term verbal behavior to deal with the _____ of the speaker.
   (a) Chomsky; transformational grammar
   (b) Skinner; performance
   (c) Crick; conscience
   (d) Pavlov; conditioned responses

2. According to the behavioral or functional account, sign language, gestures, and body movements are instances of
   (a) nonverbal communication
   (b) message transmission
   (c) verbal behavior
   (d) culture and tradition

3. **ADVANCED ISSUE**: In terms of interlocking contingencies, a vertical arrow (downward) from the speaker's operant chain to the listener's indicates that
   (a) the speaker's behavior causes stimulation and/or reinforcement for the listener's behavior
   (b) the listener is causally motivated to behave as the speaker requests
   (c) the speaker is motivated to produce a condition for the listener

      (d) the interaction between the speaker and listener is mutually beneficial and anticipated

4. One kind of conditioned establishing operation (CEO) called the _____ CEO involves withholding an object or item necessary to complete a behavioral sequence.
      (a) no item method
      (b) absent object technique
      (c) interrrupted item method
      (d) blocked response

5. When a verbal response depends on a verbal discriminative stimulus, the verbal relations are
      (a) manding
      (b) tacting
      (c) intraverbal
      (d) textual

6. In echoic behavior, when _____ by the child correspond to those of the adult, the _____ patterns also overlap.
      (a) sounds; temporal
      (b) phonemes; reverberation
      (c) speech; phoneme
      (d) articulations; acoustical

7. When pecking the keys is based on line angle or form depending on the state of the houselight (on/off), we can say that the pigeon shows
      (a) simple discrimination
      (b) conditional discrimination
      (c) simple generalization
      (d) generalized discrimination

8. A response such as "I have butterflies in my stomach" can be analyzed as _____.
      (a) generalized tacting
      (b) generalized manding
      (c) formal manding
      (d) formal tacting

9. When reinforcement is based on matching of geometric forms to different line angles, the procedure is called
      (a) identity matching
      (b) matching to sample
      (c) transitivity matching
      (d) symbolic matching

10. If the picture of a dog, the spoken word "dog," and the written word DOG all regulate the same behavior, we say that the stimulus classes are
      (a) overlapping
      (b) the same
      (c) equivalent
      (d) confounded

Quiz Answers (*page*): b(325); c(325); a(329); d(332); c(333); d(336); b(338); a(343); d(347); c(350)

CHAPTER 13
Applied Behavior Analysis

IN THIS CHAPTER

1. Find out about applied behavior analysis, its methods, and data recording.
2. Discover what is known about self-control and how to reduce impulsive behavior.
3. Learn about a Personalized System of Instruction and Precision Teaching as effective behavioral applications in education.
4. Discover the ABC program for the treatment of autistic behavior.
5. Inquire about activity anorexia as a basis for the prevention and treatment of human anorexia.
6. Explore the MammaCare program for the detection and prevention of breast cancer, an important behavioral technology.

The experimental analysis of behavior is a science that easily lends itself to application. This is because the focus of the discipline is on those environmental events that directly alter the behavior of organisms. Almost half a century ago (e.g., Dollard & Miller, 1950; Skinner, 1953), behavior analysts suggested that since operant and respondent principles regulate behavior in the laboratory, they likely affect human behavior in the everyday world. Thus, principles of behavior can be used to change socially significant human conduct.

Principles of behavior change have been used to improve the performance of university students (Mayfield & Chase, 2002; Pear & Crone-Todd, 1999), increase academic skills (Eckert Ardoin, Daly, & Martens, 2002; Sulzer-Azaroff, 1986), teach developmentally delayed children self-care (Kissel, Whitman & Reid, 1983), reduce phobic reactions (Jones & Friman, 1999), get people to wear seat belts (Sowers-Hoag, Thyer, & Bailey, 1987), prevent industrial accidents (Sulzer-Azaroff & De Santamaria, 1980), and help individuals stop cocaine abuse (Budney, Higgins, Delaney, Kent, & Bickel, 1991; Higgins & Katz, 1998). Behavioral interventions have had an impact on clinical psychology, medicine, counseling, job effectiveness, sports training, and environmental protection. Applied experiments have ranged from investigating the behavior of psychotic individuals to analyzing (and altering) contingencies of entire institutions (see Kazdin, 1994).

Characteristics of Applied Behavior Analysis

Behavioral principles, research designs, observational techniques, methods of analysis, and so on transfer readily to an applied science. When this is done to improve performance or solve social problems, the technology is called applied behavior analysis (Baer, Wolf, & Risley 1968). Thus, **applied behavior analysis** is a field of study that focuses on the application of the principles, methods, and procedures of the science of behavior. Because applied behavior analysis is a wide field of study, it cannot be characterized by a single definition.

Nonetheless, several features in combination distinguish applied behavior analysis as a unique discipline.

Concentration on Research

Behavior therapists and applied researchers are committed to a scientific analysis of human behavior. What a person does and the events that govern behavior are objectively identified. In this regard, operant and respondent conditioning are assumed to regulate much human action. However, verbal behavior, generalized imitation, equivalence relationships, and physiology complicate human behavior.

Applied behavior analysis involves two major areas of research. The application of operant and respondent principles to improve human behavior has concerned many behavior analysts. A good deal of literature has documented the success of this enterprise (see the *Journal of Applied Behavior Analysis* for many examples). Many experiments have shown how basic conditioning principles can be used in a variety of complex settings. Problems that are unique to the applied context have been addressed, and treatment packages that are designed for the modification of behavior have been described and evaluated (see Martin & Pear, 1999).

Another set of studies have not focused directly on behavior change, but are a part of applied behavior analysis. Such investigations are involved with the analysis of everyday human behavior and have long-range implications for improving the human condition. For example, studies that investigate environmental factors that produce cooperation, competition, successful teaching, and coercive family dynamics may identify basic principles of complex human interaction (Epling & Pierce, 1986). Researchers in this area of applied behavior analysis are attempting to specify the contingencies that produce social problems (Lamal, 1997).

Behavior Is the Primary Focus

Applied behavior analysts focus on the behavior of people. Behavior is not considered to be an expression of inner causes like personality, cognition, and attitude. Marital difficulties, children who are out of control, littering, phobic reactions, poor performance on exams, excessive energy use, and negative self-descriptions are analyzed as problems of behavior. Interventions for these and other problems are directed at changing environmental events to improve behavior.

Of course, people think, feel, and believe a variety of things associated with what they do. Individuals experiencing difficulty in life may have unusual thoughts and feelings. A depressed person may feel worthless and think that nobody likes him or her. The same person does not spend much time visiting friends, going to social events, or engaging in the usual activities of life. A behavioral intervention for this problem would likely focus on increasing the person's activity, especially social interaction. The individual may be asked to set goals for completing various tasks, and reinforcement is arranged when they are accomplished. When people become more socially involved, physically active, and complete daily tasks, they do not describe themselves as depressed. In this and many more cases, a change in behavior produces a change in feelings and cognition.

A Case Study

In other cases, what a person says about his or her feelings and thoughts may be treated as verbal operants that require change (see Chapter 12). Tammi was an 8-year-old girl who

was diagnosed as neurotic by a physician who saw her in his general practice. She was referred to a behavior analyst (Frank Epling) for evaluation and treatment.

When she was 6 years old, Tammi had witnessed a gruesome farm accident in which her brother was killed. The girl frequently talked about killing herself and joining her brother in heaven. She had also cut herself with a kitchen knife on two occasions. Her parents were asked to record the circumstances that preceded and followed these episodes and the number of times they occurred.

Tammi had cut herself on two occasions since her brother's death, but had not done so during the past year. Talking about suicide had, however, increased, and she did this about three times a week. This talk usually took place at the evening meal when both parents were present. She did not talk about dying to her older siblings or to other people. Quite naturally, these episodes upset her mother and father and they routinely attempted to "calm her down and reason with her" when they occurred.

This information suggested stimulus control and (unintentional) reinforcement by parental attention. After the mother and father were taught a few simple principles of extinction, they withdrew social reinforcement when talk about suicide occurred. The parents were instructed to avoid eye contact, make no comment, and if possible turn away from Tammi when she talked about killing herself. They were also told that extinction would likely produce an initial increase in the form and frequency of the behavior. In other words, Tammi would temporarily get worse, but a rapid improvement could be expected to follow. At the end of 5 weeks and at a 6-month follow-up, talk of killing herself went to zero and cutting herself did not occur again.

The Importance of Conditioning

This discussion should make it clear that problem behavior may, in many cases, be understood in the same fashion as any other behavior. Principles of conditioning are neutral with respect to the form and frequency of behavior. Maladaptive, annoying, or dangerous responses may be inadvertently produced by environmental contingencies.

Consider an institutional setting in which three staff nurses are in charge of 20 disabled children. The nurses are busy and as long as the children behave, they are left alone. This natural response to a strenuous work schedule may, for some children, result in deprivation for adult attention. When one of the children accidentally hits his or her head and is hurt, a staff member rushes over and comforts the child. It is possible that head hitting will increase in frequency because it has been reinforced by contingent attention (e.g., Lovaas & Simmons, 1969). Of course, when people are injured they cannot be ignored. One way to deal with the problem would be to provide social reinforcement for appropriate play, academic activities, ward chores, self-hygiene, and so on. This tactic is called **differential reinforcement of other behavior**, or **DRO** (e.g., Burgio & Tice, 1985; Lowitz & Suib, 1978; Piazza, Moes, & Fisher, 1996). In the preceding example, the procedure would strengthen responses that are incompatible with self-injury and reduce deprivation for adult attention.

Although much human behavior is a function of contingencies of reinforcement, biological factors also produce behavior change. A person who has experienced a stroke, a child with fetal alcohol syndrome, an individual in the later stages of syphilis, and an adult suffering from Huntington's chorea may emit responses that are a function of brain damage, toxic agents, disease, and genetics. Even when this is the case, principles of conditioning can often be used to improve behavior (see Epling & Pierce, 1990, pp. 452–453).

Direct Treatment of Problem Behavior

Applied behavior analysts usually focus directly on the environmental events that generate and maintain behavior. Typically, target behavior and the events that precede and follow those responses are counted for several days. During this baseline, treatment is withheld so that a later change in behavior can be evaluated. This assessment also provides information about stimulus control (events that precede the behavior) and contingencies of reinforcement (events that follow behavior) that maintain responses.

Following a baseline period of assessment, a behavioral plan of action may be negotiated between the behavior therapist, the client, and concerned others (e.g., Azrin et al., 1994, for treatment program aimed at drug abuse). This plan usually includes a statement of target responses, consequences that follow different actions, and long-term goals. In many cases, a detailed **behavioral contract** is drawn up that objectively specifies what is expected of the client and the consequences that follow behavior (Hall & Hall, 1982). Figure 13.1 outlines the major principles of behavioral contracts. At a minimum, the behavior analyst should clearly identify the problem behavior; and the contract should specify in a straightforward manner the reinforcement for meeting behavioral objectives, the people who provide reinforcement, and the contingencies of reinforcement.

A GUIDE TO BEHAVIORAL CONTRACTING

1. Specify the target behavior.

2. Describe the behavior in a way that an observer may count or time.

3. Collect baseline data on the frequency of response or time spent responding.

4. Identify consequences that may be used to increase desired behavior (positive and negative reinforcers).

5. Find people who will monitor the behavior and provide the consequences.

6. Write the contract in clear statements of behavior and consequences (e.g. if you do "X' then you receive "y").

7. Collect data on frequency of response or time spent responding and compare with baseline level.

8. Modify the contract if the desired behavior does not increase (e.g., try different consequences).

9. Gradually, remove arbitrary consequences and replace with natural reinforcers - rewrite the contract and monitor the behavior.

10. Plan for generalization - implement the contract in a variety of settings.

FIG. 13.1. *Steps in writing a behavioral contract, based on How to Negotiate a Behavioral Contract, by R. V. Holl and M. C. Hall, 1982, Lawrence, KS: H. & H. Enterprises.*

Applied behavior analysts do not typically focus on what has been called the thera-peutic process. This is because they do not place much faith in talking about problems to relieve stress or develop insight. They prefer to arrange contingencies of reinforcement to alter behavior problems. Although this is the case, Dr. Steven Hays at the University of Nevada—Reno is a behavior analyst who has recognized the importance of rule-governed behavior in a therapeutic setting. From his perspective, talking is a form of social influence that may be used to change the client's actions. That is, instructions and other verbal stimuli may directly alter the probability of behavior (see S. C. Hayes, 1987; Zettle & Hayes, 1982). Today, most applied behavior analysts prefer contingency management, but others are inves-tigating the practical importance of instructions, rules, and therapeutic advice (see Hayes, 1989b).

Programming for Generality

In terms of direct treatment of problem behavior, applied behavior analysts have been concerned with the generality of behavior change (Baer, 1982; Stokes & Baer, 1977). That is, researchers attempt to ensure that their interventions produce lasting changes in behavior that occur in all relevant settings. As noted in Chapter 7, when organisms are reinforced in the presence of a particular stimulus, they typically produce a gradient of generalization that falls on both sides of the discriminative stimulus. Rather than rely on the organism to generalize automatically in an appropriate manner, the applied behavior analyst attempts to program for generality.

Generality of behavior change involves three distinct processes: stimulus generaliza-tion, response generalization, and behavior maintenance (Martin & Pear, 1999). Behavior change has generality if the target response(s) occurs in a variety of situations, spreads to other related responses, and persists over time. Stimulus generalization occurs when the person responds similarly to different situations (e.g., a person greets one friend as she does another). **Response generalization** occurs when a target response is strengthened and other similar responses increase in frequency (e.g., a child reinforced for building a house out of Lego subsequently may arrange the pieces in many different ways). **Behavior maintenance** refers to how long a new behavior persists after the original contingencies are removed (e.g., an anorexic man who is taught to eat properly shows long-lasting effects of treatment if he maintains adequate weight for many years).

Donald Bear at the University of Kansas has emphasized the importance of training behavioral generality and provides the following illustration:

> Suppose that a client characterized by hypertension has been taught systematic progressive re-laxation techniques on the logic that the practice of relaxation lowers blood pressure a clinically significant amount, at least during the time of relaxation, and that the technique is such that relaxation can be practiced during all sorts of everyday situations in which the client encoun-ters the kinds of stress that would raise blood pressure if self-relaxation did not pre-empt that outcome. Suppose that the relaxation technique has been taught in the clinician's office, but is to be used by the client not there, but in the home, work, and recreation settings in which stress occurs. Thus, generalization of the technique across settings, as well as its maintenance after clinical treatment stops, is required. (Baer, 1982, p. 207)

To program generality of behavior change, Baer (1982) suggests a variety of procedures that affect stimulus and response generalization and behavior maintenance. First, stimulus generalization of relaxation (or any other behavior) is promoted when the last few training sessions are given in situations that are as similar as possible to everyday settings. Second, when relaxation training is done in a variety of different contexts, such as different rooms

with different therapists and different times of day, stimulus generalization increases. Finally, a therapist who trains relaxation in the presence of stimuli that elicit hypertension in everyday life is programming for stimulus generalization.

Response generalization is increased when the client is taught a variety of ways to obtain the same effect. For example, to relax and reduce blood pressure, the client may be taught meditation, progressive relaxation, and controlled breathing. In addition, a person may be taught to produce new forms of response, as when the therapist says, "Try to find new ways of relaxing and reducing blood pressure," and reinforces novel responses.

Behavior change may be programmed to last for many years if operant responses contact sources of reinforcement outside of the therapeutic setting. Applied behavior analysts who teach their clients skills that are reinforced by members of the social community are programming for behavior maintenance. This sort of programming has been called **behavior trapping** because, once learned, the new behavior is "trapped" by natural contingencies of reinforcement (e.g., Durand, 1999; Stokes, Fowler, & Baer, 1978). The aversive consequences of hypertension are reduced when a person learns techniques of relaxation that decrease blood pressure and these practices are trapped by automatic negative reinforcement.

In fact, relaxation training has been used to reduce hypertension over a long time with generalized effects. Usually, hypertension is treated with drugs, but there are many difficulties, including side effects of the drugs and failure by patients to follow the proposed treatment. Beiman, Graham, and Ciminero (1978) taught two men diagnosed with hypertension to relax deeply. The men were taught to practice relaxation at home and when they were tense, anxious, or angry, or felt under pressure. Blood pressure was monitored in a variety of everyday settings and during therapy sessions. Following behavior modification, both men had blood pressure readings within the normal range. These effects were maintained at a 6-month follow-up.

Focus on the Social Environment

From a behavioral point of view, the physical environment and social system require change, not the person. James Holland at the University of Pittsburgh highlighted this issue when he said:

> Our contingencies are largely programmed in our social institutions and it is these systems of contingencies that determine our behavior. If the people of a society are unhappy, if they are poor, if they are deprived, then it is the contingencies embodied in institutions, in the economic system, and in the government which must change. It takes changed contingencies to change behavior. (Holland, 1978, p. 170)

Behavior-change programs usually are more circumscribed in their focus than Holland recommends (but see Chapter 14 for a discussion of cultural design). Applied behavior analysts have seldom been in a position to change institutional contingencies. They have targeted more local contingencies involving family and community. In the case of Tammi, the social contingencies for talking about suicide were located in the family. When her parents stopped attending to such talk, she stopped saying that she wanted to kill herself. The focus of the intervention was on the family system rather than Tammi's neurosis.

Most behavior-change programs attempt to identify and alter significant variables that maintain target responses. As we have said, these variables are usually in the person's social environment. For this reason, treatment programs are often conducted in schools, hospitals, homes, prisons, and the community at large (see Glenwick & Jason, 1980; Lamal,

1997). Parents, teachers, friends, spouses, and others typically control significant sources of reinforcement that maintain another person's behavior. These individuals are often instructed in how to change contingencies of reinforcement to alter a client's behavior.

Research in Applied Behavior Analysis

In Chapter 2, we discussed A–B and A–B–A–B reversal designs for operant research. For single-subject research, basic or applied, the A–B–A–B reversal design has the highest level of internal validity—ruling out most extraneous factors. While a reversal design is always preferred, there are practical and ethical difficulties that restrict its use in applied settings.

In natural settings, behavior is often resistant to a reversal procedure. For example, a child's shyness may be altered by using contingencies of reinforcement to increase socially acceptable playing. If the reinforcement procedure is now withdrawn, the child will probably continue playing with other children. This may occur because the shy child's behavior is maintained by social reinforcement from playmates. In other words, the child's behavior is trapped by other sources of reinforcement. While this is a good result for the child, it is a bad outcome in terms of inference and research design. This is because the applied analyst cannot be sure that the original improvement in behavior was caused by his or her intervention.

Another difficulty with the reversal design in applied settings is that it requires the withdrawal of a reinforcement procedure that may improve behavior. For example, a psychiatric patient may be restrained with leather cuffs for biting his arms. A DRO procedure is implemented and arm biting is substantially reduced, to a point at which the cuffs are no longer necessary. Although we cannot be sure that the DRO contingency caused the reduction in self-injury, it would be cruel to remove the contingency only to show that it was effective. Thus, the A–B–A–B reversal design is sometimes inappropriate for ethical reasons.

Multiple Baseline Designs

To solve the problems raised by the A–B–A–B reversal design, applied behavior analysts have developed other single-subject designs. Multiple baseline designs demonstrate experimental control and help eliminate alternative explanations for behavior change. There are three major types of multiple baseline designs as first described by Hall et al. (1970). These designs are (a) multiple baseline across stimulus conditions, (b) multiple baseline across subjects, and (c) multiple baseline across behaviors.

Multiple Baseline Across Stimulus Conditions

In this design, a reinforcement procedure is applied in one situation but is withheld in other settings. When behavior changes in the situation where it is reinforced, the contingency is applied to the same response in another setting. Hall and his associates (1970) used this design in a modification of children's tardiness in getting to class after recess or lunch.

Figure 13.2 shows the multiple baseline across stimulus conditions used by Hall and his colleagues (1970). The researchers used a "patriots chart" to modify lateness after lunch and after morning and afternoon recess. Children in the fifth grade who were on time for class had their names posted on the chart. As you can see, punctuality improved when the chart was posted. Notice that the chart was first posted after lunch time, but it was not
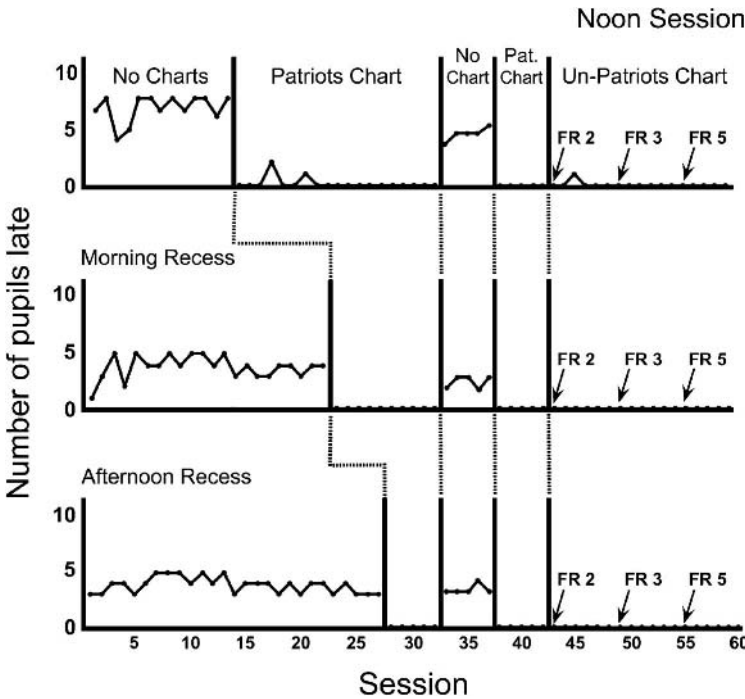
FIG. 13.2. *The multiple baseline design across stimulus conditions used From "Teaching and parents as Researchers Using Multiple Baseline Designs," by R. V. Hall, C. Cristler, S. S. Cranston, and B. Tucker, 1970,* Journal of Applied Behavior Analysis, 3, *pp. 247–255. Copyright 1970, Society for the Experimental Analysis of Behavior, Inc. Reprinted with permission.*

introduced following morning or afternoon recess. The number of students who were late for class after lunch declined from about eight to less than two. This was not the case for the recess periods; the number of students who were tardy after recess remained at four or five. Next, the researchers continued to post the patriots chart after lunch, but they added the chart following the morning recess. When this occurred, all students were on time for class following both lunch and morning recess. Finally, when the chart was also posted following the afternoon recess, all students were on time for all three class periods. The multiple baseline across stimulus conditions demonstrates an effect of the intervention by staggering the introduction of the independent variable over time and settings.

Multiple Baseline Across Subjects

A similar logic is used when an intervention is progressively introduced to different subjects who exhibit similar target behavior. In experiment 2, Hall and his colleagues (1970) attempted to improve three students' scores on French quizzes. Modification involved a requirement to stay after school for tutoring if the student scored below a C on a quiz. The contingency was first introduced to Dave, then to Roy, and finally to Debbie. Figure 13.3 shows that Dave's quiz performance dramatically improved when the contingency was applied. The other students also showed improvement after the contingency went into effect. All of the students received grades of C or better when contingency management was used to improve their performance in the French class.
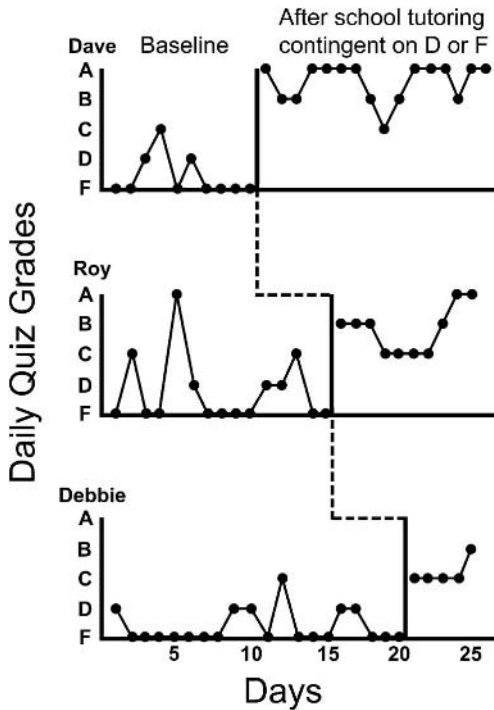
FIG. 13.3. *The multiple baseline design across subjects used From "Teaching and Parents as Researchers Using Multiple Baseline Designs," by R. V. Hall, C. Cristler, S. S. Cranston, and B. Tucker, 1970,* Journal of Applied Behavior Analysis, 3, *pp. 247– 255. Copyright 1970, Society for the Experimental Analysis of Behavior, Inc. Reprinted with permission.*

Multiple Baseline Across Behaviors

A multiple baseline design across behaviors is used when a reinforcement procedure is applied progressively to several operants. In this case, the subject, setting, and consequences remain the same, but different responses are sequentially modified. Hall and his associates (1970) provided an example of this design when they modified the after-school reading, work on a Campfire honors project, and practicing the clarinet of a 10-year-old girl. The girl had to spend at least 30 min on an activity or else she had to go to bed early. She had to go to bed 1 min earlier for every minute less than 30 she spent on an activity. As you can see from Fig. 13.4, practicing the clarinet was modified first, and time spent playing the clarinet increased from about 15 to 30 min. Next, both practicing the instrument and working on the Campfire project were targeted and both performances were at about 30 min. Finally, reading for book reports was modified and all three target responses occurred for 30 min. The avoidance contingency seems effective because each behavior changes when the contingency is introduced, but not before.

Multiple baseline and A–B–A–B reversal designs are the most frequently used research methods in applied behavior analysis. There are, however, many variations of these basic designs that may be used to increase internal validity or to deal with specific problems in the applied setting (e.g., Carr & Burkholder, 1998). Often the basic designs are combined in various ways to be certain that the effects are due to the independent variable. In fact, Hall and his associates (1970) used a reversal phase in their experiment on tardiness and the patriots chart, but for reasons of clarity this was not shown in Figure 13.2. There are many other designs that are useful in a given situation. A **changing criterion design** involves progressive increases (or decreases) in the performance criterion for reinforcement. For example, a hyperactive child is reinforced for spending progressively more time on academic work. At first the child may be required to spend 3 min working quietly, then 5 min, then 10,
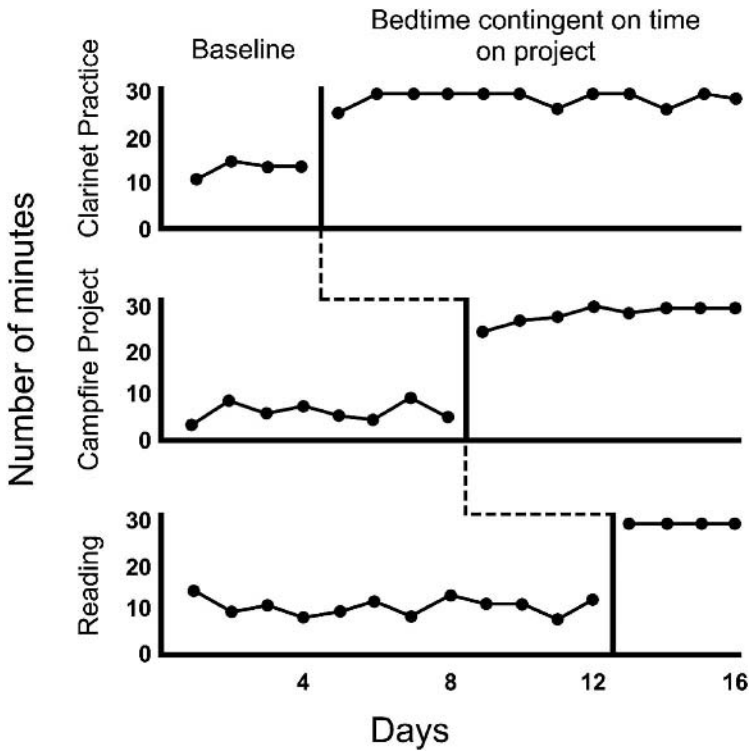
FIG. 13.4. *The multiple baseline design across behaviors used From "Teaching and Parents as Researchers Using Multiple Baseline Designs," by R. V. Hall, C. Cristler, S. S. Cranston, and B. Tucker, 1970,* Journal of Applied Behavior Analysis, 3, pp. 247–255. Copyright 1970, Society for the Experimental Analysis of Behavior, Inc. Reprinted with permission.

and so on. The child's behavior is measured at each level of the criteria. A research example of this design is given in the section on self-control (see also Belles & Bradlyn, 1987).

Issues of Measurement in Applied Behavior Analysis

It is relatively easy to define an operant objectively in the laboratory. Responses are defined by switch closures, and there is no dispute about their occurrence. When responses occur, they are recorded by computers and other electronic equipment. In the applied setting, definition and measurement of the behavior is much more difficult, especially when parents, teachers, and psychologists are used to identify problem behavior. In this regard, Kazdin (1989) has made the point that:

> Identification of the target behavior may appear to be a relatively simple task. In a given set-ting (e.g., the home, school, or workplace), there is general agreement as to the "problems" of the clients whose behaviors need to be changed and as to the general goals of the pro-gram. Global or general statements of behavioral problems are usually inadequate for actually beginning a behavior modification program. For example, it is insufficient to select as the goal alteration of aggressiveness, learning deficits, speech, social skills, depression, psychotic symptoms, self-esteem, and similar concepts. Traits, summary labels, and personality charac-teristics are too general to be of much use. Moreover, definitions of the behaviors that make

up such general labels may be idiosyncratic among different behavior change agents (parents, teachers, or hospital staff). The target behaviors have to be defined explicitly so that they can actually be observed, measured, and agreed upon by individuals administering the program. (p. 54)

Kazdin goes on to discuss three criteria of an adequate response definition (see also Johnston & Pennypacker, 1993). The first criterion is *objectivity*. This means that the response definition should refer to observable features of behavior in clearly specified situations. *Clarity* of definition is another requirement. This means that the description of the response can be read and then clearly restated by a trained research assistant or observer. Finally, the definition should be *complete* in the sense that all instances of the behavior are distinguished from all nonoccurrences. Thus, a troublesome student may be objectively defined as one who talks without permission when the teacher is talking and who is out of seat without permission during a lesson. The definition is clear in that it is easily understood and may serve as a basis for actual observation. Completeness is also shown since only these two responses are instances of the troublesome behavior class, and any other responses are not.

This definition of response assumes that there is a problem with the student's performance, not the teacher's judgment. The applied behavior analyst must be sensitive to the possibility that the teacher is too critical of the student. It is possible that many students talk without permission and leave their seats during lessons. The teacher, however, only gets upset when Anna is running about or talking during instruction. In this case, response definition may be accurate and modification successful, but the intervention is unfair. Applied behavior analysts must constantly be aware of whether they are part of the solution or part of the problem (Holland, 1978). If the problem lies with the teacher, it is his or her behavior that requires change.

Recording Behavior

Once a suitable response has been defined, the next step is to record the behavior when it occurs. The simplest tactic is to record every instance of the response. Practically, this strategy may be very time-consuming and beyond the resources of most applied behavior analysts. One alternative is to count each instance of behavior only during a certain period of the day (e.g., lunch, recess, first class in the morning, and so on). This method of observation is called event recording for specified periods.

Another strategy is to select a block of time and divide the block into short, equal intervals. This is called **interval recording**. For example, a 30-min segment of mathematics class may be divided into 10-s bits. Regardless of the number of responses, if the behavior occurs in a given 10-s segment, then the observer records it as a single event. One way this could be done is to have an observer wear a headset connected to a cassette tape recorder that plays a tape that beeps every 10 s. When the target behavior occurs, the observer records it on a piece of paper divided into segments that represent the 10-s intervals (see Figure 13.5). After each beep, the observer moves to the next interval.

Time sampling is another method of recording used in applied behavior analysis. This technique samples behavior over a long time scale, with observations made at specified

FIG. 13.5. *Interval recording method used in behavioral observation and measurement.*

times throughout the day. For example, a patient on a psychiatric ward may be observed every 30 min, as a nurse does the rounds, and instances of psychotic talk are recorded. Again, the issue is whether the target behavior is occurring at the time of the observation, not how many responses are made.

When behavior is continuous, **duration recording** is a preferred method of observation. Continuous behavior involves responses like watching television, riding a bicycle, sitting in a chair, and so on. When behavior is continuous, an observer may use a stopwatch to record the duration of occurrence. When the person is sitting in a chair the watch is running, and when the person does something else the watch is stopped.

Reliability of Observations

No matter what method of recording behavior is used, reliability of observation is a critical issue. Briefly, reliability of observation involves the amount of agreement among observers who independently record the same response. For example, two observers may sit at the back of a classroom and use 10-s intervals to record the occurrence of Jessica's out-of-seat behavior. After 30 min of observation, 180 intervals of 10 s have been recorded by each researcher. One way to assess reliability is to count the number of times both observers agree that the behavior did or did not occur within an interval. This calculation can be expressed as a percentage agreement that varies from zero to 100%. Generally, applied behavior analysts strive for reliability of greater than 80% agreement.

FOCUS ON EDUCATION: PERSONALIZED SYSTEM OF INSTRUCTION AND PRECISION TEACHING

Behavior principles have been applied in a wide variety of educational settings (Sulzer-Azaroff, 1986). University students have shown better academic performance after being taught with Fred Keller's personalized system of instruction, or PSI (Keller, 1968; Kulik, Kulik, & Cohen, 1980). In addition, learning has been accelerated for elementary school children (and others) by precision teaching (Lindsley, 1972). Athletic performance has been improved by applying behavior principles to physical education (Martin & Hrycaiko, 1983). Autistic children have benefited from the teaching of social and living skills (Lovaas, 1987; Morrow, Terzich, & Williamson, in press). These are but a few of the many applications of behavior principles to education. In this section we focus on two examples, but there are many more educational applications than reported here.

A Personalized System of Instruction

The traditional lecture method used to instruct college and university students has been largely unchanged for thousands of years. A teacher stands in front of a number of students and talks about his or her area of expertise. There are variations on this theme; students are encouraged to participate in discussion, to discover new facts for themselves, to reach conclusions by being led through a series of questions, and to be active rather than passive learners. During lectures, various forms of logic are used to arrive at conclusions, classroom demonstrations are arranged, and so on. Basically, however, the lecture method of teaching is the same as it has always been.

Fred Keller recognized that the lecture method of college teaching was inefficient and in many cases a failure. He reasoned that anyone who had acquired the skills needed to attend

college was capable of successfully mastering most or all college courses. Some students might take longer than others to reach expertise in a course, but the overwhelming majority of students would be able to do so. If behavior principles were to be taken seriously, there were no bad students, only bad teachers.

In a seminal article, titled "Good-bye, teacher . . .," Fred Keller outlined a college teaching method based on principles of operant conditioning (Keller, 1968). Keller called his teaching method a **personalized system of instruction**, or **PSI**. The method has also been called the "Keller Plan" (Sherman, Ruskin, & Semb, 1982). Basically, PSI courses are organized such that students move through the course at their own pace. Some students may finish the course in a few weeks; others require a semester or longer.

Course material is broken down into many small units of reading and (if required) laboratory assignments. Students earn points (conditioned reinforcement) for completing unit tests and lab assignments. Mastery of the lab assignments and unit tests is required. If test scores are not close to perfect, the test (usually in a different form) is taken again. The assignments and tests build on one another, so they must be completed in order. Undergraduate proctors are recruited to assist with running the course. These individuals tutor students and mark unit tests and laboratory assignments. Proctors are "chosen for [their] mastery of the course content and orientation, for [their] maturity of judgment, for [their] understanding of the special problems that confront . . . beginner[s], and for [their] willingness to assist [with the course]" (Keller, 1968; p. 81). Lectures and class demonstrations are an optional privilege; students may or may not attend them. Lectures are scheduled once the majority of students in the class have passed a sufficient number of unit tests to indicate that they are ready to appreciate the lectures; no exams are based on these lectures. The course instructor designs the course, makes up the tests, delivers the optional lectures, adjudicates disputes, and oversees the course.

Comparison studies have evaluated student performance on PSI courses against performance for those students given computer-based instruction, audio-tutorial, traditional lecture-based teaching, visual-based instruction, and other programmed instruction methods. College students instructed by PSI outperformed students taught by these other methods when given a common final exam (see Lloyd & Lloyd, 1992, for a review). Despite this positive outcome, logistical problems in organizing PSI courses, teaching to mastery level (most students get an A for the course), and allowing students more time than the allotted semester to complete the course have worked against the wide adoption of PSI in universities and colleges (Binder & Watkins, 1989).

The Method of Precision Teaching

In the early 1950s, B. F. Skinner stated that "rate of responding appears to be the only datum which varies significantly and in the expected direction under conditions which are relevant to the learning process" (Skinner, 1950) Despite this declaration, behavior analysts that moved from the laboratory to the classroom setting usually adopted "percentage correct" as a measure of academic performance, a measure that pertains only to accuracy. The temporal dimensions of behavior (e.g., rate), or fluency measures, mostly were ignored except for obvious cases like typing speed.

Celeration and the Charting of Behavior Change

Ogden Lindsley extended the method of free operant conditioning to humans, emphasizing Skinner's dictum to focus on rate of response. In what became known as **Precision Teaching**, Lindsley (1990b) devised a method of systematic instruction that encouraged students and teachers to target specific behaviors, count, time, and graph them, and revise
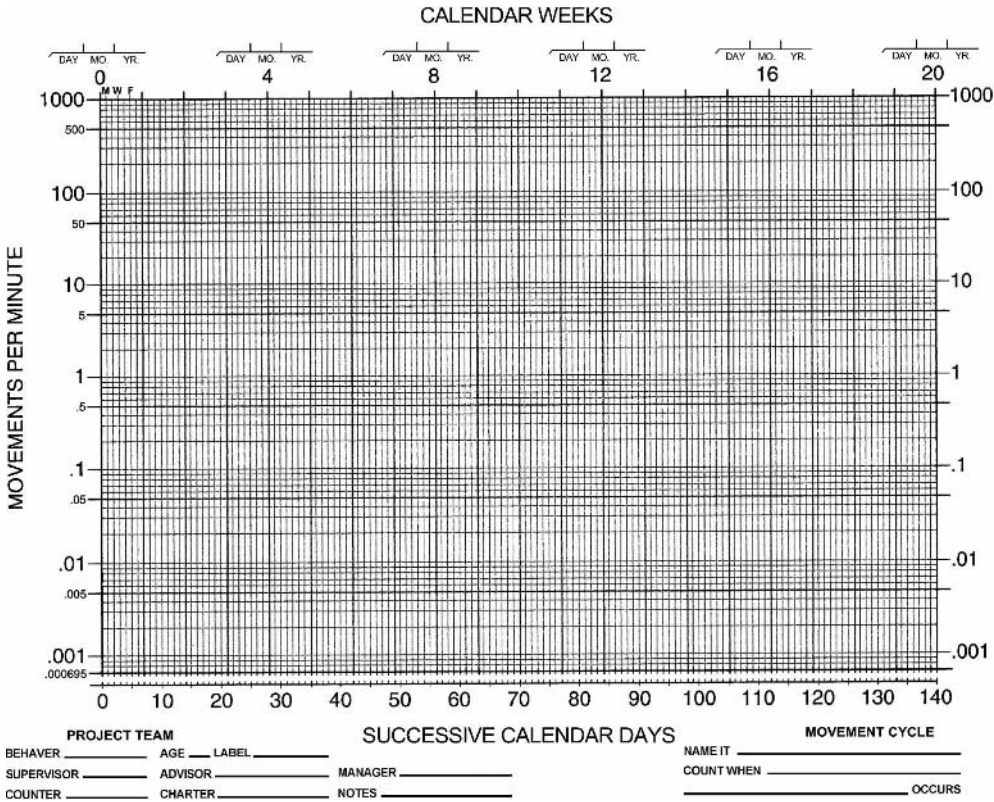
FIG. 13.6. *A Standard Celeration Chart using 6-cycle semilogarithmic coordinates.*

instructional procedures based on the charted data (Lindsley, 1972). As part of the instructional package, Lindsley devised the *Standard Celeration Chart* for graphing the rate of a target behavior over calendar days. The word **celeration** is used to denote two kinds of behavior change, acceleration and deceleration. Acceleration occurs when the rate of target behavior (frequency/time) is increasing over days, while deceleration involves decreasing rate over this period. Behavior graphing allows for evaluation behavior change and revision of the instructional components based on the observed celeration (change in rate over days).

Figure 13.6 shows the Standard Celeration Chart used in educational settings (White & Haring, 1980). The chart uses a 6-cycle semilogarithmic scale with counts per minute (rate of target behavior) on the *y* axis and calendar days on the *x* axis. The chart differs from a simple line graph in that tick marks on the *y* axis involve six exponential increments ranging from 0 to 1000 responses. The 6-cycles or increments are .001–.01; .01–.10; .10–1.0; 1.0–10; 10–100; 100–1000. Using this scale, a student whose rate of spelling targeted words increased from 2 to 4 words (a minute) per week would appear the same as another student who increased from 20 to 40 occurrences in the same period. That is, the students show the same relative (proportional) amount of improvement or learning when plotted on the celeration graph.

When the charted rate doubles from one week to the next, we say that it is accelerating at "times 2" or at ×2. On the other hand, a rate that is cut in half from one week to the next is said to be decelerating at "divided by 2" or at /2. A behavior change procedure that resultes in an increase from 1 to 2 (×2) would look similar to a change from 50 to 100 responses (×2). On a simple add scale, a change from 1 to 2 is +1 but also ×2 whereas a change from

50 to 100 is +20 but only ×1.25. Based on this kind of distortion, Lindsley (1990a) proposes that we discard the terms "increase" and "decrease" when describing behavior change. One of the major discoveries of Precision Teaching is that all behavior "multiplies" or "divides" and it is best to think in this way.

A straight line drawn from the lower left corner to the upper right corner of the Standard Celeration Chart has an angle of 33 degrees. This angle represents a ×2 change in behavior per week and is often used as a behavioral objective for effective instruction and learning. On the other hand, a straight line from the upper left corner to the bottom right depicts a ×2 deceleration in behavior, a useful target when behavior is at excessive levels. Overall, based on the celeration plotting, teachers and students work together to find instructional variables (procedures) that produce x2 changes in academic behavior.

Basic Principles of Precision Teaching

As an instructional system, Precision Teaching has four guiding principles: (1) A focus on directly observable behavior; (2) Rate as the basic behavioral measure; (3) The charting of behavior on a Standard Celeration Chart; and (4) The learner knows best.

In terms of the *focus on behavior*, Precision Teaching involves translating learning tasks into concrete, directly observable behaviors that can be counted, timed and recorded. Observable behavior refers to something the person is doing or the product of something that has been done. For example, during a period of oral reading, the number of words read correctly could be counted (doing), or a student could be asked to write a paragraph in so much time and the number of correctly written words could be tallied (product).

But, you say, what about private behavior, such as silent reading? In this case, the teacher must make "silent reading" public in some way. A child, Sally, who is poor at silent reading might be asked to read out loud so that counts of the number of correct words can be obtained (a measure of so-called "decoding" skills). In order to assess her comprehension skills, the teacher might provide a list of questions to Sally after she silently reads a passage from a book. Following this, the teacher would count the number of correct answers that Sally made on the quiz.

Once behavior is defined so that counts may be obtained, the rate of behavior is used as the basic measure of learning (or performance). The rate is the average number of responses during the period of assessment or *counts per minute*. In a 4-min test of spelling, a student who spells 12 words correctly has a rate of 3 correct words per minute. The use of rate (frequency/time) focuses instruction on **fluency** or accuracy *and* high frequency. When a performance becomes fluent, the behavior is retained longer, persists during long periods on the task, is less affected by distractions, and is more likely to be available in new learning situations (i.e., to combine with other well-learned behaviors) (see Binder, 1996; West & Young, 1992).

Once the teacher has a rate measure of behavior in terms of counts per minute, the next requirement of Precision Teaching is to *plot the rate* on a Standard Celeration Chart. As we have seen, the celeration chart allows the teacher and student to observe improvement in the target behavior, usually against a ×2 objective for each week. The degree of acceleration (or deceleration) is a useful measure of learning in academic settings. In this regard, West and Young (1992) stated:

> When data are plotted on the standard celeration chart, learning is generally represented by a straight or nearly straight line. The value of the slope of the line which best fits the distribution of values [plotted rates over days] on a logarithmic scale is thought of as an "index of learning." The steeper the slope the faster the learning is; the flatter the slope, the slower the learning is. (p. 132)

The whole idea of Precision Teaching is to improve learning in a way that is objective and quantifiable. Teachers and students work out plans for improvement, implement the instructional procedures, and assess the effects of the interventions.

Instructional components of Precision Teaching consider four basic factors that correspond to principles of stimulus control, reinforcement, extinction, and punishment: (1) what to do before the target behavior occurs (materials, teaching assistance, etc.), (2) what to do after a correct response occurs (consequences of behavior), (3) what to do after an incorrect response occurs (ignore it or provide an aversive stimulus), and (4) what to do about how the teacher practices the task with the child. These teaching strategies are beyond the scope of this textbook but Martin and Pear (1999) provide an excellent introduction to the teaching procedures and factors influencing their effectiveness.

As a general rule, Precision Teaching takes the stand that "the learner knows best." This dictum arose from an incident that Lindsley (1990b) recounts about his early experience in the animal laboratory.

> When I was a graduate student, I trained a rat whose behavior did not extinguish as the charts in Skinner's (1938) book had shown. My rat at first had responded much more rapidly when his responding was no longer reinforced. The rapid responding went on for about 30 minutes, at which time the rat stopped abruptly. I took the cumulative record of the rat's unusual extinction to Dr. Skinner and asked him how this has happened. How could the rat do this when the book showed a very different gradual extinction curve? Skinner answered, "In this case, the book is wrong! *The rat knows best*! That's why we still have him in the experiment!" (p. 12)

The general rule, then, is that the *learner knows best*. That is, if a student is progressing according to the instructional plan, then the program is appropriate for that student. In contrast, if the targeted behavior for a student shows little celeration (e.g., less than ×2 or doubling), the program needs to be changed. In other words, precision teaching requires that we alter the teaching strategy rather than blame the student (e.g., "John is stupid"). That is, the student is always "right" and, in the context of low improvement, new instructional procedures are required to improve learning and performance.

Application and Precision Teaching

Precision Teaching is a cost-effective technology (Albrecht survey cited in Lindsley, 1991) that has been successfully applied to teach learners that range from developmentally delayed to university graduate students (White, 1986). Binder and Watkins (1990) reported on a Precision Teaching program conducted in Great Falls, Montana in the early 1970s. Over a 4-year period, teachers at Sacajawea elementary school added 20 to 30 min of Precision Teaching to their regular curriculum. On the Iowa Test of Basic Skills, the students given Precision Teaching improved between 19 and 40 percentile points compared with other students in the district. More generally, improvements of two or more grade levels per year of instruction are commonly observed in Precision Teaching classrooms (e.g., West, Young, & Spooner, 1990).

Similar improvements have been reported as the Morningside Academy, a school that focuses on Precision Teaching for developmentally delayed people. Johnson and Laying (1994) described the exceptional results at Morningside in these terms.

> Due to its successes, Morningside Academy now offers parents two money-back guarantees. The first is for [learning disabled] children who are two or more years behind in school. . . . These learners, who have rarely gained more than a half a year in any one academic year, will gain at least two grade levels per school year or their parents will receive a tuition refund in proportion to the shortfall. The second guarantee is for any other [attention deficit disordered, ADD]

learners . . . who stand apart from their peers because they do not coordinate visual and motor skills effectively, as is most apparent in their handwriting. . . . Morningside Academy guarantees that these learners will increase their time-on-task endurance from 1 to 3 minutes spans to 20 minutes or more . . . . [Over seven years] . . . Morningside has never had to refund tuition for failure to meet its money-back guarantees. (pp. 174–175)

Although highly successful in promoting rapid and fluent learning, Precision Teaching remains only a small part of mainstream education. One possibility is that educators and psychologists in education have resisted a behavioral solution to learning, one that emphasizes the accountability of the teacher. That is, the teacher is responsible to identify instructional procedures that result in targeted behavior changes in the student. These behavior changes are easily observed on the standardized chart while lack of successful instruction is also apparent. Ironically, the fact that Precision Teaching makes learning objective and quantifiable may be the biggest reason for nonadoption by the educational community.

Another reason for the marginality of Precision Teaching may lie in popular negative views regarding behaviorism and behavior analysis. That is, behavioral research, theory, and philosophy are often seen to encroach on Americans' beliefs in freedom and dignity of the individual (Skinner, 1971). A behavioral technology of education appears to go against our cultural values—for example, individual responsibility suggests that students should be motivated to learn. We shouldn't have to program instruction for them! As we have seen in this section, this is a wrong-headed notion but it is upheld by our culture.

In what Skinner (1984a) called *The Shame of American Education*, he indicated that most educational problems "could be solved if students learned twice as much in the same time and with the same effort" (p. 947). This is exactly what Precision Teaching is all about. The problem, said Skinner, is that theories of human behavior based on humanism and developmental and cognitive psychology are most often taught in schools of education, but learning based on these theories is often ineffective. In his solution, Skinner pointed to several steps that needed to be taken to advance the educational system: (1) be clear about what is to be taught, (2) teach first things first, in an ordered sequence of progression, (3) stop making all students advance at essentially the same pace, and (4) program the subject matter—a good program of instruction guarantees a great deal of successful action.

In the end, as we have mentioned, the problem of American education rests with our culture. Skinner stated: "a culture that is not willing to accept scientific advances in the understanding of human behavior, together with the technology that emerges from these advances, will eventually be replaced by a culture that is" (Skinner, 1984a, p. 953) The survival of the American way of life depends on education of the young. The question is are American people willing to adopt and promote a scientific approach to effective education?

Applications of Behavior Principles

As noted throughout this book, behavior principles have been applied to many practical problems. In this section, we highlight a few well-known applications of operant and respondent conditioning and discuss the basic principles underlying the effectiveness of these techniques.

Self-Control

An important part of socialization involves learning to give up immediate gains for greater long-term benefits. It also involves accepting immediate aversive consequences for later positive outcomes. When people manage their behavior in such a way that they choose the more beneficial long-range consequences, they are said to show **self-control**. From a behavioral perspective, self-control occurs when a person emits a response that affects the probability of subsequent behavior.

A person who sets the alarm clock before going to bed is showing self-control if this response ensures that he or she gets up for classes in the morning. Setting the alarm may be called a **controlling response** because it alters conditions that affect subsequent behavior— getting up for school rather than sleeping. Getting up for school is the **controlled response** in the sense that its probability of occurrence is altered by the effects of the controlling response. In a behavioral view of self-control, both the controlling and controlled responses are determined by the species history and contingencies of reinforcement. That is, there is no self or internal agent that controls what you do; behavior that is said to show self-control is similar to other complex operants and is regulated by the same principles.

Skinner (1953) has discussed a variety of self-control techniques that people commonly use, involving controlling and controlled responses. Physical restraint is a simple but prevalent method of self-management in which a person physically prevents a subsequent response. For instance, a person may put a hand over his or her mouth to prevent laughter. In this case, the controlling response, clasping the mouth, prevents the controlled response of laughing in an awkward situation.

Another technique is called changing the stimulus conditions. This occurs when a person manages the stimuli that control subsequent behavior. A student who must have a particular text for class could put the book by the front door. Deprivation and satiation can be used for self-control, as when an individual eats an apple before dinner to lower food consumption during the subsequent meal.

Manipulation of emotional conditions is also a self-control technique. Students may "psyche themselves up" to have the courage to protest a low grade. Here self-control involves rehearsing the unjust reasons for the low mark, thereby increasing the chances of protesting it. Aversive stimulation may be used in self-control. Students who say to themselves, "I may fail the course if I don't get the paper completed," increase the probability of writing it. People occasionally use drugs as a technique of self-management, as when a person has a few drinks to alleviate the stress of an upcoming talk or presentation (we do not recommend this because it negatively reinforces drinking alcohol).

Self-reinforcement and punishment also are used to manage behavior. As we wrote this book, we finished each day's effort by running a word count on the computer. Running the word count was self-reinforcement for writing (or punishment for not writing much). After making a fool of oneself at a party, a person may chastise or punish himself or herself in an attempt to reduce future acts of idiocy. Finally, just doing something else may be used to alter subsequent behavior. If you do not want to talk about what happened on your last date, you can change the topic of conversation to plumbing, politics, dry cleaning, the economy in Algeria, or some other interesting topic.

A Case Study of Self-Control

In applied behavior analysis, self-control techniques may be taught to clients, who are then better able to manage their own behavior. As we have mentioned, one common
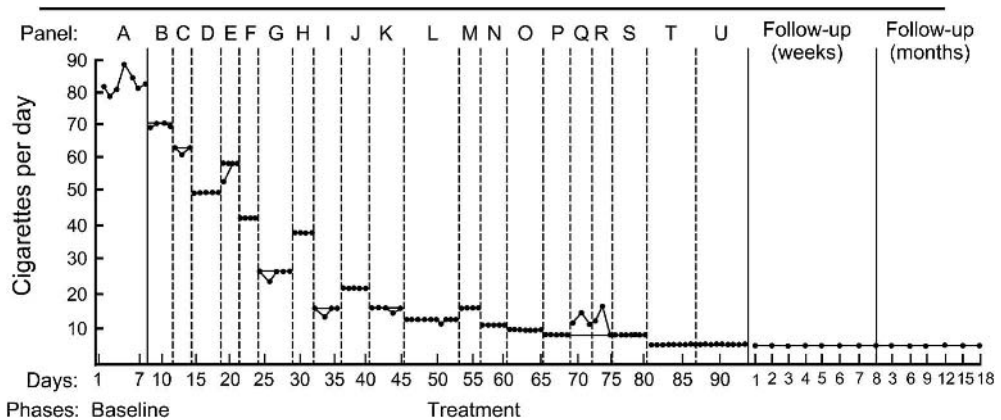
FIG. 13.7. *A changing criterion design used in the modification of excessive smoking as described From "The Use of the Changing Criterion Design in Achieving Controlled Smoking in a Heavy Smoker," by D. Belles and A. S. Bradlyn, 1987,* Journal of Behavior Therapy and Experimental Psychiatry, 18, *77–82, reprinted with permission Copyright 1987, Elsevier, Ltd. by the Journal of Behavior Therapy and Experimental Psychology.*

technique for self-control is called self-reinforcement. An interesting study was conducted by Belles and Bradlyn (1987), who modified the behavior of a heavy smoker by arranging self-reinforcement and self-punishment over the telephone. The client was a 65-year-old man who lived 200 miles away from the clinic. The researchers arranged a treatment program with the client and his wife. For each day that he smoked less than a specified number of cigarettes, he added $3 to a savings fund that was used to buy items that he wanted. When he exceeded the agreed-on number of cigarettes, he had to send a $25 check to the therapist, who donated the money to a charity that was unacceptable to him. His wife verified the number of cigarettes he smoked each day by unobtrusively monitoring his behavior.

A *changing criterion design* was used to evaluate the effectiveness of the self-control procedure. In this design, the criterion for the number of cigarettes smoked each day was progressively lowered over 95 days. The effects of self-reinforcement are shown if the subject meets or falls below the criterion set by the researchers. Figure 13.7 shows the effects of the treatment. The target level for each period is shown by a horizontal line, and the client generally matched his behavior to this criterion. Notice that although the criterion generally decreased, the researchers occasionally set a value higher than a previous phase and the client's behavior changed in accord with the contingencies. After 81 days on the program, the client's cigarette consumption had declined from about 85 to 5 cigarettes each day. At this point, he was satisfied with his progress and said that he wanted to remain at this level. Follow-up reports on his smoking over 18 months showed that he continued to have only 5 cigarettes a day.

Behavioral Choice and Self-Control

As we saw in Chapter 10, modern behavioral researchers use behavior analysis of choice and preference to investigate the underlying processes that result in self-control (e.g., Ainslie, 1974; Logue, 1988b; Rachlin & Green, 1972). In the laboratory, self-control occurs when an organism chooses a larger, more delayed reinforcer rather than an immediate, smaller reward. The choice of the smaller, immediate reinforcer is called impulsiveness. For

example, choosing an immediate payment of $50 now rather than $200 after 3 months is impulsive behavior.

The probability of an impulsive response varies with the relative amount of reinforcement and with the relative delay to reinforcement. A person is more likely to choose the delayed reinforcer if the amount is increased from $200 to $1,000 while the small, immediate payment is held constant at $50. Similarly, the larger payment of $200 is more likely to be selected if its delay is reduced from 3 months to 6 weeks (see Logue, Pena-Correal, Rodriguez, & Kabela, 1986, for research with humans; Logue, 1998 provides a review of self-control and an application to educational administration).

One way to solve the problem of choosing the smaller, immediate reinforcer over the larger, delayed reinforcer is to make a commitment. A *commitment* is a controlling response made before the actual choice (see Chapter 10 for a more formal definition). The commitment ensures that the larger, delayed payoff is always chosen. People will make a commitment only if they benefit more from this behavior than from alternative action.

For example, when payday arrives at the end of the month, the value of spending $100 is greater than the value of saving it (i.e., having $1,200 at the end of a year). An important finding is that the worth of an immediate, smaller reinforcer ($100) is discounted more rapidly with time than the worth of a larger, delayed reinforcer ($1,200) (e.g., Ainslie, 1974; Rachlin & Green, 1972). This means that there is a time, prior to payday, when saving $1,200 over a year is more valuable than spending $100. This change in the value of a reinforcer with time is called *preference reversal* (more in Chapter 10). Because of preference reversal, a customer will sign a contract (commitment) with the bank to debit his or her checking account $100 at the end of each month. The money is used to pay off a government savings bond that will yield $1,200 plus interest at maturity. The contract with the bank ensures that the customer always chooses to save rather than spend when his or her paycheck arrives.

Teaching Autistic Children

Autistic children show an early lack of social interaction with parents, other family members, and peers. For example, these children often resist being held and may have tantrums if picked up or hugged. When autistic children get older they may be mistaken as deaf because they don't talk or even establish eye contact when talked to. These children often show repeated stereotyped patterns of behavior such as rocking back and forth, spinning a top, wiggling their fingers in front of their eyes, and so on. More than 85% of autistic children fail to speak at an age when other children are highly verbal. The long-term outcome for this disorder is grim; the overwhelming majority of such children require extended care and supervision.

Ivar Lovaas, at the time of this writing a professor of psychology at the University of California at Los Angeles, has been working on the treatment of autism since the 1960s. Lovaas and his collaborators (Lovaas, 1966; 1977; 1987; McEachin, Smith, & Lovaas, 1993) have reported on the successful behavioral treatment of autistic children. Lovaas (1977) describes intensive behavioral interventions that increase social behavior, teach the child to speak, and eliminate self-stimulation. Most treated autistic children showed significant improvement in their daily functioning. Incredibly, when the treatment was applied to autistic children that were less than 30 months old, 50% of these children were later indistinguishable from normal school children. No other treatment of autistic children has produced such dramatic improvement (Lovaas, 1993; Schopler & Mesibov, 1994).

FIG. 13.8. *Joe Morrow and Brenda Terzich are the founders of Applied Behavioral Consultants (ABC). Reprinted with permission.*

Because the treatment that Lovaas reported was highly effective, Joe Morrow and Brenda Terzich (Figure 13.8) started a business devoted to behavioral intervention for autistic children (Morrow & Terzich, 1997). The intervention they implemented was (and is) based on the treatment package described by Lovaas. Morrow and Terzich started their company, *Applied Behavior Consultants* or ABC, in 1987 in Sacramento, California. They concentrated on providing intensive in-home treatment for these children. Because they delivered an effective and well-designed treatment, the demand for their services quickly overwhelmed them. At this point they began hiring and training behavioral technicians.

As their business grew, they developed an in-home treatment technique that they continue to use today. Behavior technicians with some undergraduate training in behavior analysis are hired as behavior consultants. These people are then further trained by ABC staff to work with autistic children. When consultants are judged skilled enough to deliver behavioral services, they visit the homes of the client children. At this point, a behavioral assessment is conducted and an individualized treatment package is designed.

Parents are taught the necessary behavioral skills for training their child. The treatment package includes specific intervention strategies for accomplishing behavioral outcomes. For example, the children are reinforced for making eye contact when the teacher talks to them. Appropriate life skills such as eating meals with utensils, dressing oneself, and personal hygiene (i.e., brushing teeth, combing hair, etc.) are reinforced with tokens and social approval. Verbal skills including manding and tacting are also targets for behavior change. ABC staff members monitor progress and, if necessary, advise program changes.

In 1994, Morrow and Terzich started a communication-based private school in for children diagnosed as autistic. At ABC school, autistic children receive individualized behavioral training for about 5 hr a day, 218 days per year. The emphasis at the school is on verbal and academic behavior as well as on social skills (Bondy, 1996; Bondy & Frost, 1994). A primary objective of the program is to move children from the ABC school to public schools, either general or special education, within 2 years. To accomplish this, ABC uses a five-step program that "guides the progression of lessons from discrete trials [learning] to

the ultimate transfer of the control of social behavior to the verbal community, including the child's peer group . . . ." (Morrow et al., in press) .

Level 1 of the program involves discrete trials procedures where the teacher presents a stimulus and the response by the child is reinforced (or corrected). The training at this level also includes training generalization of subskills to new situations, trainers, and variations within the standard teaching setting. At level 2, the teaching is focused on stimulus generalization. That is, once an appropriate response is mastered by the child in the presence of a specific S^D (level 1), the teacher varies properties of the S^D while maintaining the appropriate response. The S^D may be "What am I doing" and hand waving by the teacher and the child is reinforced for saying "You're waving your hand." At level two the teacher may say "I'm doing what?" or "Hey, what's happening here?" (varying the S^D) and reinforcement remains contingent on the response, "You're waving your hand." At level three, the training emphasizes maintaining learned concepts and skills. The training ensures that the child demonstrates generalization of skills when lessons are changed from one location or time to another. Level 3 training also involves programmed environmental distractions, similar to everyday interruptions in a classroom. The child is taught to maintain accurate responding in face of these random interruptions.

At level 4, children are taught "splinter skills." A child may be able to use the toilet and to dress herself but be unable to select the clothes to wear. In the classroom, a child may be able to write on a piece of paper when instructed by the teacher, but be unable to get a piece of paper on her own. Formally, the training at this level is focused on completion of extended behavior chains or sequences. The final level of the program, level 5, is focused on the training and generalization of social skills (greetings, reciprocity, empathy, etc.) that will be necessary to interact with others in everyday settings (e.g., classroom, playground, and home). For example, the child is taught to discriminate between greeting his or her parents and saying hello to a playmate. Training at level five also insures that this kind of social skill is maintained in a variety of appropriate settings.

How successful is this kind of behavioral program? Well, at the time of admission to the program, 57% of the autistic children have no speech. After one year, all children, both vocal and nonvocal, are *manding* (e.g., requesting, asking for, etc.) vocally, or by sign language (see Chapter 12 on manding).

What about transition from the behavioral program to regular classrooms? The first thing to note is that almost no children move from traditional, nonbehavioral treatment programs to public school classrooms (Lovaas, 1987). Over the first 4 years of ABC's school operation, 71 children had completed all five levels of behavioral training and had made the move to regular education classrooms. Of the 31 children who were 6 years or more in age (eldest group) on admission to the ABC school, none made successful transitions to public education classrooms. For the 25 children between 4 and 6 years in age at admission (middle group), only 8% made a successful transition. When the children's age at admission was 4 years or less (youngest), 40% moved into the public education system and did not return to ABC. The preliminary data indicate that intensive behavioral intervention is most successful for younger children.

The data at ABC school substantiates recommendations by Maurice, Green, and Luce (1996) concerning intensive behavioral treatment of autism. Their manual indicates that intensive behavioral programs work best when (1) children are less than 5 years of age—the younger the better, (2) the program includes at least 30 hours of treatment per week, and (3) children continue in the program for at least 2 years. Under these conditions, even very low functioning children make behavioral gains, and as we have seen, about 40% will be able to function in the public school system. Overall, this is fantastic news for parents of autistic children.

Because of the success and subsequent demand for in-home and classroom behavioral treatment, ABC currently has several hundred employees. Since the time they started (in 1987), more than 1000 autistic children have been treated by ABC's behavioral technology. Each of these children has received about 30 hr a week of one-on-one behavior therapy. ABC has been able to reach such a large number of autistic children because of their emphasis on training parents to work with these youngsters (rather than directly providing therapy themselves). Although time-consuming, early-intensive behavior therapy has rescued many children from an otherwise isolated and impoverished life. Happily, this intervention is also much more cost-effective than providing a lifetime of supervision or institutionalization. The state of California has recognized both of these facts and provides most, or all, of the money for the program.

The Causes and Prevention of Behavior Problems

In recent years, behavior analysts have focused attention on the factors that produce behavior problems. Animal models of disordered behavior have been developed that provide insight into the causes of problem behavior (see Epling & Pierce, 1992; Keehn, 1986). Other researchers have been concerned with promoting behavior related to physical health. The area of behavioral medicine includes behavior-change programs that target health-related activities such as following special diets, self-examination for early symptoms of disease, exercising, taking medicine, and so on (see Doleys, Meredith, & Ciminero, 1982; Friman, Finney, Glasscock, Weigel, & Christophersen, 1986). The idea is that many problems of behavior and health may be prevented before treatment is necessary.

Activity Anorexia

Substantial evidence indicates that excessive physical activity is central to an understanding of human self-starvation, or anorexia (Epling and Pierce, 1996a; Pierce & Epling, 1991). Separate research areas indicate that, contrary to common sense, increasing amounts of physical exercise may reduce a person's appetite. Also, lowered food intake can induce physical activity. Thus, declining food intake produces activity and activity suppresses food intake. These two effects combine to produce an **activity anorexia** that occurs in animals and accounts for a significant number of cases of anorexia nervosa (Epling & Pierce, 1992).

Anorexia Nervosa

A young woman goes on a severe diet and continues to the point of starvation. How can this person be anything but mentally disturbed? In fact, anorexia nervosa is currently classified as a neurotic disorder by psychiatrists and psychologists (see Diagnostic and Statistical Manual, 4th edition, DSM IV). Mental illness and disturbed cognitions are suggested by the many symptoms that accompany willful starvation (see Garner & Desai, 2000, for a multidimensional analysis). These symptoms include fear of being fat, obsessive food rituals, distorted body image, and disturbed self-perception.

Notably, modern psychiatry has reinforced the view that cognitive and mental events cause abnormal human behavior. This is convincing to people, because unusual thoughts often accompany bizarre behavior. Although these thoughts may occur and are associated

with disturbed eating, this evidence is not sufficient to claim that they are causes. One reason for this association may be that anorexics learn to label their emotional states and behavior in accord with the expectations of therapists, family, and friends.

The numerous and varied symptoms of anorexia also arise from starvation itself (Epling & Pierce, 1992; Keys, Brozek, Henschel, Mickelsen, & Taylor, 1950). Keys and his associates (1950) observed many of the symptoms of anorexia nervosa in psychologically healthy men who participated in a study of forced starvation. Symptoms similar to those found in anorexia nervosa developed as the men lost weight. On psychological tests the men became neurotic (a few scored in the psychotic range), they were obsessed with food, some became bulimic (excessive overeating), and so on. Importantly, these symptoms *followed* rather than preceded starvation—suggesting that they were not the causes of anorexia.

The study by Keys and his colleagues (1950) strongly suggests that starvation causes the symptoms of anorexia nervosa. If this is the case, then what determines starvation? Substantial evidence suggests that food restriction and excessive physical activity underlie most human anorexia.

Physical Activity and Anorexia

Clinical reports of anorexia nervosa have viewed excessive physical activity as an interesting but unimportant symptom of the syndrome. For example, Feighner et al. (1972) have described diagnostic criteria that include periods of overactivity as one of six possible secondary symptoms. In the traditional view, activity is secondary because it is simply a way that the anorectic burns off calories. That is, physical activity reflects the patient's desire to lose weight.

Although this interpretation is widely accepted, there is evidence that it is wrong. Excessive physical activity appears central to many cases of human self-starvation (Epling & Pierce, 1992). The evidence for the importance of activity comes from a variety of sources. Controlled experiments with animals have shown that physical activity can make an animal give up eating when food is relatively abundant (Epling & Pierce, 1984, 1988). Research with humans has also suggested a link between activity and starvation (e.g., Davis, 1999; Davis, Kennedy, Ravelski, Dionne, 1994). Beumont and his colleagues asked 25 anorexics to identify their symptoms and the order of occurrence (Beumont, Booth, Abraham, Griffiths, & Turner, 1983). Of the 28 reported symptoms, only manipulating food servings and increased sport activity were present in all patients. Generally, the ordering of the symptoms indicated that changes in dieting and food intake were followed by increased physical activity. Many other studies have documented excessive physical activity in anorexic patients (see Epling, Pierce, & Stefan, 1983).

Anorexia in Animals

The process of activity anorexia begins when rats are fed a single daily meal and are allowed to run on an activity wheel. It is important to note that the size of the meal is more than adequate for survival. Also, animals are not forced to exercise on the wheel. They can choose to remain in an attached cage or just lie in the wheel. In fact, the animals start running, and this activity increases daily because of the food restriction (Epling & Pierce, 1996b).

As shown in Figure 13.9, wheel running rapidly increases to excessive levels. An adolescent rat may run up to 20 km a day at the peak. Ordinarily, these animals would run less than 1 km a day. This excessive activity is surprising because the animal is expending many more calories than it is consuming. For this reason, the activity is life-threatening.
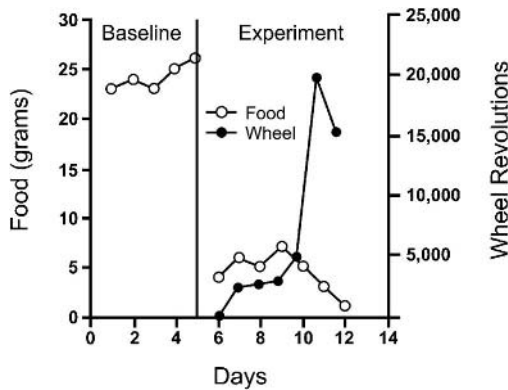
FIG. 13.9. *Excessive running and reduction of food intake by an adolescent rat reported in "A Theory of Activity-Based Anorexia," by W. F. Epling, W. D. Pierce, and L. Stefan, 1983,* International Journal of Eating Disorders, 3, *27–46.*

A more startling effect is that food intake drastically declines as running becomes excessive. As you can see, at the end of 1 week (Figure 13.9), the animal is eating very little. The rat is giving up eating in spite of increasing energy expenditure through wheel running. If this process is allowed to continue, the animal dies of starvation. The drop in running on the last day occurs because the rat is too weak to continue.

Motivational Basis of Eating and Running

In Chapter 7, we discussed the interrelations of eating and running (Pierce et al., 1986). Recall that the research evidence indicates that rats will work more for an opportunity to run on a wheel as food deprivation increases. The animals bar pressed many more times for 60 s of wheel running as their body weights declined. Additionally, rats pressed a lever for food less when they had run on a wheel the night before a food session. This effect occurred even though the animals had several hours of rest before being placed in the operant chamber. The overall findings suggest that the reinforcing effectiveness of physical activity increased as a function of food deprivation. Also, the reinforcement value of eating food decreased when preceded by a bout of physical activity. These two reinforcement relations provide a behavioral account of the activity–anorexia cycle (see Chapter 7 for the biological basis of these reinforcement relationships).

Activity-Induced Taste Aversion

The suppression of eating during activity anorexia may also involve conditioned taste aversion (CTA) as discussed in Chapter 7. Taste aversion might occur when a distinctive taste becomes a conditioned stimulus (CS) that is followed by the physiological consequences of wheel running, the unconditioned stimulus (US). Lett and Grant (1996) were the first to test the CTA hypothesis. In their experiment, rats were exposed to flavored liquids that were paired or unpaired with wheel running. Compared with control rats that remained in their home cages, experimental rats drank less of the flavor paired with wheel running—the rats showed CTA induced by wheel running. Subsequent research has replicated the basic effect and ruled out mere novelty of the wheel as the basis for the original finding (Heth, Inglis, Russell, & Pierce, 2000; Nakajima, Hayashi, & Kato, 2000).

Sarah Salvy is a Ph.D. graduate student in psychology (University of Quebec at Montreal) who currently is working on her dissertation in our laboratory at the University of Alberta. Her research has shown that CTA induced by wheel running can be eliminated

by preexposure to the wheel running US (Salvy, Pierce, Heth, & Russell, 2002). This result is consistent with habituation effects and a respondent conditioning account of CTA induced by wheel running. Her research has also indicated that CTA is related more to the contingency between a distinctive taste and wheel running, than to the intensity of the physical activity. That is, the association between taste and the physiological effects of wheel running is more important than the "dose" level of physical activity. Finally, Sarah is the first researcher to find CTA to food stimuli induced by wheel running. Her work on food aversion and physical activity constitutes significant "bridging experiments" between the CTA–wheel running protocol and the animal model of activity anorexia.

Humans and Anorexia

The seemingly willful starvation of animals appears similar to cases of human anorexia. For humans, social reinforcement can increase the tendency to diet or exercise. An individual may learn these responses to escape or avoid criticism for being overweight or to gain approval for being slim and fit (see Pierce & Epling, 1997, for an analysis of the social contingencies). The type and intensity of dieting and exercise is initially regulated by the responses of others. However, once social reinforcement has encouraged food restriction, especially in the context of increasing exercise, the activity–anorexia cycle may be initiated. When the process starts, the person is trapped by the activity/food reduction cycle.

Humans self-impose diets for a variety of reasons. All diets do not generate excessive activity. The type, severity, and pattern of diet are important factors contributing to physical activity. For example, many anorexics change their meal pattern from several meals to one per day. This change in the number of meals may be important in generating activity anorexia (Kanarek & Collier, 1978).

Mandrusiak (2002), an honors student in psychology, conducted an interesting experiment in our laboratory at the University of Alberta. Using a foraging model, rats had to press a procurement lever in order to produce food on a second lever (the meal lever). Michael wanted to find out whether rats would self-starve, without any imposed food restriction by the experimenter. The findings indicate that rats "choose" to starve when the procurement cost of meals is high (the number of responses required to gain an opportunity to eat a meal) and an opportunity for physical activity is available. Basically, the high cost of meals drives down the number of eating bouts per day (to one meal a day); interestingly, the amount of food consumed during the meal does not compensate for the reduction in number of eating bouts (no energy balance). The rat literally places itself on a restricted food schedule.

When self-imposed food restriction is combined with the opportunity for physical activity (the rat can choose to run on a wheel), the activity–anorexia cycle is initiated and the animals will eventually die. The foraging model is another animal analogue for human self-starvation. In humans, the cost of taking meals could include social contingencies based on appearance or alternative sources of reinforcement involving work, family, or school (Pierce & Epling, 1997). As the social costs for eating, increase, people self-impose food restriction and become physically active. The result would be that some people inadvertently initiate the activity–anorexia cycle.

Assessment, Treatment, and Prevention

The activity–anorexia model has important practical implications. In the book *Solving the Anorexia Puzzle: A Scientific Approach*, Epling and Pierce (1992) outlined the criteria for assessment, treatment, and prevention of activity anorexia. In terms of assess-

ment, the primary criteria involve a history of low and declining food intake, a history of excessive physical activity, and psychological symptoms that follow rather than precede weight loss. Treatment is based on traditional behavior-modification procedures but is directed at the responses that compose the activity–anorexia cycle. For example, contingencies are arranged to stop excessive dieting and exercise. In addition, patients are taught how to eat and to discriminate between moderate and excessive levels of exercise.

Prevention of activity anorexia involves changing the sociocultural conditions that promote excessive dieting and exercising. Medical doctors are in the best position to call attention to the role of diet and exercise in the onset and maintenance of eating disorders.

Self-help groups concerned with eating disorders may have members who recognize the biobehavioral processes involved in self-starvation. These groups can play an important role in preventing onset and relapse of activity anorexia. A second major function of self-help groups is education and social change. The groups may send speakers to schools, public meetings, and professional conferences. These groups may also lobby physicians, government agencies, private organizations, and public companies. Because of this active and organized involvement, self-help groups may be the most important source of prevention for activity anorexia.

ON THE APPLIED SIDE—MAMMACARE—DETECTION AND PREVENTION OF BREAST CANCER

About 180,000 American women develop breast cancer each year. The disease kills an additional 46,000 women. Every women is a potential victim and about 12% of women will develop breast cancer at some time in their lives. In addition to loss of life, victims of breast cancer often undergo disfiguring surgery that may physically and emotionally disable them.

Early detection of a malignant tumor in the breast is a major weapon in the fight against breast cancer. At present, doctors do not know how to prevent breast cancer, but early detection significantly improves a woman's chances of survival. Importantly, the victims of the disease are almost always the first ones to detect the tumor. In most cases, however, women only detect the tumor after the cancer has reached an advanced stage. Regular and proficient self-examination by young women could substantially improve the detection of small tumors. Early detection would dramatically increase survival and lower the likelihood of disfiguring surgery.

Surprisingly, a study by Baxter (2001) based on a summary of the literature concluded that teaching breast self-examination (BSE) to women 40–49 years old has no benefits (in terms of detection or lowering death) and is actually harmful because women are constantly going to doctors based on false readings. The conclusions of this study are controversial (Larkin, 2001), but could be accurate in terms of the breast self-examination programs included in the review. Often BSE programs use pamphlets, posters and films to teach the requisite skills, but these teaching aids alone are not enough. There is reason to believe, however, that a strict behavioral program of BSE would fare much better.

Dr. Henry S. Pennypacker (Figure 13.10) and his associates at the University of Florida have developed a behavioral program called MammaCare to teach women effective

FIG. 13.10. *Henry S. Pennypacker, the founder of MammaCare. Reprinted with permission.*

self-examination of their breasts (Hall et al., 1980; Pennypacker et al., 1982). He began to work on this program because:

> like many before me, I took a degree in classical experimental psychology and began an academic career. I rapidly became uncomfortable with the hypocrisy inherent in my position: I was an "expert" in learning using none of my expertise in my work. My interest turned to education at all levels, partly because of the critical role it plays in the survival and evolution of the culture and partly because it looked like an easy place to make a contribution. How wrong I was! . . . [W]ith hindsight . . . I have a better understanding of the problems we face and general strategies needed to solve them. MammaCare is a step in that direction. (Pennypacker, personal communication, February 22, 1989)

The MammaCare program is based on the assumption that women often are unable to detect small tumors simply because they have not been trained to do so. The pressure receptors of the fingertips allow for subtle discrimination of surface contour (e.g., from smooth to bumpy), as is clearly demonstrated by blind people who read Braille. It follows that women may be trained to detect small lesions in the breast related to cancerous tumors. An effective program must teach women to tell the difference between small tumors and the normal lumpiness of the breast itself.

Components of MammaCare

An initial step involves *discrimination training*. The patient is trained to use her fingertips to discriminate small lesions from ordinary nodules in the breast. This training is accomplished with the used of silicone breast models that have been developed to match the physical properties of real breast tissue (Bloom, Criswell, Pennypacker, Catania, & Adams, 1982; Hall et al., 1980). A woman palpates the breast model in order to detect lumps of different hardness, located at various depths, and varying in lateral mobility. Detection of lumps functions as reinforcement that maintains searching for and reporting on abnormal breast tissue.

Once the patient is able to detect small lumps (e.g., diameter 0.4 mm) with her fingertips, she is taught additional *palpation and search skills* (Saunders, Pilgram, & Pennypacker, 1986). A technique of palpitation is trained which emphasizes breast examination using the pads of the fingers and multiple pressures. A vertical strips pattern of search is used because of greater success at detection when compared with concentric circles or radial spokes patterns

(Saunders et al., 1986). The target of these procedures is to ensure that a woman's fingers contact a maximum volume of breast tissue during self-examination. In this phase, the woman learns palpation and search on her own breast while being carefully evaluated by a trained professional.

As with all behavioral programs, simple but precise and objective *measurement* procedures are used to indicate a patient's proficiency at detection and thoroughness of self-examination. A patient must be at least 95% proficient before leaving the training center. This level of proficiency helps ensure that self-examination techniques become an integrated skill that may be practiced monthly as recommended.

A final component of the program ensures maintenance of self-examination by *reinforced practice*. After MammaCare training, each woman is given a take-home kit that contains a breast model that is matched to the firmness and nodularity of her own breast tissue. This breast model is used to update the patient's tactile skill just before she carries out the monthly self-examination. The practice model contains five small tumor simulations that the patient can find only if she performs the examination correctly. Based on this reinforced practice, a woman who finds nothing unusual during a breast examination can be almost certain that there was nothing there to detect.

Effectiveness of the Program

Women who have learned the MammaCare method of breast self-examination are able to detect lesions as small as 0.4 mm in diameter. This compares favorably to the average tumor that women discover by accident, measuring 3.6 cm in diameter. It also compares well with conventional self-examination, in which women detect tumors in the 2.0-cm range. Evidence also shows that training in self-examination improves detection in actual breast tissue (Pennypacker et al., 1982, pp. 109–110). The greater effectiveness of a behavioral system of breast self-examination lies in the fact that the program directly teaches women what to feel for and how to search their breasts thoroughly.

Extending the Use of the Program

The MammaCare program is now available to a greater number of women at a lower cost. Further research has resulted in a learning system that may be done at home, at the woman's convenience (MammaCare Learning System). The system includes a silicone breast model with simulated tumors, a step-by-step videocassette to train mastery-level proficiency in self-examination, and a practice kit that includes a second model, a written review manual, a reminder calendar, and a record booklet (for information write to The Mammacatch Corporation, 930 NW 8th Ave., Gainesville, FL 32601 or go to http://www.mammacare.com/). A woman uses the learning system to master the self-examination skills and then is asked to perform a portion of the breast exam in the presence of a trained professional who can correct any problems.

Finally, the MammaCare system is now available to physicians or other health professionals through a special 2-hr clinical training course, with optional 3- and 5-day training seminars. Professional training is focused on those who must evaluate the breast self-examination skills of many women—including nurses, patients in a large medical practice, or employees in a large organization (Pennypacker, Naylor, Sander, & Goldstein, 1999; Trapp, Kottke, Viekrant, Kaur., & Sellers, 1999). Also, women who complete the 5-day program may arrange to offer the 3-day course to professionals in their own neighborhood. In this way, an effective behavioral technology for breast self-examination is transmitted to a wider circle of health-care professionals, who in turn pass these skills on to more and more women.

KEY WORDS

Activity anorexia	Commitment (as controlling response)	Interval recording
Applied behavior analysis		Multiple baseline designs
Behavior maintenance	Controlled response	Personalized system of
Behavior trapping	Controlling response	instruction (PSI)
Behavioral contract	Differential reinforcement	Precision teaching
Celeration	of other behavior (DRO)	Response generalization
Changing criterion design	Duration recording	Self-control
Continuous recording	Fluency	Time sampling

ON THE WEB

http://www.envmed.rochester.edu/wwwrap/behavior/jaba/jabahome.htm Much of the applied research described in this textbook comes from the *Journal of Applied Behavior Analysis*. Go to this Web site to get more information on the journal and its articles.

http://rsaffran.tripod.com/aba.html A collection of Internet resources for parents of children with autism and related disorders based on applied behavior analysis. The site provides help in finding service providers, private schools, parental experiences, intervention principles, and much more.

http://www.iaba.com/ The Web site for the Institute for Applied Behavior Analysis in southern California that offers behavioral management services, and supported educational and employment services to people with developmental disabilities.

http://www.bacb.com/ Want to become a certified behavior analyst? Go to this Internet address to get more information on the steps and examinations. The Behavior Analyst Certification Board is a nonprofit corporation established as a result of credentialing needs identified by behavior analysts, state governments, and consumers of behavior analysis services.

STUDY QUESTIONS

1. What is one rationale for application of behavior principles? (358) Give examples of behavioral applications. (358)
2. Define the term applied behavior analysis and distinguish it from the experimental analysis of behavior. (359)
3. Discuss the concentration on research as a characteristic of applied behavior analysis. (359) Describe human behavior as the central focus of applied behavior analysis. (359) What does this mean for treatment of human problems? (359)
4. How did Dr. Epling help Tammi, the girl who talked of suicide? (360) State how conditioning principles are used in the analysis of Tammi's neurosis. (360)
5. Explain how staff at an institution could inadvertently condition a child to bang her head repeatedly. How could this behavior be eliminated by conditioning principles? (360). Define differential reinforcement of other behavior (DRO). (360)
6. Give examples of biological factors that produce behavior change. Can conditioning principles help in these cases? (360)
7. Explain what is meant by the direct treatment of behavior problems. (361) What is a behavioral contract? (361) State the principles of behavioral contracting. (Figure 13.1)

8. In terms of therapy, what do applied behavior analysts focus on? (362) Is there a role for "talk therapy" in applied behavior analysis? (362)

9. How do applied behavior analysts attempt to ensure lasting change or modification of behavior? (362) In terms of generality of behavior change, what are the roles of stimulus generalization, response generalization, and behavior maintenance? (362)

10. Outline and analyze Don Baer's example of hypertension and how to program for lasting behavior change. (362) Explain what is meant by behavior trapping. (363) How can it be used to modify hypertension? (363)

11. Explain what Jim Holland (1978) means when he says, "It takes changed contingencies to change behavior." (363) Discuss changing behavior by changing the social environment. (363)

12. State some of the practical and ethical difficulties with a reversal design. (364) Name three types of multiple baseline designs. (364) In terms of design, discuss the multiple baseline across stimulus conditions used by Hall, Cristler, Cranston, and Tucker (1970) to modify tardiness. (364)

13. Outline the multiple baseline across subjects design. (365) How did Hall and associates (1970) use this design to improve academic performance? (365)

14. What is a multiple baseline across behavior design? (366) Explain how Hall and associates (1970) used this design to modify three target responses of a 10-year-old girl. (366) Are there other designs not detailed in this textbook? Name one. (366)

15. Discuss problems of definition and measurement of behavior in applied settings. (367) According to Kazdin (1989), what are three criteria for adequate response definition? (367) Even with adequate response definition, how can a modification procedure be unfair and inappropriate? (368)

16. Distinguish among the various methods of recording behavior. (368) How do applied behavior analysts ensure reliability of observation? (369)

17. **FOCUS ON**: What teaching method did Fred Keller invent? (369) Describe the personalized system of instruction. (370) Does PSI work? (370) What method of teaching did Lindsley invent? (370) Define the term celeration, the *x* and *y* axes on the Standard Celeration Chart and the six cycles on this chart? (371) What is mean by ×2 and /2 on this chart? (371) Discuss the basic principles of precision teaching. (372) State what is meant by "the learner knows best." (373) Has precision teaching worked? Discuss. (27–28) Describe the place of precision teaching in mainstream education. Why is this? (373)

18. Define self-control from a behavioral perspective. (375) Distinguish between the controlling and controlled responses. (375) Give several examples of self-management discussed by Skinner (1953). (375)

19. Discuss self-control as a problem of immediate and long-term consequences. (376) What is commitment and how does it work to increase self-control? (377) Describe preference reversal. (377)

20. How did Belles and Bradlyn (1987) use self-control techniques to modify the smoking of a 65-year-old man? Did the modification work? (376)

21. Describe the major behavioral excesses and deficits that distinguish autistic children from other children. (377) Discuss the ABC approach to the treatment of autism. (378). Describe the 5 levels of the ABC school for autism. (379) How successful has ABC school been at the treatment of autism? (379)

22. What is activity anorexia and how is it different from anorexia nervosa? (380) Outline the evidence that physical activity is central to the onset of human anorexia. (381) Describe the process of activity anorexia in animals and its motivational basis. (381)

23. What is activity induced taste aversion and what do we know about it? (382) How does activity anorexia develop in humans, referring to the Mandrusiak (2002) findings. (383) How can activity anorexia in humans be treated and prevented? (383)
24. What is the prevalence of breast cancer? Discuss the importance is early detection, referring to the medical controversy? (384) Who founded the MammaCare program and what was its basic assumption? (384)
25. Outline the behavioral procedures (components) used in the MammaCare program. (385) How effective is the program and how has it been extended to new applications? (386)

BRIEF QUIZ

1. Applied behavior analysis is a field of study that focuses on the application of the _____, methods, and procedures of the science of behavior.
   (a) equations
   (b) principles
   (c) research
   (d) findings
2. In terms of a behavioral contract, the details usually specify
   (a) what is expected of the client
   (b) the level of attention required
   (c) the consequences that follow behavior
   (d) both a and c
3. What is behavior trapping?
   (a) the fact that animal behavior leads to trapping by hunters
   (b) Don Baer got trapped by a behavioral contingency
   (c) new behavior is trapped by the natural contingencies
   (d) an attempt to overcome the traps that our behavior causes
4. Which of the following are multiple baseline designs?
   (a) multiple baseline across stimulus condition
   (b) multiple baseline across subjects
   (c) multiple baseline across behaviors
   (d) all of the above
5. Fred Keller wrote a seminal article on college teaching called _____.
   (a) Farewell to college education
   (b) Good-bye teacher
   (c) Keller on teaching
   (d) So long to higher education
6. In terms of celeration, what is twice the charted rate?
   (a) times 2 or $\times 2$
   (b) divide by 2 of /2
   (c) the ratio of 2 to 1
   (d) 1/2 over a day
7. Belles and Bradlyn (1987) conducted a stop smoking study using a(n) _____ design.
   (a) multiple baseline across subjects
   (b) A–B–A–B reversal
   (c) changing criterion
   (d) factorial

8. Level 1 of the ABC school program for autistic children involves
   (a) teaching of "splinter skills" to able students
   (b) teaching of stimulus generalization to those who are advanced
   (c) training and generalization of social skills, especially with parents
   (d) discrete trials of stimulus, response and reinforcement

9. In conditioned taste aversion induced by wheel running, _____ is the US and _____ is the CS.
   (a) wheel running; distinctive flavor
   (b) distinctive flavor; wheel running
   (c) wheel running; drug
   (d) drug; distinctive taste

10. Which of the follow is (are) a component(s) of the MammaCare system for breast self-examination?
    (a) discrimination training
    (b) finger tip utilization
    (c) palpitation and search skills
    (d) both a and c

Quiz Answers (*page*): b(358); d(361); c(363); d(364); b(369); a(371); c(376); d(378); a(382); d(385)

CHAPTER 14
Three Levels of Selection: Biology, Behavior, and Culture

IN THIS CHAPTER

1. Explore evolution, natural selection, and contingencies of survival.
2. Learn about the genetic control of egg laying in the marine snail *Aplysia* and operant control of feeding in the same organism.
3. Discover how operant conditioning furthered the survival and reproductive success of organisms, including humans.
4. Find out how the operant regulation of verbal behavior contributed to the transmission of cultural practices.
5. Learn how behavior analysts are contributing to the design of culture and the improvement of humankind.

Natural selection is one of the great scientific discoveries of humankind. Although most people know something about Darwin's theory of evolution, they seldom consider its implications for the behavior of organisms, especially humans. Contemporary behaviorists have, however, emphasized an evolutionary analysis, suggesting that principles of variation and selection are fundamental to any account of behavior.

Given a fecundity (surplus) of responses or organisms, with even slight individual variability, selection can operate to promote reproductive success. Organisms or behaviors do not evolve toward perfection but only toward advantage; they only have to be good enough. Once the behavior adapts sufficiently to obtain the reinforcer, or the organism to produce sufficient offspring, evolution becomes stable. For example, there has been little change in the alligator for millions of years, whereas Grant and Grant (1989) report significant changes in beak length of finches in less than 20 years due to selection pressure. Artificial selection, wherein humans intervene and match morphologies for breeding, can also result in very rapid change. In a remarkable study, Trut (1999) reported a 40-year investigation with farm-fox selective breeding where within 30 to 35 generations the foxes evolved into virtual dogs. Their temperament, behavior, coat color, tail angle, ears, and skull shape all changed from the basic wild fox toward a breed with domestic characteristics. The breeding stock were selected each generation on the basis of "tameness" (a subjective judgment) and all other characteristics were found to be heritable as collateral polygenes.

Notice that the breeding requirements (set by humans) were for domesticated farm-foxes, and based on these arbitrary contingencies the foxes became more domestic over generations. In natural selection, the habitat (or niche) inadvertently sets requirements for survival and reproduction. Those organisms with features appropriate to the natural contingencies of the habitat survive long enough to reproduce, and their genes become

more represented in subsequent generations. Differential reproduction based on meet-ing the requirements of the natural environment is one example of selection by conse-quences.

Behavioral researchers have suggested that **selection by consequences** is the operating principle for biology, behavior, and culture (e.g., Pierce & Epling, 1997). It is a general form of causation that goes beyond the push–pull mechanistic Newtonian model of physics (Hull, Langman, & Glen, 2001). With regard to biology, mutation and sexual reproduction ensure a range of variation in genes that code for the features of organisms. Some physical attributes are more helpful than others in the sense of meeting the requirements of the environment. Organisms with the adaptive features survive and reproduce, passing their genetic material to the next generation. Organisms without these characteristics do not survive as well, and their genes are less represented in the subsequent population. Natural selection is therefore a form of selection by reproductive consequences that occurs at the biological (population) level.

Selection by consequences as a working concept has been extended to the level of behav-ior. Operant conditioning may be viewed as an expressed characteristic of many organisms, including humans. A major aspect of such conditioning is selection by the consequences of behavior. Organisms with an extensive range of operant behavior adjust to new environmen-tal situations on the basis of reinforcement. Richard Dawkins (1986, p. 487), an eminent zoologist, noted that "the whole point of [behavioral-level] selection by consequences is that it can solve problems that [genetic-level] selection has not solved." Organisms that increased or decreased behavior on the basis of reinforcing or aversive consequences were more likely to survive and reproduce. Thus, operant conditioning became a major mode of adaptation.

As noted throughout this book, operants are the physical units selected at the behav-ioral level. The process of selection and change of operants is analogous to evolution and natural selection at the genetic level. Emitted behavior varies in form and frequency. Those responses that meet the environmental requirements (both physical and social contingen-cies) are reinforced, increasing in frequency during the lifetime of an individual. Other responses that fail to satisfy the contingencies decrease in frequency or cease to occur. Re-inforcement is therefore an ontogenetic process that extends selection by consequences to the level of behavior.

A third level of evolution and selection occurs at the cultural level. The physical unit of selection at this level is the cultural practice, including tradition and ritual. A cultural practice involves the interlocking operant behavior of many people. As with operants, cultural practices vary in form and frequency. Different ways of doing things are more or less successful in terms of efficiency, productivity, and survival of group members. For example, in terms of making automobiles, Henry Ford's assembly-line method produced more cars at less cost than other manufacturing systems. It also resulted in higher wages and more economic growth. These outcomes increased adoption of the assembly-line practice throughout the automotive industry. Generally, cultural practices are selected by such aggregate outcomes, increasing or decreasing the rate of adoption of the practice.

In this chapter, selection by consequences is examined at the genetic, behavioral, and cultural levels (see Figure 14.1). In showing the parallels among these different levels, behavioral researchers seek to integrate the study of behavior with biology on the one hand and the social sciences on the other. The attempt is not to reduce behavior to biology, or culture to behavior. Rather, it is to show the common underpinnings of all life science in terms of the extension and elaboration of basic principles.

CONTINGENCY OF SURVIVAL

Ecological   •   Genotype ⟶   Benefits/costs
environment   •   for reproduction
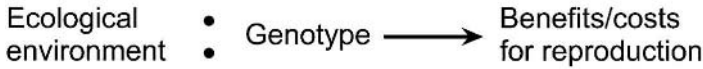
[In a specific habitat, species characteristics resulting from
differences in genotype produce more (or less) reproductive
success - process is natural selection]

CONTINGENCY OF REINFORCEMENT

Situation   •   Operant ⟶   Reinforcement/
               •   punishment
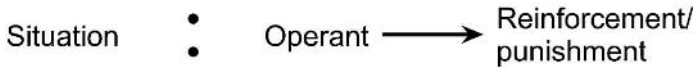
[In a specific situation, a particular response from an operant
class produces reinforcement (or extinction) that increases
(or decreases) the rate of occurrence of the operant - the
process is reinforcement]

METACONTINGENCY

Technological •   Cultural ⟶   Benefits/costs
environment   •   practice   for survival of group
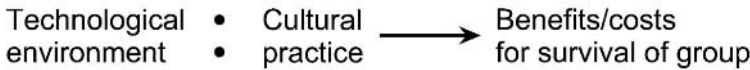
[In a specific technological environment, a particular kind of
cultural practice produces outcomes for the group that increase
(or decrease) the practice - process of cultural selection]

FIG. 14.1.   *Selection by consequences operates at three levels: biology, behavior, and culture.*

Level 1: Evolution and Natural Selection

The theory of evolution is not speculation. Scientific research has shown that the major principles are well established. Based on this realization, the theory of evolution is a factual account of the origins of species. Even though most scientists accept the process of evolution, there are still disputes over minor details. For example, some evolutionary biologists argue that very rapid steps in evolution can occur (e.g., Alvarez, 1982; Alvarez, Alvarez, Asaro, & Michel, 1980; Alvarez, Asaro & Michel, 1980; Alvarez, Asaro, Michel, & Alvarez, 1982), whereas others favor a more gradual elaboration of species characteristics (see Gould, 1989, 2002 for punctuated versus gradual evolution). Another issue involves the unit of selection. Some researchers emphasize the gene rather than the individual as the unit of selection. From this perspective, the organism is simply the gene's way of "getting into the next generation" (Dawkins, 1976). All of these viewpoints are consistent with the major principle

FIG. 14.2. *Charles Darwin in his middle years. Darwin discovered the principle of natural selection. (Archives of the History of American Psychology, The University of Akron. Reprinted with permission.)*

of natural selection. Thus, disagreements about how evolution operates do not challenge the fact of evolution (Barash, 1982).

Natural Selection

The evolutionary history of a species, or **phylogeny,** is the outcome of natural selection. Charles Darwin (see Figure 14.2) showed how organisms change in accord with this principle (Darwin, 1859). Based on a thorough analysis of life forms, Darwin concluded that reproductive success was the underlying basis of evolution. That is, individuals with more children pass on a greater number of their characteristics to the next generation.

Darwin noticed structural differences among members of sexually reproducing species. Except for identical (monozygotic) twins, individuals in a population vary in their physical features. Thus, birds like the thrush show variation in color of plumage, length of wings, and thickness of beak. Based on differences in their features, some individuals in a population are more successful than others at surviving and producing offspring. Differences in reproductive success occur when certain members of a species possess attributes that make them more likely to survive and reproduce in a given environment. Generally, individuals with features that meet the survival requirements of a habitat produce more offspring than others. As the number of descendants increases, the genetic traits of these individuals are more frequently represented in the population. This process of differential reproduction is called **natural selection**, and the change in the genetic makeup of the species is **evolution**.

Contingencies of Survival

From a behavioral viewpoint, natural selection involves **contingencies of survival** (Skinner, 1986). The habitat or environment inadvertently sets requirements for survival of individuals. Members of a species who exhibit features appropriate to the contingencies survive and reproduce. Those with less appropriate characteristics have fewer offspring and their genetic lines may become extinct. Natural selection therefore occurs as particular organisms satisfy (or fail to satisfy) the contingencies of survival.

An important implication of a contingency analysis of evolution is that the requirements for survival may change gradually or suddenly. For example, during the time of the dinosaurs,

the collision of a large asteroid with the earth may have drastically changed the climate, fauna, and temperature of the planet. Given these changes in environmental contingencies, dinosaurs could not survive. The smaller mammals, however, that possessed features more appropriate to the new habitat lived and reproduced. Changes in the contingencies due to large-scale disasters may, therefore, occasionally favor characteristics that have advantages in a changed environment. This would occur even though these characteristics may have been a disadvantage in the past (see Gould, 1989, 2002, for a punctuated-equilibrium view of evolution).

Phenotype, Genotype, and Environment

Evolutionary biologists distinguish between phenotype and genotype. An organism's **phenotype** refers to all the characteristics observed during the lifetime of an individual. For example, an individual's size, color, and shape are anatomical aspects of phenotype. Behavioral features include taste preferences, aggressiveness, shyness, and so on. Different phenotypic attributes of individuals may or may not reflect underlying genetic variation.

The **genotype** refers to the actual genetic makeup of the organism. Some observable characteristics are largely determined by genotype, while other features are strongly influenced by experience. But, as shown in Figure 14.3, most result from an interaction of genes and environment. Thus, the height of a person is attributable to both genes and nutrition. Evolution only occurs when the phenotypic differences among individuals are based on differences in genotype. If differences in height or other features did not result from genetic differences, selection for tallness (or shortness) could not occur. This is because there would be no genes for height to pass on to the next generation. People who engage in bodybuilding by lifting weights and taking steroids may substantially increase their muscle size (phenotype), but this characteristic will not be passed on to their children. Natural selection can only work when there are genes that underlie physical features.

Sources of Genetic Variation

There are two major sources of heritable genetic variation: sexual recombination of existing genes and mutation. Genetic differences among individuals arise from sexual reproduction. This is because the blending of male and female genes produces an enormous number of random combinations. Although sexual recombination produces variation, the number of genetic combinations is constrained by the existing pool of genes. In other words, there are a finite number of genes in a population, and this determines the amount of variation caused by sexual reproduction.
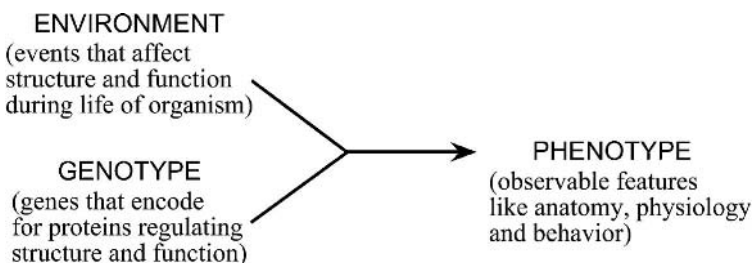
FIG. 14.3. *Phenotype is a product of genotype and environment.*

Mutation occurs when the genetic material (e.g., genes or chromosomes) of an individual changes. These changes are accidents that affect the genetic code carried by ovum or sperm. For example, naturally occurring background radiation may alter a gene site or a chromosome may break during the formation of sex cells or gametes. Such mutations are passed on to offspring, who display new characteristics. In most instances, mutations produce physical features that work against an organism's survival and reproductive success. However, on rare occasions mutations produce traits that improve reproductive success. The importance of mutation is that it is the source of new genetic variation. All novel genetic differences are ultimately based on mutation.

Natural selection depends on genetic variation attributed to sexual recombination and mutation. Genes code for proteins, which in turn regulate embryonic development and structural form. This means that differences in genes result in phenotypic differences in the anatomy (e.g., size and form of the brain) and physiology (e.g., release of hormones) of organisms.

Based on such differences in phenotype, some organisms are better adapted to meet the contingencies for survival arranged by the habitat. That is, some individuals exhibit features that satisfy the contingencies while others do not. Selection occurs when specific genes underlying these phenotypic features contribute to survival or advantage. Individuals with such characteristics have more offspring, ensuring that their genes occur at a higher frequency in the next generation.

Evolution and Behavior

Darwin (1871) recognized that the behavior of organisms was a heritable characteristic. The evolution of behavioral characteristics is shown in sociobiological studies of animal behavior. Woodchucks, yellow-bellied marmots, and Olympic marmots are three species of marmots that show differences in social behavior (Barash, 1973a, 1973b). There is evidence that the behavioral diversity of these marmots depends on natural selection (see Figure 14.4).

FIG. 14.4.   *Olympic marmots studied by Barash (1973a, 1973b; reprinted from Barash, 1982, with permission of Elsevier, Amsterdam). From* Sociobiology and Behavior, *p. 40, by D. P. Barash, 1982, Amsterdam: Elsevier. Copyright 1982, David P. Barash. Reprinted with permission.*

Variation in Social Behavior by Habitat

Woodchucks live at low elevations, primarily in food-abundant fields throughout the eastern United States. They are aggressive and solitary animals who associate only briefly at mating. The young are raised by the female woodchuck, who chases them out of the burrow as soon as they are weaned. Young woodchucks are completely on their own by the first year of life, and they are sexually mature by the second year. In contrast, Olympic marmots live at high elevations in Olympic National Park and inhabit the alpine meadows, where there is a brief growing season. These animals are nonaggressive and highly tolerant of one another. Olympic marmots raise their pups in colonies, and the young disperse from the colony around the third year—becoming sexually active in the fourth year of life. Finally, yellow-bellied marmots live at medium elevations where there is an intermediate growing season. They are moderately aggressive and disperse their young in the second year.

Barash (1982) has pointed to the importance of natural selection in the behavioral differences of these marmots. He explains the process as follows:

> The most important environmental factor appears not to be elevation itself but, rather, the amount of food available to individuals of each species during a year. There is good evidence that aggression from adult marmots is instrumental in causing the young to disperse, to leave their colony of birth. It would clearly be adaptive for the adults to refrain from any aggressive-ness that would precipitate the suicidal dispersal of their own undersized young. The progres-sively increasing need for delayed dispersal among marmot inhabitants of environments with progressively less available food may at least in part explain the striking correlation of marmot social systems with their environments. (Barash, 1982, p. 41)

The aggressive behavior of woodchucks functions to disperse the young at an early age. This is possible and an acceptable adaptation in a food-abundant environment where immature woodchucks may easily survive on their own. When food was scarce, cooperative behavior was selected and Olympic marmots became nonaggressive in accord with the longer caretaking requirements set by their habitat. Both aggressive and cooperative behavior may have been adaptive depending on the contingencies of survival set by.the environment.

Genetic Regulation of Behavior

Behavioral Rigidity

As we have noted, the behavior of organisms is always a phenotypic expression of genes and environment. Some behavioral characteristics are closely regulated by genes, and in such instances the environment plays a subsidiary role. For example, in some species, de-fense of territory occurs as a ritualized sequence of behavior called a fixed action pattern (e.g., Tinbergen, 1951). The sequence or chain is set off by a specific stimulus, and the com-ponent responses are repeated almost identically with each presentation of the stimulus (see Chapter 3). The behavior pattern is based on a "genetic blueprint," and the environment simply initiates the sequence.

For example, the male stickleback fish will aggressively defend its territory from male intruders during mating season. The fish shows a fixed sequence of threatening actions that are elicited by the red underbelly of an intruding male. Tinbergen (1951) showed that this fixed action pattern occurred even in response to cigar-shaped pieces of wood that had red patches painted on the bottoms. In addition, he showed that a male intruder with its red patch hidden did not evoke the threatening sequence. Generally, the male stickleback is genetically programmed to carry out the attack sequence given a specific stimulus at a particular moment in time.

FOCUS ON RESEARCH: GENETIC CONTROL OF A FIXED ACTION PATTERN

Richard Scheller, a geneticist at Stanford University, and Richard Axel, a professor of pathology and biochemistry at Columbia University College of Physicians and Surgeons, reported on the genetic control of a complex behavioral sequence. Scheller and Axel (1984) used the techniques of recombinant DNA to isolate a subset of gene locations that control the egg-laying sequence of a marine snail (*Aplysia*).

Recombinant DNA techniques are beyond the scope of this book, but the important thing is that these procedures can be used to identify gene sites that encode for specific neuropeptides. In the Scheller and Axel (1984) experiment, the researchers isolated a set of gene sites that coordinated the release of several peptides. These chemicals caused neurological changes that invariably produced the egg-laying sequence.

Using techniques of genetic manipulation, Scheller and Axel were able to "turn on" the gene sites that controlled a complex and integrated sequence of behavior. In this sequence, the snail first contracts the muscles of the reproductive duct and expels a string of egg cases. Next, the animal grasps the egg string in its mouth and waves its head, behavior that typically functions to remove eggs from the duct. It then attaches the tangle of string to a solid surface. This behavioral sequence is shown in Figure 14.5. The fixed action pattern was activated in an unmated snail by direct manipulation of the egg-laying hormone (ELH) gene.

The DNA sequences that control egg laying may play an important role in other aspects of this animal's behavior. For example, the genetic material that encodes for head-waving behavior may be duplicated and appear in other genes that regulate feeding. In this regard, Scheller and Axel (1984) suggested:

> the same peptide may be incorporated in several different precursors encoded by different genes. Consider head waving in *Aplysia*. A characteristic waving of the snail's head takes place during feeding as well as during egg-laying. The same peptide or peptides could elicit the same behavioral component (head waving) in two very different contexts. To this end the head-waving peptide (or peptides) may be encoded in some other gene—one implicated in feeding behavior—as well as the ELH gene. In this way complex behaviors could be assembled by the combination of simple units of behavior, each unit mediated by one peptide or a small number of peptides. (p. 62)

When environments were stable and predictable, the replication of the same DNA sequence in a new genetic context may have been one way that organisms evolved complex behavior. This solution involves using the same genetic code in different combinations. Although a high level of behavioral complexity may be achieved in this manner, the resulting behavior is tightly controlled by the underlying genetic context.

Some forms of animal communication are strongly determined by genotype. For example, the dance of the honeybee is a highly ritualized sequence of behavior that guides the travel of other bees (see Figure 14.6). After abundant foraging, a bee returns to the hive and begins to dance while other bees observe the performance in the hive in the dark. Subsequently, the bees who observe the dance fly directly to the foraging area in a so-called beeline. The position of the sun with respect to food plays an important role in determining the initial dance. A bee may dance for several hours, and during this time the dance changes. These behavioral changes occur as the position of the sun with respect to food is altered by the rotation of the earth. That is, the bee's dancing corrects for the fact that the sun rises and falls over the course of a day.

The survival value of the dance relates to increased food supply for the hive. One problem is accounting for the occurrence of the dance before other bees responded to it—
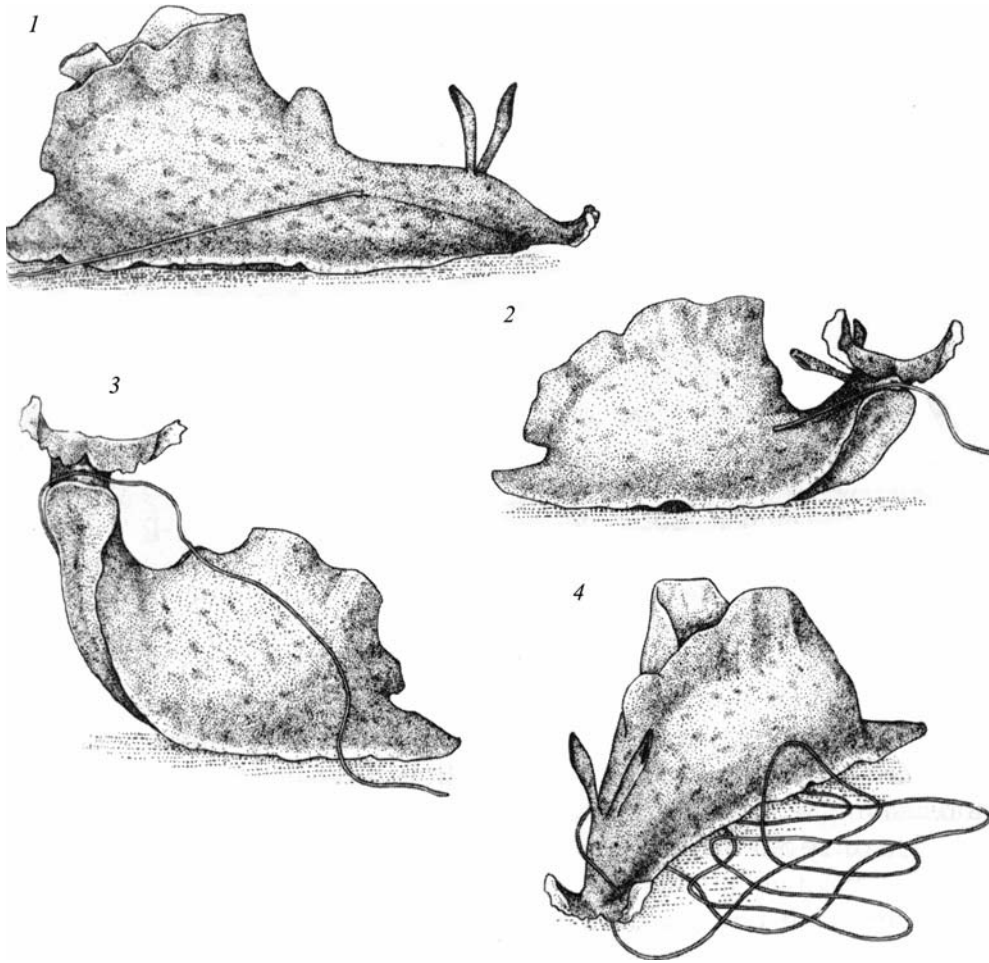
FIG. 14.5. *The egg-laying sequence of the marine snail (Aplysia). The sequence involves (1) expelling a string of egg cases, (2) grasping the egg string by the mouth, (3) waving the head to draw the string out of the duct, and (4) affixing a triangle of string to a solid substance. This behavior was elicited by genetic procedures that activated the gene coding for egg-laying hormone (ELH) and other peptides associated with egg-laying behavior. From "How Genes Control Innate Behavior," by R. H. Scheller and R. Axel, 1984,* Scientific American, 250, *54–62. Copyright 1984, Estate of Ikuyo Tagawa Garbar. Reprinted with permission.*

that is, before the dance had survival value. Presumably, the distance and direction that bees traveled had some effect on their behavior. Signs of fatigue and phototropic movements may have varied with distance and the position of the sun when they returned. Bees that evolved sensitivity to what others did could respond to these aspects of behavior—relying on genes that coded for specific neurochemicals. Over time, natural selection favored variations in phototropic (and other) movements that made honeybee dancing more effective. Foraging bees would dance in conspicuous ways that allowed other bees to travel more accurately to the food source (for a similar analysis, see Skinner, 1986, p. 116).

Fixed action patterns and the communication of bees are examples of behavior that is predominantly regulated by genes and is usually called species-specific. In both instances,
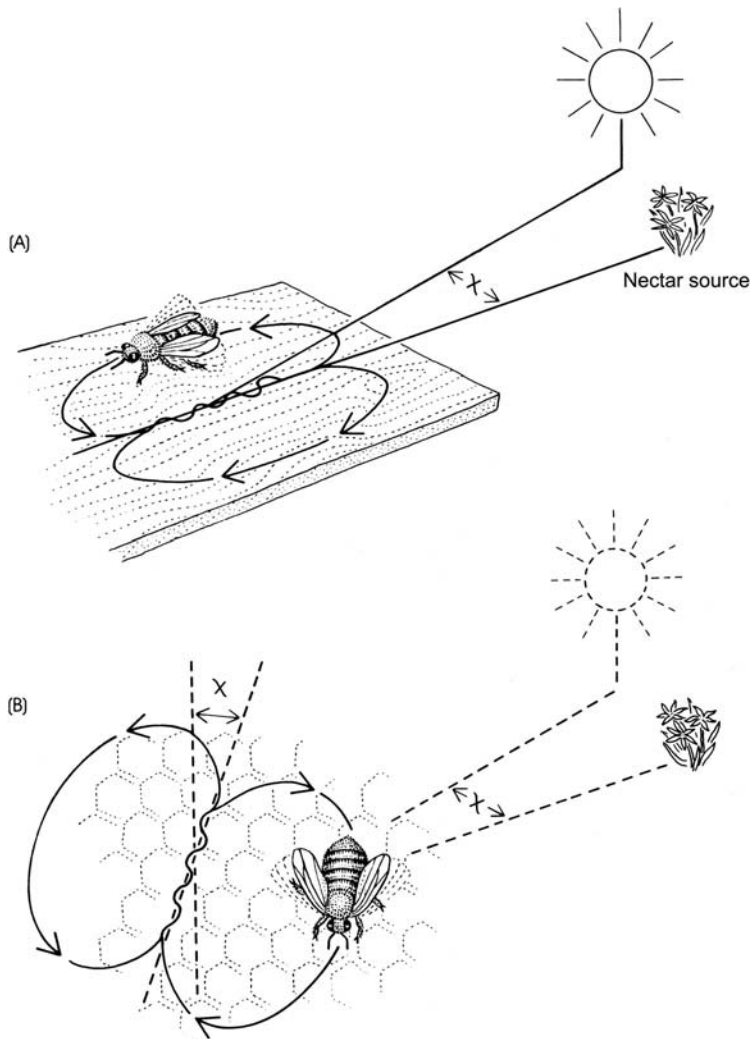
FIG. 14.6. *The dance of a honeybee illustrates a phylogenetic form of communication in animals. When the bee returns to the hive from a nectar source, the dance begins with the insect waggling its abdomen. The number of waggles and direction of movement control the flight pattern of other bees that observe the performance. The orientation of the food source, relative to the current position of the sun, is also indicated by the waggle dance. From* Animal Behavior: An Evolutionary Approach, *p. 201, by J. Alcock, 1989, Sunderland, MA: Sinauer Associates. Copyright 1989, Sinauer Associates, Inc. Reprinted with permission.*

complex sequences of behavior are activated by specific stimuli and carried out in a highly ritualized manner. As shown in Figure 14.7, this form of behavior regulation was selected when the habitat of an animal was relatively stable and predictable.

In terms of habitat and species-specific behavior, Hal Markowitz (1997) advocated that zoos not only be repositories for animal genotypes but also serve as environments that perpetuate species-specific behaviors, allowing the eventual reintroduction of animals into the wild. Although it is impossible and undesirable to produce truly natural habitats for
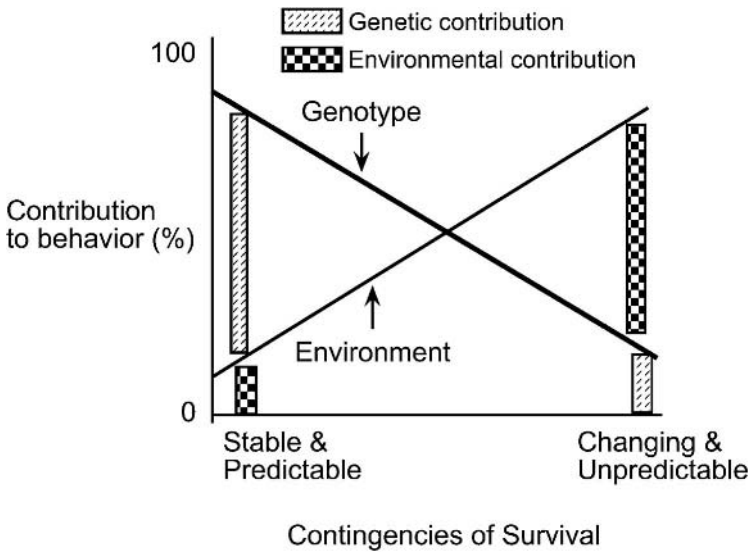
FIG. 14.7. *When contingencies of survival are relatively stable and predictable, genetic regulation of behavior is predominant (e.g., fixed-action patterns) and the environment plays a subsidiary role. As contingencies of survival become more uncertain, the role played by the environment and conditioning increases, while direct genetic regulation of behavior declines.*

most captive species, "Careful identification of the important life contingencies for species in nature and the establishment of circumstances that allow for the maintenance of appropriate responses to those or similar contingencies in captive settings is essential to the conservation of species-typical behavior" (Markowitz, 1997, p. 2).

Behavioral Flexibility

When organisms were faced with unpredictable and changing environments, natural selection favored those individuals whose behavior was flexible—adjusting on the basis of past experience. In this case, genes played a subsidiary role, coding for general processes of learning. These processes allowed an organism to adjust to changing environmental requirements throughout its life span. Flexibility of behavior in turn contributed to the reproductive success of the organism.

Skinner (1984b) noted the survival advantage of behavioral flexibility:

> Reproduction under a much wider range of conditions became possible with the evolution of two processes through which individual organisms acquired behavior appropriate to novel environments. Through respondent (Pavlovian) conditioning, responses paired in advance by natural selection could come under the control of new stimuli. Through operant conditioning, new responses could be strengthened (reinforced) by events which immediately followed them. (p. 477)

In other words, respondent and operant conditioning are processes that are themselves genetically determined.

There is evidence for the selection of conditioning. Hirsch and McCauley (1977) showed that the blowfly, *Phormia regina*, could be classically conditioned and that the process of
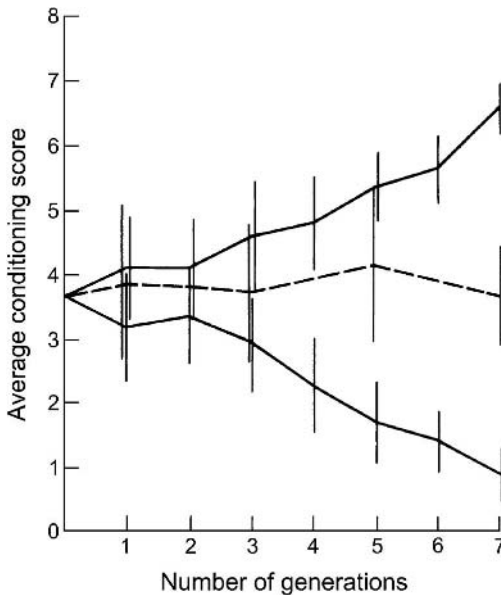
FIG. 14.8. *Artificial selection for respondent conditioning in the blowfly,* Phormia regina, *reported by Hirsch and McCauley (1977). Flies mated for high conditioning scores showed more conditioned responses over generations than flies that were randomly paired. Other flies that were mated on the basis of low conditioning scores did progressively worse than their ancestors. The data are from "Successful Replication of, and Selective Breeding for, Classical Conditioning in the Blowfly (*Phorma regina*)," by J. Hirsch and L. McCauley, 1977, Animal Behavior, 25, pp. 784–785.*

conditioning was heritable. Blowflies can be trained to extend their probosces (or snouts) whenever water is applied to their feet, if they are given sugar that is paired with foot wetting. Even though this conditioned reflex is learned, the process of establishing the reflex can be modified dramatically by artificial selection.

Flies varied in the number of elicited responses to the conditioned stimulus on trials 8 through 15 and were assigned a conditioning score between 0 and 8. Subjects with higher conditioning scores were selected and mated with each other, as were subjects with lower scores. A control group of flies were mated independent of their conditioning scores.

As shown in Figure 14.8, over seven generations, flies selected for conditioning showed increasingly more conditioned responses on test trials than their ancestors. When conditioning was selected against, each generation of flies showed fewer conditioned responses than the previous population. Flies mated regardless of conditioning scores (control) did not show a change over generations. At the end of seven generations, there was no overlap in the distribution of conditioning scores for the three groups—indicating that selection resulted in three separate populations of flies.

Hirsch and McCauley's (1977) experiment demonstrates that conditioning of a specific reflex has a range of variability. Based on this variation, selection can enhance the process of conditioning or eliminate it for distinct behavioral units. From a behavioral view, contingencies of survival continually mold the degree of behavioral flexibility of organisms—extending (or removing) the process of conditioning to a wide range of responses.

With mammals the classic illustration of the contribution of genetics to learning is Tryon (1940). He differentially bred rats from either end of the range of maze learning performance of a single population of rats and eventually produced what he called "maze bright" and "maze dull" populations. By breeding the swifter animals together and the slower animals together he artificially separated the performers into two categories. Animal breeders of all kinds do similar selective mating to produce a plethora of physical traits.

In the case of human evolution, natural selection produced a high degree of behavioral flexibility. This behavioral flexibility was not achieved by selection for a broader repertoire of conditioned reflexes. It involved the evolution of selection by consequences as a

behavioral process. That is, natural selection extended and elaborated the process of operant conditioning to most aspects of human behavior.

Level 2: Selection by Reinforcement

The evolution of operant behavior allowed variation and selection to work throughout the lifetime of an organism. Many organisms evolved genetic programs that coded for operant processes. For some species, natural selection ensured that operant processes were extended to more and more aspects of behavior. Individuals who inherited an extensive capacity for operant conditioning could adjust to complex and changing, often social, situations on the basis of behavioral consequences. Selection by reinforcement therefore became a major mode of adaptation (Glenn & Field, 1994).

Selection for Operant Processes

Glenn (1991) noted the biological advantage of operant processes and selection by behavioral consequences:

> The instability of local environments and what might be considered a limit on behavioral complexity in genetic programs appears to have given rise to a less cumbersome and more rapid sort of variation and selection. Instead of building thousands of complex behavioral relations into DNA, evolution built a few programs for behavioral processes that allowed changing environments to build behavior repertoires "as needed" during the lifetime of individuals. A relatively small change in a bit of DNA could result in profound changes in the possibility for ontogenetic adaptability if that change involved a gene for a behavioral process. All that was required as a first step was genetically uncommitted activity and susceptibility of that activity to selection by behavioral consequences. (p. 43)

The evolution of operant conditioning, a range of uncommitted behavior, and susceptibility to certain kinds of reinforcement resulted in a second level of selection. Behavioral selection supplemented and extended selection at the biological level (i.e., natural selection).

An example of how behavioral selection supplements the genetic control of behavior is seen in the marine snail *Aplysia* (see Focus On Research in this chapter). This simple organism serves as a model system for investigating the role of operant processes in the regulation of feeding (Brembs, Lorenzetti, Reyes, Baxter, and Byrne, 2002). Intact, freely behaving *Aplysia* with extracellular electrodes in the buccal ganglia were observed during food ingestion. Recorded neural activity which accompanied eating was delivered contingent upon spontaneous biting (no food present), and this biting increased during the session and occurred at some level when tested 24 hr later. These observations were taken as evidence of operant learning (biting reinforced by the eating-related neural activity), and also for "memory" of that behavior (reoccurrence sometime later), in the intact animal.

Subsequently, the buccal ganglia neural network was removed from trained subjects and its sensitivity to depolarizing current compared to that of networks taken from nontrained and yoked controls. Differential activity indicated that buccal motor patterns became ingestion-like as a result of training. Finally, one cell called B51, which is active during feeding (and could be the site of operant "memory"), was isolated and received a brief puff of dopamine contingent upon depolarization and membrane changes. There was a significant decrease in this cell's threshold compared to control cells indicating an operant

reinforcement effect at the cellular level. That is, the contingent dopamine served to dif-
ferentially alter the cell's activity so that it produced ingestion-like motor patterns.

The research on operant conditioning of *Aplysia* at the cellular, neural network, and
behavioral levels shows the universal nature of *selection by consequences* (see Pierce, 2001,
for another example of selection at the biological, behavioral, and neural levels—activity
anorexia). Clearly, neural network and single-cell activity are modifiable by the effects of
what happens when they occur. As in any operant, the consequences at the neural and
cellular levels affect the reoccurrence of the activity and thereby contribute to the regula-
tion of feeding in *Aplysia*. Additionally, the work on *Aplysia* illustrates the continuum of
behavioral regulation based on both genetic and environmental influences. That is, analysis
of egg-laying and feeding by *Aplysia* suggests genetic-based hormone control combined with
the operant regulation of behavior.

Operant Selection and Extinction

The unit of selection at the behavioral level is the operant. An operant is a unit of behavior
composed of responses that make contact with the environment (i.e., an operant class).
Response forms vary from moment to moment, and some variations change the environment
in ways that increase those forms. A child who manipulates a rubber duck in the bathtub
may inadvertently squeeze it in ways that produce a squeaking sound. If the sound functions
as reinforcement, the operant of squeezing the duck that makes a sound increases over time.
Recall that reinforcers are defined not by what they are (squeaking rubber duck) but by
their effect on behavior.

If few (or no) response variations are reinforced, the operant decreases because of ex-
tinction. That is, all members of an operant class cease to exist when they no longer result
in reinforcement. The sound device in the toy duckling may break, and squeezing it in
different ways no longer has the characteristic effect. Over time, the child will squeeze the
rubber duck less and less as the operant undergoes extinction.

Extinction not only eliminates operants but also generates behavioral variation. Greater
variation in the behavior increases an individual's chances of contacting the prevailing
contingencies. In the bathtub, the child may push the broken rubber duck under the water,
emitting a response that has never occurred before. The effect of this behavior may be to
generate bubbles on the surface that, in turn, reinforce the child's behavior.

A more profound example of extinction and behavioral variation concerns people trying
new ways of doing things when old ways no longer work (or do not work well). Thomas
Edison's invention of the electric light bulb involved behavioral variation and selection.
To generate electric light, Edison collected and tested a variety of materials to produce an
effective lamp filament (Etzkowitz, 1992, p. 1005). He was known as the trial-and-error
inventor, but a better description of his performance is "trial and success." Invention oc-
curs when novel forms of response (trying different filaments) are generated by extinction
and the appropriate response (using a carbon filament) has been selected by the prevailing
contingencies of reinforcement (effective and efficient light). Creativity, originality, or in-
vention can be defined as nonrepetitive perseverance and control by operant contingencies
contributes to such behavior.

Susceptibility to Reinforcement

Contingencies of reinforcement resemble contingencies of survival (Skinner, 1986). Many
animals eat and copulate simply because these responses have contributed to reproduction

or survival of the genes. Male black widow spiders copulate and are then eaten by their mates. For these animals, copulating only had survival value for the genes—passing on the genetic code even though the individual dies following the act. Other organisms evolved sensory systems that allowed food and sexual contact to reinforce behavior. That is, an animal whose actions resulted in sexual contact was more likely to act that way again. At this point, organisms had two redundant reasons for eating and copulating—survival of the genes and reinforcement.

When food and sexual contact became reinforcing, new forms of behavior, indirectly related to eating and copulating, could be established. Animals could acquire new ways of finding, gathering, and processing foods based on reinforcement. Similarly, sexual reinforcement could establish and maintain a diversity of actions. These include looking at erotic objects, seeking out sexual partners, attracting a desirable mate, and performing a variety of sexual responses (e.g., genital contact with parts of body, position of intercourse, etc.).

Susceptibility to reinforcement may sometimes depend on the species and the particular behavior. Species-specific reinforcement is also shown by the fact that chaffinches (*Fringilla coelebs*) will peck a disk for food, but will not peck for contingent presentation of bird song. The same bird, however, will step on a perch for species-specific song, suggesting the biological preparedness of the response–reinforcer relationship (Hinde & Stevenson-Hinde, 1973; see also Chapter 5).

Primates may also be susceptible to species-specific reinforcement. The work of Harlow and Zimmerman (1959) on mother–infant attachment suggests that "contact comfort" may function as reinforcement for infants staying close to and preferring their mothers. Infants who only received food reinforcement from their mothers did not show strong attachment behavior. These findings again suggest that the response–reinforcer relationship is biologically prepared.

Organisms who are susceptible to reinforcement may acquire behavior that is not adaptive (Pierce & Epling, 1988). One paradoxical byproduct of selection for operant conditioning is that people behave in ways that have distinct biological costs. Humans choose foods that are not healthful and engage in sexual behavior that is not related to procreation. In addition, conditioned reinforcement ensures that people come to value objects and events that are unrelated to survival. Conditioned reinforcement may shape behavior that decreases reproductive success. People learn to use birth control, love adopted children, risk their lives to help others, risk their lives to kill others, and some even kill themselves.[1] The point is that susceptibility to reinforcement has been adaptive, but this sensitivity may occasionally generate behavior with no adaptive value.

Evolution, Reinforcement, and Verbal Behavior

Social Signals

As noted earlier, a honeybee signals the location of food by dancing in ways that affect the travel of other bees. This form of communication involves a high degree of genetic regulation. Genes, as we have seen, code for the general behavioral processes known as respondent and operant conditioning. Once these learning capacities evolved, signaling could be acquired on the basis of an organism's interaction with the environment.

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[1]We are not making a value judgment about these activities; the point is that these behaviors do not contribute to biologically defined reproductive success.

Skinner (1986) explained the acquisition of human gestures in terms of selection by consequence and susceptibility to aversive stimulation. He analyzed the contingencies as follows:

> One person can stop another by placing a hand on his chest, and if the person who is stopped finds the contact aversive, he will stop on later occasions before contact is made. The movement of the arm and hand changes from a practical response to a gesture. Once that happened, the topography can change until it would have little or no physical effect.
>
> The gesture that means "Come here" is another example. It presumably originated as practical pulling but became effective as a gesture when people who were pulled moved quickly to avoid physical contact. The topography of the gesture still varies with distance, possibly because of visibility, but also as if some practical work remained to be done: When the parties are far apart, the whole arm is moved; when they are fairly near, only the forearm; and when they are close, only a hand or a finger. (pp. 116–117)

For Skinner, gesturing is behavior that results from social contingencies of reinforcement. A social contingency involves the behavior of two (or more) people who arrange stimuli and reinforcement for each other's actions.

The person who sees a surprising sight may pull a companion toward the view and be reinforced by the friend's reactions to the sight (see Figure 14.9). On later occasions, a pulling motion may occur before the companion is in reach. The friend may avoid being dragged to the sight by coming when the pulling motion is first made. The reinforcement contingencies composed of each person's behavior establish and maintain this social episode.

Although social contingencies are clearly involved in human signs and gestures, other processes may play an important role. The research on stimulus equivalence discussed in Chapter 12 is relevant to signs and gestures (Sidman & Cresson, 1973). Humans easily distinguish equivalent stimulus classes, but other organisms do not. Gestures and signs may stand for or be equivalent to other stimulus classes. A smile, the spoken words "good job,"

FIG. 14.9. *How pulling a person to see a sight may have evolved into the gesture of pulling the arm toward the body (Frank Epling on the left and David Pierce on the right, the original authors of this textbook).*

and the gesture for "OK" (thumb and index finger make an o) become equivalent when they have a similar effect on behavior. Equivalence relations depend on discrimination of reflexivity (A = A and B = B), symmetry (if A = B then B = A), and transitivity (if A = B and B = C, then A = C). Complex transitivity relations seem to involve evolution of species-specific capacities for discrimination as well as general behavioral processes like operant conditioning.

Humans readily generate and respond to iconic or representational signs when there is a requirement to communicate but speaking is not possible (Kuschel, 1973; Meissner & Philpott, 1975). For example, Brown (1986) recounts a study that compared severely deaf children with a normally hearing group (Goldin-Meadow & Morford, 1985). The deaf children were raised by parents who refused to sign to them because they believed that signing would retard vocal speech. Each of the 10 deaf children independently acquired a similar repertoire of iconic signs. Presumably, particular ways of signing were more effective than others in altering the behavior of the parents. The hearing children also showed iconic signing that gradually diminished as vocal speech increased. This later finding suggests that speech has some advantages over gestures and iconic signs when speakers and listeners have normal hearing.

Corballis (1999) reviewed several perspectives dealing with the probable evolution of language from manual gestures, hand to mouth. He indicated that with the emergence of the genus *Homo* and their increased brain size and adequate vocal apparatus, contingencies could have further promoted the development of speech and language. In this regard, it is useful to provide a behavior analysis of the evolution of speech sounds.

Speech Sounds

Natural selection must have been important in the evolution of speech sounds. Compared with gestures and iconic signs, sounds can affect a listener's behavior when it is too dark to see, others are out of sight, or no one is looking at the speaker. Spoken sounds are also an advantage to speakers whose hands are full—warding off predators or holding weapons to attack an enemy. Additional benefits of speech sounds over gestures were noted by Skinner (1986):

> There are special advantages, however, in large operant repertoires, especially the enormous variety of available speech sounds. Gestures are not as conspicuously different as speech sounds and hence are fewer in number, and the sounds one produces are more like the sounds one hears than gestures are like the gestures one sees (because they are seen from a different point of view). One learns to gesture through movement duplication, but to speak through product duplication, which is more precise. (p. 117)

Most of the organs that allowed speech sounds probably evolved for other reasons. The diaphragm was used in breathing, the tongue and jaws were involved in eating, and the lips could take in water by sucking and sipping. The vocal cords and pharynx did not play a direct role in survival, but may have evolved in social species who could benefit from the calls and cries of others (see Barash, 1982, on social alarms).

There were probably several other important steps in the evolution of human speech. One involved the extension of operant processes to a range of speech-relevant behavior. Each organ that contributed to speech was initially reflexive—the organism responding to specific stimulation. Survival must have been better served when reflexive behavior was supplemented by operant processes. An organism could breathe as a reflex elicited by high levels of circulating carbon dioxide, or it could hold its breath to avoid a predator. Based on natural selection, more and more speech-relevant behavior came under the control of

its consequences. Compared with the great apes, humans made an evolutionary leap when the vocal apparatus was supplied with nerves (i.e., innervated) for operant regulation.

The step to operant regulation of the vocal musculature is not sufficient to account for speech. Evolution must have also resulted in the coordination of all the systems involved in the production of speech. The great apes have complete operant control of their hands but have not developed a sophisticated system of signs or gestures. Children show early iconic signing that shifts toward spoken words as more and more speech is acquired. Both iconic signing and spoken words require that the speaker and listener respond to abstract stimulus relations along several dimensions. Thus, neural coordination of speech probably built on, and added to, specialized capacities for discrimination involving the visual, auditory, and motor systems. In less technical terms, humans evolved systems for symbolic behavior and these systems were eventually integrated with those of speech (Pierce & Epling, 1988).

Speech sounds are a large pool of uncommitted behavior. This behavior is spontaneously emitted at high frequency but plays no direct role in survival (Skinner, 1984b). From a behavioral view, wide variation in spontaneous speech sounds allows for selection of vocal operants by reinforcement supplied by listeners. Thus, Osgood (1953) found that an infant's babbling included all the speech sounds that make up the different languages of the world. This suggests that a child's speech sounds could be shaped toward adult forms by reinforcement of successive approximations, and probably by modeling and generalized imitation. Evidence also indicates that a child's speech sounds become increasingly similar to the adults in the community. Speech sounds that occur frequently in the community increase over time, whereas infrequent sounds drop out of the repertoire (Irwin, 1948, 1952). The exact bases for these changes are not known, although the social reinforcement of speech sounds has some support (Moerk, 1990; Rheingold, Gewirtz, & Ross, 1959).

Verbal Behavior

The evolution of operant processes, the coordination of speech systems, and a large variety of uncommitted speech sounds allowed for the regulation of vocal operants by others. A person in an English-speaking community learns to speak in accord with the verbal practices of the community. That is, the way a person speaks is attributable to the reinforcement practices of others. On a specific occasion, the community provides reinforcement for certain ways of speaking and withholds reinforcement or supplies aversive stimulation for other unacceptable responses. In this manner, the individual conforms to the customary practices of the community and, in so doing, contributes to the perpetuation of the culture.

In Chapter 12 on verbal behavior, we examined some of the verbal relations that are fundamental to speaking (as well as writing or signing). Verbal operants were distinguished in terms of manding and tacting. Recall that the mand is a verbal operant set up by the community for the benefit of the speaker. When a person is deprived of food, the response "Give me food" is reinforced only when a listener provides the meal. If it is raining, the response "Do you have an umbrella?" is reinforced when the other person gives you the umbrella and protects you from the rain. Because of these contingencies, mands are regulated by deprivation and aversive stimulation and the specific reinforcement supplied by a listener.

In contrast to mands, tact relations are set up for the benefit of listeners (the verbal community). The speaker who describes objects and relationships in the world supplies useful information to others. This information allows people in the community to learn from experiences of others, without testing the actual contingencies. A tact relation involves the control of a verbal operant by a specific discriminative stimulus. The child who correctly

states the colors of different objects (e.g., "That's a red ball") is tacting the stimulus property of color. In contrast to mands, tact relations are maintained by generalized reinforcement from others—such as approval, praise, or signs of correctness.

Verbal behavior allows people to coordinate their actions. When people observe rules, take advice, heed warnings, and follow instructions, their behavior is rule governed. Rule-governed behavior allows people to profit from what others say. If a fellow camper reports that a bear is near your tent, you can move the tent to a new camping site. A student looking for a good course may benefit from the advice of another student. In these examples, the listener or person who responds to the verbal report avoids an aversive event (the bear) or contacts positive reinforcement (a good course). Children are taught to follow advice and instructions. Parents and others provide simple verbal stimuli that set the occasion for reinforcement of the child's compliance. In this way, the child is taught to listen to what others say.

As we have noted, listeners benefit from the verbal reports of others. For this reason, listeners are inclined to reinforce the person who provides useful instructions. In a verbal community, people are taught to express their appreciation for the advice received from others. For example, in an English-speaking community, people say "thank you" and other variations of this response when given directions, advice, and instructions. These verbal responses by the listener reinforce the behavior of the speaker.

Verbal behavior evolved (level 2) in the sense that particular ways of speaking were more or less effective in regulating the behavior of the listener. Response variation ensured that many ways of speaking were tried and successful combinations of sounds were adopted by more and more people. At this point, many people were able to talk to one another on the basis of common standards for speech. These common linguistic practices by a verbal community were the underlying basis for a third level of selection: the selection and evolution of cultural practices.

Level 3: The Selection and Evolution of a Culture

The evolution of operant processes and verbal behavior allowed for the emergence of human culture. Sigrid Glenn (1988, 1989; see also Lloyd, 1985) proposed a behavioral analysis of culture that builds on the works of Skinner (1953) and anthropologist Marvin Harris (1979). Although social scientists often talk about culture as the ideas and values of a group, a behavioral viewpoint suggests that a culture involves the usual ways of acting and speaking in a community. These customary forms of behavior (customs, mores, etc.) are the cultural practices of the group.

Cultural Practice

From a behavioral perspective, cultural practices involve the operant behavior of many people who compose the members of a culture. Each person's behavior provides stimulation and reinforcement for the actions of others. A **cultural practice** is therefore defined in terms of interlocking social contingencies—where the behavior of each person supports the behavior of other members of the community. The pattern of behavior that arises from the interlocking contingencies is the type of practice (e.g., what people do in that culture).

This view of culture suggests that what people do in a particular community is determined by the function of a practice. The ancient Greeks adopted military tactics that were highly effective in most battles. For example, Greek soldiers would form a close body of men, called

a phalanx, and interlock their shields as a common barrier against the enemy. Although there are many ways to conduct a battle, this military maneuver became popular because of its effectiveness. In other words, what people in a particular culture do is a function of the previous benefits and costs of that practice. With changes in technology (the products of a culture), the phalanx and the interlocking of shields became obsolete—the costs in terms of casualties and lost battles increased relative to the benefits.

Cultural practices are functionally similar to operants. Both operants and cultural practices are selected by consequences (Lamal, 1997). Thus, a cultural practice increases when people have benefited from it. The practice of making water jars involves alternative sets of interlocking operants that result in a common outcome. One person gathers clay; another person makes the pot; and a consumer trades something for the jar. The common outcome of such a practice is greater efficiency in transporting and storing water. There are many ways of storing and transporting water, including shells, hollow leaves, woven baskets, clay pots, and indoor plumbing. The cultural form that predominates (e.g., plumbing) reflects the basic processes of selection by consequences. In terms of selection, operants are selected by contingencies of reinforcement and cultural practices are selected by metacontingencies (see for example Norton, 1997, on geographic practices, rule-governed behavior and metacontingencies).

Metacontingencies

Dr. Sigrid Glenn (see Figure 14.10) at the University of North Texas made an important contribution to the behavior analysis of culture when she first described the metacontingencies of cultural practices. **Metacontingencies** refer to contingent relations between cultural practices and the effects of those practices for the group (Glenn, 1988). For example, competence in science is important for people who live in a technologically advanced culture. Scientific research produces a range of benefits for the general society. These include better medicine, more productive crop yields, new and better building materials, more efficient and longer-lasting appliances, and superior regulation of human behavior. Thus, a positive metacontingency exists between educational practices that increase scientific competence and long-term benefits to the group. This analysis suggests that teaching methods that promote science were selected, while alternative methods of education declined in popularity.

FIG. 14.10. *Sigrid Glenn. Reprinted with permission.*

Metacontingency implies that there will be an increase in the forms of education that result in more and better trained students of science, but this may not occur. In complex cultures like the United States, competing (or concurrent) metacontingencies may mean that the "best" educational practice is not selected. A less than optimal form of scientific education may prevail for some time because teaching science is only part of the function of education. For example, the manifest function of education is to teach reading, writing, and arithmetic. The hidden or latent function of schooling includes keeping people out of the work force and categorizing them into high-, medium-, and low-status groups based on educational attainment. Thus, the form of education that predominates is the one that has produced the most overall benefit to the community, group, or society. If the relative outcomes of an educational practice resulting in low scientific competence exceed those of a system that yields high scientific achievement, then the less adequate educational practice will predominate in the culture (see Lamal & Greenspoon, 1992, for metacontingencies and the U.S. Congress; also, Lamal, 1997).

Origin, Transmission, and Evolution of a Cultural Practice

There exists a very useful model for studying the origins and transmission of behavioral traditions in animals. Galef and Allen (1995) illustrate how diet preferences can be established with rats and how this preference can diffuse and be socially transmitted and maintained. Founder colonies of four rats were taught an arbitrary food preference and then members were slowly replaced with naïve subjects. The original food preference was still manifest in the third generation of replacements after the last founder was replaced. This model allows an experimental analysis of some of the critical behavioral mechanisms supporting this observation.

In another similar situation, apparently, a troop of baboons (or chimpanzees) were kept in a zoo enclosure and were provided with a choice between a preferred food (bananas) and less appetizing laboratory chow (Pierce, 1991). As expected, the baboons consistently chose to eat bananas. Following a baseline period, the researchers established a negative reinforcement contingency for eating the less preferred food. Whenever any animal approached the bananas, the entire colony was drenched with water from a fire hose that was used to clean the enclosure. After exposure to this contingency, the troop attacked any member that approached the bananas. Eventually, all members of the troop were exclusively eating the less preferred laboratory chow and avoiding cold showers. The researchers then removed the reinforcement contingency—approaching and eating the bananas no longer resulted in being soaked with water. As you might expect, the group did not test the operating contingencies and continued to attack any member that went toward the preferred food. At this point, the contingencies had established a cultural taboo that was highly resistant to change. Thus, social reinforcement and observational learning contributed to the maintenance of the food taboo, even though the original reinforcement contingencies had long since been removed.

Harris (1974) has provided a functional analysis of the origin and transmission of many human cultural practices. To illustrate, in India the cow is deified and beef is not eaten by many Hindus. This was not always the case—when the last ice age ended the peoples of Northern India raised and ate cattle, sheep, goats, and many agricultural products. Cattle, however, have some advantages other than just providing meat; they may be easily herded and trained to pull plows or carts.

Population density increased greatly in the Ganges River valley and by 300 B.C. the people of the valley had destroyed the trees surrounding the river. As a result, the risk of drought increased and farms decreased in size. Small farms have little space for animals,

but draft animals were essential for working the land and transporting agricultural products. Cows provided traction, milk, and meat, but the farmer who ate his cow lost milk production and a working animal.

Thus, the people of India faced a social trap involving the immediate benefit of eating beef and the long-term loss of the cows' other advantages. A cost/benefit analysis suggests it was better to keep a cow than eat it. To avoid this social trap, the cow was deified and eating beef became a cultural taboo. The Hindu community has maintained this practice into modern times.

Other cultures also have food taboos that may be analyzed in terms of the function of cultural practices. Until very recently, Catholics did not eat meat on Friday, and many Islamic and Jewish people will not eat pork, (Harris, 1974).

Cultural Evolution

Cultural evolution presumably begins at the level of the individual. Variation in individual behavior is reinforced by its technological effects. An inventor may discover a new way of making a wheel; a farmer may find a food crop that produces higher yields; and a teacher may find a novel way to teach reading. A culture is said to evolve when these innovations are adopted by the community.

Adoption of innovations depends on the metacontingencies facing the group. For example, a new food crop with higher yield is selected when the metacontingencies favor increased grain production. This could occur when a community is impoverished or when higher yielding crops support the feeding of domestic animals used for work or consumption. Higher yield crops may not be selected when food is overly abundant, when increased grain supply leads to problems of storage, or when a new crop attracts pests that spread disease.

The evolution of a cultural practice has been reported in a classic study for a troop of Japanese macaque monkeys (Kawamura, 1959). A troop of macaques on Koshima Island are well known for their cultural innovations. In one example, an infant female called Imo began to wash sweet potatoes to remove the grit. This behavior was later observed in Imo's playmates and her mother, who taught it to another offspring. Imo was also among the first to take up swimming and to throw wheat kernels on the water. Throwing wheat on the water removed the sand that the kernels were mixed with, because the sand sank and the kernels floated. Both of these practices were eventually adopted by the entire troop (see Jolly, 1985, for more on animal culture).

A common observation is that cultural practices may remain unchanged over many generations. Persistence of a practice is illustrated by the baboons who continued to eat the less preferred food and in humans by the Jewish people's taboo on eating pork. Our analysis suggests that food taboos originated because of the aversive metacontingencies facing the group. As with behavioral (level 2) avoidance contingencies, the practices continued even though the metacontingency had changed. Thus, a practice may persist for many years because the members of the group who engage in it (i.e., avoidance of pork) fail to contact a change in the metacontingency. At the individual level, a person conforms to the taboo because the social contingencies arranged by the group (religious proclamations and sanctions) avert contact with a change in the physical environment.

Another reason that cultural practices persist over time is that the metacontingencies are stable and such practices, at least minimally, meet the contingencies. For centuries, the only way that books were manufactured was to have scribes make written copies. As a cultural practice, copying books allowed more standardized transmission of knowledge than word of mouth. Better methods of food preparation, house construction, agriculture, waste

disposal, and so on could be described in a common manner and passed from one generation to another. That is, transcription of books had survival value for human groups, ensuring the continuation of this practice. (Recall that in biology survival refers to the number of genes—or characteristics of organisms—that appear in the next generation. Culturally, survival refers to the transmission of a social–behavioral practice from one generation to the next.)

Transcription of books satisfied the metacontingencies of many cultures, but it was not the only way to produce books. The advent of the printing press allowed an alternative form of reproduction that was less costly and more productive, let alone much faster. Thus, transcription by hand was replaced by the printing press even though both forms of the practice satisfied the existing metacontingencies. Innovation is therefore important in terms of whether a culture remains static or dynamic. In this view, innovation produces variation in cultural practices much as genetic mutation produces changes in species characteristics. In both cases, the new forms (species traits and cultural practices) do not depend on a change in the contingencies. Generally, the analysis of cultural variation and metacontingencies provides a selectionist account of the evolution of group practices. Principles of behavioral and cultural selection may be used to design interventions that change cultural practices. The application of behavior principles to the change of cultural practices is what Skinner has called "the design of a culture" (Skinner, 1948, 1953; Glenn, 2001).

ON THE APPLIED SIDE: DESIGN OF CULTURE

Many governments throughout the world are faced with mounting population and declining food and resources (and many other problems). Economists, demographers, and other social scientists are frequently hired by government agencies to develop programs to help with these difficulties. Consultants often formulate plans of action based on assumptions of rational human choice or popular psychology. Because their analyses are based on assumptions that do not take contingencies into account, the programs are often ineffective (Hernandez, 1981). Behavior analysts are skilled at specifying the behavior classes that underlie the contingencies that support social behavior. Behaviorists can, for this reason, play a major role in the regulation of human social problems by providing analyses and research on controlling variables and designing new systems of reinforcement (see Lamal, 1997).

Consider the control of human populations (see Figure 14.11). Many scientists (and others) have suggested that people will eventually decimate the resources of the planet. They ask, "How can we stop this explosion of humanity?" A behavioral approach to human fertility has already been developed. As early as 1974, Wiest and Squire reported a reinforcement analysis of the adoption of birth control methods. They analyzed how different birth control methods were related to the time of use before sexual intercourse, the frequency of use, and the sex of the user. The researchers noted that "contraceptive performances that are [dependent on sexual intercourse] . . . are difficult to measure directly simply because heterosexual behavior always occurs in private" (Wiest & Squire, 1974, pp. 251–252). One solution suggested by Wiest and Squire is to target behavior that is reliably correlated with contraceptive behavior. For example, research may show that talking about the negative consequences of unwanted pregnancies and the long-term advantages of a small family is positively correlated with contraceptive use. Reinforcement contingencies applied to talking about contraception could indirectly increase the use of contraceptive devices (Krull & Pierce, 1997).
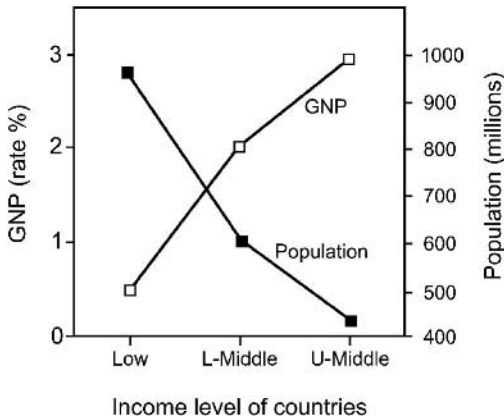
FIG. 14.11. *Increasing population and declining resources as a function of the income level of countries. The low-income data are based on countries other than China and India. The label L-middle is low to middle income countries and the U-middle is middle to upper income nations. The data are plotted from* World Development Report 1989, *by the World Bank, 1989, Oxford: Oxford University Press, Table 1, "Basic Indicators."*

Wiest and Squire's analysis separates those who are "strongly motivated to avoid pregnancy" from people who want to have several children. The researchers suggest that little reinforcement is required to contact family planning agencies if pregnancy is not wanted. In these cases, how to use contraceptives may be the problem and teaching techniques of instruction and modeling could be employed.

On the other hand, it may be more difficult to alter the behavior of those who want children. One solution is that the "government might pay each female a monthly sum, beginning [at the time when she is able to conceive] until a birth occurs. The amount would increase as pregnancy risk became greater in early womanhood, and drop as the woman aged. This would regularly reward the successfully nonpregnant, and focus attention on the cost to a woman of bearing a child" (Wiest & Squire, 1974, p. 252). Although the authors do not mention it, a similar contingency could be applied to males who do not father children (e.g., payment to men for having a vasectomy). Importantly, this kind of intervention does not force reduced family size; it simply pays (reinforces) anyone who chooses to limit the number of children they have. We are not advancing the argument that having many (or no) children is better or worse. We are suggesting that social problems such as overpopulation may be informed by a behavioral analysis of contingencies of reinforcement and metacontingencies (see Krull & Pierce, 1997, for government incentives to *increase* fertility in Quebec, Canada—a French-speaking province below the population replacement rate).

There is a clear role for behavioral analysis in the study of society and culture (Guerin, 1994). Behavior analysts are capable of designing socially important programs and policies (Glenwick & Jason, 1980; Lamal, 1991, 1997). Currently, behavioral researchers are tackling social problems at both the theoretical and applied levels. Experiments on social processes such as cooperation, competition, and exchange are being conducted (e.g., Baker & Rachlin, 2002; Gueth, Ockenfels, & Wendel, 1997; Molm, 1990; Molm, Peterson, & Takahashi, 2001; Schmitt, 1976, 1981, 1984; Tjosvold, 1995), but more is required. Empirical research is needed on the transmission of cultural practices and the metacontingencies that regulate such practices (Pierce, 1991).

Dr. John Nevin at the University of New Hampshire is concerned with cultural practices that are designed to prevent armed conflict but, in fact, increase the probability of making war. In a recent article, Nevin (1988b) suggested that the behavior of preventing war by threats of greater retaliation is counterproductive. This is because the actions of deterrence "form an operant class maintained by powerful contingencies of reinforcement. Therefore, any events that raise the probability of the military components of deterrence, such as a show

of force in a time of crisis, also raise the probability of war, the very outcome that deterrence is intended to prevent" (p. 46). This analysis of deterrence leading to war received some support from the armed conflict that occurred after Iraq invaded Kuwait and was told by the United Nations to leave or "face the consequences." One must realize, however, that such a threat cannot be empty; once made it must be completed.

The work of Nevin and other behaviorists suggests that our government and culture may profit from an analysis of contingencies operating on a large scale (Rakos, 1992). Currently, the formation of policy and evaluation of government programs is conducted by politicians, bureaucrats, economists, and others. These public servants are not usually familiar with effective contingency management, and their planning could be improved by increased knowledge of behavior principles. Behavior analysts who help design social systems will thereby contribute to the science of human behavior and to the long-term survival of humankind.

KEY WORDS

Behavioral flexibility	Evolution	Phenotype
Contingencies of survival	Genotype	Phylogeny
Cultural evolution	Metacontingencies	Selection by
Cultural practice	Natural selection	consequences

ON THE WEB

http://www.ucmp.berkeley.edu/history/evolurion.html Explore the theory of evolution and the history of evolutionary thought.

http://www.bbc.co.uk/education/darwin/index.shtml The Web site of the BBC for Darwin: the man, his work, and the controversy over evolution and natural selection.

http://cas.bellarmine.edu/tietjen/RootWeb/simulations.htm Try out computer simulations of biology and ecology at this Web location.

http://www.jura.ch/lcp/cours/dm/dilemme/prisoner.htm The evolution of cooperation based on game theory and the Prisoner's Dilemma, as well as computer simulations.

STUDY QUESTIONS

1. What is the general form of causation for biology, behavior, and culture? Define three levels of selection. Diagram and describe the contingencies at the three levels. How does selection by consequences operate at each level? (392; Figure 14.1)

2. Discuss biological evolution as a fact and note the dispute over details. Describe the process of natural selection as formulated by Darwin. What is evolution? (393)

3. How does natural selection involve contingencies of survival? What happens when the contingencies of survival change? (394)

4. Define phenotype and genotype. Discuss the interaction of genes and environment. (395)

5. Identify two major sources of genetic variation and how each operates. In terms of embryonic development, what is the result of differences in genetic material? (395)

6. Discuss differences in behavior as heritable characteristics using Barash's (1982) example of woodchucks, yellow-bellied marmots, and Olympic marmots. Explain the importance of natural selection for such behavioral differences. (396)

7. Know what is meant by behavioral rigidity and give an example using the fixed-action pattern. (397)

8. **FOCUS ON**: Describe the research of Scheller and Axel (1984) on the genetic control of egg laying in *Aplysia*. Outline the components of the egg-laying sequence. Why is this experiment important for the study of relatively complex animal behavior? (398) Analyze the dance of the honeybee as genetic regulation of complex behavior. Point to the stimulus control exerted by the position of the sun. What is the survival value of the dance? How could the dance have evolved? (398)

9. Under what conditions is behavioral rigidity likely to be selected? When does behavioral flexibility have survival value? State the advantage of behavioral flexibility according to Skinner (1984b). (401)

10. Use an experiment by Hirsch and McCauley (1977) to show that conditioning is a heritable behavioral process. Talk about the variability in conditioning, and selection for (or against) behavioral flexibility. (402)

11. Describe the biological advantage of reinforcement as a behavioral process. State Glenn's (1991) analysis of this problem. (403)

12. Discuss selection by consequences in *Aplysia* at the behavioral, neural, and cellular levels. (404)

13. Talk about operant selection and extinction using the example of a child's behavior and the sound of a rubber duck. Discuss behavioral variation during extinction and its importance for human invention (e.g., electric light). (404)

14. How does susceptibility to reinforcement supplement the survival value of eating and copulating? What happened when organisms evolved susceptibility to food and sexual reinforcement? (404)

15. Show that susceptibility to reinforcement may be species-specific. How can susceptibility to reinforcement occasionally lead to behavior that is not biologically adaptive? (405)

16. In terms of determinants of social signals, what is the difference between the honeybee dance and human gestures (e.g., gesture for "come here")? What role could stimulus equivalence play in communication by gestures? (406) Discuss the emergence of iconic signing an the contingencies that support this behavior. (406)

17. Discuss the evolution of speech sounds, pointing to Skinner's (1986) analysis. What were three important steps in the evolution of speech sounds? (407)

18. How did the evolution of speech sounds contribute to verbal behavior? Is manding for the benefit of the speaker or listener? What about tacting? Why? (408)

19. Discuss verbal behavior and the coordination of action. Why does the listener provide reinforcement for the speaker's behavior? How could ways of speaking be selected by social reinforcement? (409)

20. What is a cultural practice? Use the Roman phalanx to show the function of a cultural practice. Discuss how operants and practices are selected by consequences. (409)

21. Know what is meant by metacontingency, and give an example based on education, science, and a technologically advanced culture. Why isn't the "best" educational practice always adopted? (410)

22. Outline the origin of a food taboo for a troop of baboons in a zoo enclosure. How was the taboo transmitted? What maintained the cultural practice? Discuss Harris's

(Harris, 1974) functional analysis of the origin and transmission of human cultural taboos. (411)
23. Discuss cultural evolution in terms of adoption of innovations and metacontingencies. Cite examples of innovation by the infant Imo in a troop of Japanese macaque monkeys. How can cultural practices (e.g., transcription of books) remain unchanged over many generations? (412)
24. How can selection by reinforcement and metacontingencies be used in cultural design? Analyze the growth of human populations as a social problem. What kind of contingencies do Wiest and Squire (1974) suggest for modifying birth control practices? (413)
32. What is the role of behavior analysis in the future? (414)

BRIEF QUIZ

1. The single common principle operating at the level of biology, behavior, and culture is
   (a) selection by design
   (b) survival of the fittest
   (c) phylogenetic contingencies
   (d) selection by consequences
2. Natural selection involves
   (a) differential reproduction
   (b) genetic variation
   (c) reproductive diversity
   (d) ontogenetic adaptation
3. At what levels does selection by consequences occur?
   (a) cultural
   (b) biological
   (c) behavioral
   (d) all of the above
4. Two major sources of genetic variation are mutations and
   (a) phenotypic genes
   (b) sexual recombination
   (c) random novelty
   (d) social pressure
5. Egg laying in *Aplysia* is an example of
   (a) genetic control of behavior
   (b) environmental control of behavior
   (c) basic instincts
   (d) released action patterns
6. The behavior of invertebrates such as *Aplysia* is totally
   (a) controlled by genes
   (b) learned
   (c) reflexive
   (d) none of the above
7. Operant behaviors are selected by
   (a) chromosomes
   (b) consequences

   (c) choice
   (d) cognitions
 8. The ability to have one's behavior strengthened by reinforcement is
   (a) learned
   (b) heritable
   (c) determined
   (d) disadvantageous
 9. Social signaling
   (a) is mostly genetically regulated in bees
   (b) is mostly due to reinforcement contingencies in humans
   (c) may involve stimulus equivalence in humans
   (d) all of the above
 10. What allowed for the emergence of human culture?
   (a) evolution of operant processes
   (b) evolution of verbal behavior
   (c) social signaling by bees
   (d) both a and b

Answers to brief quiz (*page*): d(392), a(394), d(394), b(395), a(399), d (403), b(404), b(405), d(405), d(409)

Glossary

A–B–A–B design. This is the most basic single-subject research design. Also called a *reversal design*, it is ideally suited to show that specific features of the environment regulate an organism's behavior. The A-phase, or baseline, is used to measure behavior before the researcher introduces an environmental change. During the baseline, the experimenter takes repeated measures of the behavior under study, and this establishes a criterion against which any changes (attributed to the independent variable) may be assessed. Following the baseline phase, an environmental condition is changed (B-phase) and behavior is measured repeatedly. If the independent variable, or environmental condition, has an effect, then the behavioral measure (dependent variable) will change–increase or decrease. Next, the baseline phase is reintroduced (A) and behavior is again measured. Since the treatment has been removed, behavior should return to baseline levels. Finally, the independent variable is introduced again and behavior is reassessed (B). According to the logic of the design, behavior should return to a level observed in the initial B-phase of the experiment. This second application of the independent variable helps ensure that the behavioral effect is caused by the manipulated condition.

Absolute stimulus control. When operant responses are regulated by the physical properties of one stimulus (e.g., a red light), this is called absolute stimulus control. See also **relative stimulus control**.

Activity anorexia. Physical activity decreases food intake and declining food intake increases activity. This negative feedback loop is called activity anorexia. A similar cycle occurs in many anorexic patients.

Ad libitum weight. The body weight of an organism that has free access to food 24 hr a day.

Adjunctive behavior. Also called interim behavior. On interval schedules of reinforcement, or time-based delivery of food, organisms often show excessive behavior within the interreinforcement interval. For example, rats may drink up to three times their usual daily water intake (polydipsia) over a 1-hr session. This behavior immediately follows reinforcement and is a side-effect of periodic food delivery.

Ainslie–Rachlin principle. The principle states that reinforcement value decreases as the delay between making a choice and obtaining the reinforcer increases. This principle predicts preference reversal when a delay precedes the choice between a small, immediate reward and a large, deferred reinforcer. That is, at some time prior to the choice the large, deferred reinforcer becomes more valued than the small, immediate reward.

Anticipatory contrast. The schedule of reinforcement following the target component (B) in a sequence of schedules (A → B → C) generates strong contrast that increases as training progresses. The strong contrast effect is called anticipatory contrast to distinguish it from the weak elicited responding evoked by the preceding schedule.

Applied behavior analysis. This is a branch of behavior analysis that uses behavior principles to solve practical problems.

Associative strength. During respondent conditioning, the term associative strength is used to describe the relation between the conditioned stimulus (CS) and the magnitude of the conditioned response (CR). In general, associative strength increases over conditioning trials and reaches some maximum level.

Assumption of generality. The assumption of generality implies that the effects of contingencies of reinforcement extend over species, reinforcement, and behavior. For example,

a fixed-interval schedule is expected to produce the scalloping pattern for a pigeon pecking a key for food, as well as for a child solving mathematics problems for teacher approval, all other things being equal.

Autistic children. This term refers to children who show an early lack of social interaction with parents, other family members, and peers. For example, these children often resist being held and may have tantrums if picked up or hugged. When autistic children get older they may be mistaken for being deaf because they don't talk or establish eye contact when talked to. These children often show repeated stereotyped patterns of behavior such as rocking back and forth, spinning a top, wiggling their fingers in front of their eyes, and so on.

Autoshaping. Refers to a respondent conditioning procedure that generates skeletal responses. For example, a key light is turned on a few seconds before grain is presented to a pigeon. After several pairings of key light and grain, the bird begins to peck the key. This effect was first reported as autoshaping, an automatic way to teach pigeons to key peck.

Aversive stimulus. An event or stimulus that an organism evades, escapes, or avoids.

Avoidance. See negative reinforcement.

Backward chaining. A method used to train a chained performance. The basic idea is to first train behavior that is closest to primary reinforcement; once responding is established, links in the chain that are farther and farther from primary reinforcement are added. Each link in the chain is reinforced by the S^D (which is also a conditioned reinforcer) that signals the next component in the sequence.

Backward conditioning. In the respondent procedure of backward conditioning, the US comes on before the CS. The general consensus has been that backward conditioning is unreliable, and many researchers question whether it occurs at all. There is evidence that backward conditioning can occur when the CS has biological significance (e.g., the sight of a predator).

Baseline. The term refers to the base rate of behavior against which an experimental manipulation is measured. An uncontrolled baseline is the rate of an operant before any known conditioning; a controlled baseline (e.g., the rate of response on a variable-interval 60s schedule) may be established to assess the effects of an experimental manipulation (e.g., presentation of intermittent shocks).

Behavior. Refers to everything that an organism does, including covert actions like thinking.

Behavior analysis. Behavior analysis is a comprehensive experimental approach to the study of the behavior of organisms. Primary objectives are the discovery of principles and laws that govern behavior, the extension of these principles over species, and the development of an applied technology.

Behavior analysts. Researchers and practitioners of behavior analysis.

Behavior maintenance. Refers to how long a new behavior persists after the original contingencies are removed (e.g., an anorexic patient who is taught to eat properly shows long-lasting effects of treatment if he or she maintains adequate weight for many years).

Behavior system. A species-specific set of responses related to a specific US. That is, for each species there is a behavior system related to procurement of food, another related to obtaining water, still another for securing warmth, and so on.

Behavior trapping. Refers to the teaching of new behavior that, once established, is "trapped" by natural contingencies of reinforcement.

Behavioral contract. This is a behavioral plan of action that is negotiated between a client, child, spouse, etc. and concerned others. The plan usually includes a statement of target responses, consequences that follow different actions, and long-term goals. The contract objectively specifies what is expected of the person and the consequences that follow behavior.

Behavioral contrast. Contrast refers to a negative relationship between the response rates on the two components of a multiple schedule—as one goes up the other goes down. There are two forms of contrast, positive and negative. Positive contrast occurs when rate of response in an unchanged component of a multiple schedule increases with a decline in behavior in the other schedule. Negative contrast is defined when rate of response declines on the unaltered schedule and an increase in behavior occurs in the other component of the multiple schedule.

Behavioral dynamics. Refers to an area of research that attempts to analyze schedule effects in terms of a few basic processes. Behavioral dynamics requires a high level of mathematical sophistication. Both linear and nonlinear calculus are used to model the behavioral impact of schedules of reinforcement. If performance on schedules can be reduced to a small number of fundamental principles, then reasonable interpretations may be made about any particular arrangement of the environment. Also, it should be possible to predict more precisely behavior based on knowledge of the operating contingencies and the axioms that govern reinforcement schedules.

Behavioral economics. The use of economic concepts (price, substitute commodity, etc.) and principles (marginal utility, etc.) to predict, control, and analyze the behavior of organisms in choice situations.

Behavioral flexibility. When organisms were faced with unpredictable and changing environments, natural selection favored those individuals whose behavior was flexible—adjusting on the basis of past experience. In this case, genes played a subsidiary role, coding for general processes of learning. These processes allowed an organism to adjust to changing environmental requirements throughout its life span. Flexibility of behavior in turn contributed to the reproductive success of the organism.

Behavioral medicine. Behavior change programs that target health-related activities such as following special diets, self-examination for early symptoms of disease, exercising, taking medicine, and so on. In many instances, the idea is that problems of behavior that affect health may be prevented before treatment is necessary.

Behaviorism. A term that refers to the scientific philosophy of behavior analysis.

Bias. For the generalized matching equation, bias is indicated by variation in the value of k from 1. Generally, bias is produced by some unknown asymmetry between the alternatives on a concurrent schedule that affects preference over and above the relative rates of reinforcement.

Biological context. The evolutionary history and biological status of an organism are part of the context for specific environment–behavior interactions.

Blocking. In respondent compound conditioning, a CS that has been associated with a US blocks a subsequent CS–US association. A CS_1 is paired with a US until the conditioned response reaches maximum strength. Following this conditioning, a second stimulus or CS_2 is presented at the same time as the original CS_1, and both are paired with the unconditioned stimulus (US). On test trials, the original CS_1 elicits the CR but the second stimulus or CS_2 does not.

Break and run. A pattern of response, seen on a cumulative record, that occasionally develops on fixed-interval schedules. There is a long postreinforcement pause (PRP) followed by a brief burst of responses that result in reinforcement.

Celeration. The word celeration is used in Precision Teaching to denote two kinds of behavior change, acceleration and deceleration. Acceleration occurs when the rate of target behavior (frequency/time) is increasing over days, while deceleration involves decreasing rate over this period. Behavior graphing allows for evaluation of behavior change and revision of the instructional components based on the observed celeration (change in rate over days).

Chain schedule of reinforcement. A chain schedule of reinforcement refers to two or more simple schedules (CRF, FI, VI, FR, or VR), each of which is presented sequentially and signaled by an S^D. Only the final or terminal link of the chain results in primary reinforcement. See also homogeneous and heterogeneous chain schedules.

Change in associative strength. A factor that affects the increment in associative strength on any one trial is the change in associative strength, which is the difference between the present strength of the CS and its maximum possible value.

Changeover delay (COD). A changeover delay is a control procedure that is used to stop rapid switching between alternatives on concurrent schedules of reinforcement. The COD contingency stipulates that responses do not have an effect immediately following a change from one schedule to another. After switching to a new alternative, a brief time is required before a response is reinforced. For example, if an organism has just changed to an alternative schedule that is ready to deliver reinforcement, there is a brief delay before a response is effective. As soon as the delay has elapsed, a response is reinforced. The COD contingency operates in both directions whenever a change is made from one alternative to another.

Changeover response. On a concurrent schedule, a changeover is a response that an organism emits when it switches from one alternative to another. See also **Findley procedure**.

Changing criterion design. A research design primarily used in applied behavior analysis. The rate of target behavior is progressively changed to some new criterion (up or down). For example, the criterion for the number of cigarettes a person smokes each day could be progressively lowered over several months. The effects of the independent variable are shown if the subject meets or falls below the criterion for any set of days (e.g., the criterion is 20 cigarettes for week 3, but changes to 10 by week 6).

Choice. From a behavioral view, choice is the distribution of operant behavior among alternative sources of reinforcement.

Coercion. Coercion is defined as the "use of punishment and the threat of punishment to get others to act as we would like, and to our practice of rewarding people just by letting them escape from our punishments and threats" (Sidman, 2001, p. 1). That is, coercion involves the basic contingencies of punishment and negative reinforcement.

Commitment response. The commitment response is some behavior emitted at a time prior to a choice point that eliminates or reduces the probability of impulsive behavior. A student who invites a classmate over to study on Friday night (commitment response) ensures that he or she will "hit the books" and give up partying when the choice arrives.

Compound stimuli. In respondent conditioning, two (or more) conditioned stimuli (e.g., tone and light) called a compound are presented together and acquire the capacity to elicit a single conditioned response (e.g., salivation).

Concurrent-chains schedule. Refers to two or more chain schedules that are simultaneously available. See also **chain schedule of reinforcement** and **concurrent schedules of reinforcement**.

Concurrent schedules of reinforcement. Two or more schedules of reinforcement (e.g., FR, VR, FI, VI) are simultaneously available. Each alternative is associated with a separate schedule of reinforcement and the organism is free to distribute behavior to the schedules.

Conditional discrimination. A conditional discrimination is a discrimination that depends on the stimulus context (a four-term contingency of reinforcement). Consider a matching-to-sample experiment where a bird has been trained to match to triangles and squares based on the sample stimulus. To turn this experiment into a conditional-discrimination task, a house light is inserted that may be turned on or off. The bird is required to match to the sample when the house light is on and to choose the

noncorresponding stimulus when the house light is off. Conditional matching to sample involves simultaneous discrimination of three elements in a display. The animal must respond to geometric form depending on the sample, to the correspondence or noncorrespondence of the comparison stimuli, and to the condition of the house light (on/off). See also **matching to sample**.

Conditioned aversive stimulus (S^{ave}). An aversive stimulus that acquires its function based on a history of conditioning. See **aversive stimulus**.

Conditioned establishing operation (CEO). An establishing operation that depends on a history of reinforcement for completing a behavioral sequence of chain. One procedure is called the blocked-response CEO, in which a response that usually occurs is blocked because of the temporary absence of a specific condition, stimulus, or event. For example, you may leave your seminar notes at home as you rush to the university. Because you cannot complete the behavioral sequence of giving a seminar presentation, obtaining the notes would function as reinforcement for making a telephone call to get them. The notes would not have a reinforcement function during a casual lunch with an old friend, because they are not necessary to this behavioral sequence. Whenever an event or stimulus is required to complete a behavior chain, withholding the event will establish it as reinforcement for operant behavior.

Conditioned inhibition. In respondent conditioning, when a CS is presented repeatedly without the US (extinction), the conditioned stimulus is said to acquire increasing amounts of inhibition, in the sense that its presentation suppresses the response.

Conditioned reflex. See **conditioned response** and **conditioned stimulus**.

Conditioned reinforcement. The presentation of a conditioned reinforcer and the subsequent increase in rate of the operant that produced it.

Conditioned reinforcer. A conditioned reinforcer is an event or stimulus that has acquired its effectiveness to increase operant rate on the basis of an organism's life or ontogenetic history.

Conditioned response (CR). An arbitrary stimulus, such as a tone, is associated with an unconditioned stimulus that elicits reflexive behavior (e.g., food elicits salivation). After several pairings, the stimulus is presented alone. If the stimulus now elicits a response (tone now elicits salivation), the response to the tone is called a conditioned response (CR).

Conditioned stimulus (CS). An arbitrary stimulus, such as a tone, is associated with an unconditioned stimulus that elicits reflexive behavior (e.g., food elicits salivation). After several pairings, the stimulus is presented alone. If the stimulus now elicits a response (tone elicits salivation), it is called a conditioned stimulus (CS).

Conditioned-stimulus function. An event or stimulus that has acquired its function to elicit a response on the basis of respondent conditioning. When a tone is followed by food in the mouth, the tone becomes a conditioned stimulus (CS) for salivation.

Conditioned suppression. In conditioned suppression, a previously conditioned CS (e.g., tone, light, etc.) is paired with an aversive US such as an electric shock. After several pairings, the original CS becomes a conditioned aversive stimulus (CS^{ave}). Once the CS^{ave} has been conditioned, its onset suppresses ongoing operant behavior. A rat may be trained to press a lever for food. After a stable rate of response is established, the CS^{ave} is introduced. When this occurs, the animal's lever pressing is suppressed.

Conditioned withdrawal. When a CS that accompanies drug use is presented people are said to have "cravings" and this respondent process is called conditioned withdrawal. The CS elicits reactions that are ordinarily countered by the US. However, when the US is not delivered and the CR reactions occur, people experience withdrawal. A heroin addict can have their withdrawal symptoms immediately terminated by a heroin injection.

If you are accustomed to having a cigarette after a meal the craving you experience can be alleviated with a smoke.

Construction of S^Ds. In solving problems, people make up or construct their own discriminative stimuli. A person who has an important early morning appointment may set an alarm clock for 6:00 a.m. Technically, setting the alarm is precurrent behavior, or an operant that precedes some other response or performance. That is, setting the alarm is behavior that results in the alarm ringing at 6:00 a.m., setting the occasion for getting up and going to the meeting. A major function of precurrent behavior is the construction of SDs that regulate subsequent action. See also **precurrent behavior**.

Context for conditioning. Refers to the ontogenetic and phylogenetic history of an organism, its current physiological status, and the contextual events or stimuli that are present when conditioning occurs.

Contextual stimuli. In terms of operant and respondent conditioning, contextual stimuli are uncontrolled sights, sounds, smells, and so on that are the background for conditioning. These stimuli are conditioned at the same time that behavior is strengthened.

Contingencies of survival. Refers to the contingencies (in the sense of "if–then" requirements) that result in differential reproduction or natural selection. The habitat or ecological environment sets requirements for the survival of individuals and their genes. Members of a species who exhibit features appropriate to the contingencies survive and reproduce, and those with less appropriate characteristics have fewer offspring. Natural selection (differential reproduction) therefore occurs as particular organisms satisfy (or fail to satisfy) the contingencies of survival.

Contingency. In respondent conditioning, contingency refers to a correlation between CS and US. Rescorla (1966) suggested that a positive correlation between CS and US, rather than the mere pairing of these stimuli, is necessary for conditioning. For operant conditioning, see **contingency of reinforcement**.

Contingency of reinforcement. A contingency of reinforcement defines the relationship between on occasion, an operant class, and the consequences that follow the behavior (e.g., SD: R → S^r). We change the contingencies by altering one of the components and observing the effect on behavior. For example, a researcher may change the rate of reinforcement for an operant in a given situation. In this case, the R → S^r component is manipulated while the SD : R component is held constant. Contingencies of reinforcement can include more than three terms as in conditional discrimination (e.g., four-term relations); also, the effectiveness of reinforcement contingencies depends on motivational events called establishing operations.

Contingency-shaped behavior. Refers to operant behavior that is directly under the control of contingencies of reinforcement, as opposed to rule-governed behavior.

Contingency-specifying stimuli. A technical term for verbal stimuli that regulate the behavior of listeners. Rules, instructions, advice, maxims, and laws are contingency-specifying stimuli in the sense that the verbal stimulus describes an actual contingency of reinforcement of everyday life. See **rule-governed behavior**.

Continuous recording for specified periods. A tactic used in applied behavior analysis for assessing the rate of target behavior. Each instance of behavior is counted during certain periods of the day (e.g., lunch, recess, first class in the morning, and so on).

Continuous reinforcement (CRF). When each response produces reinforcement (e.g., each lever press produces food), the schedule is called CRF or continuous reinforcement.

Controlling stimulus (S). A controlling stimulus is a stimulus or event that changes the probability of operant behavior. An S^D increases the probability of response, and an S^Δ makes responding less likely. An S^{ave} may increase or decrease the likelihood of operant behavior, depending on the operating contingency.

Controlled response. In self-control, setting an alarm may be called a controlling response because it alters conditions that affect subsequent behavior—getting up for school rather than sleeping. Getting up for school is the *controlled response* in the sense that its probability of occurrence is altered by the effects of the controlling response.

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Correspondence relations. Survival or reinforcement contingencies that select for equivalance, matching, or similarity between (a) the behavior of a model and observer, as in imitation, (b) what a person says and what is done (say–do correspondence), (c) what is done and what is said (do–say correspondence), (d) private stimulation and a verbal report (describing emotions), (e) an instruction or rule and what is done (rule-governed behavior).

Correlation. As used in respondent conditioning, the percentage of conditioning trials in which the CS is followed by the US, and the percentage of trials in which the CS is not followed by the unconditioned stimulus. See also **contingency**.

Cultural evolution. Cultural evolution begins at the level of the individual, when its technological effects reinforce the behavior of a person. An inventor may discover a new way of making a wheel; a farmer may find a food crop that produces higher yields; and a teacher may find a novel way to teach reading. A culture is said to evolve when the community adopts these innovations.

Culture. In behavior analysis a culture is all the conditions, events, and stimuli arranged by other people that regulate human action.

Cultural practice. A cultural practice is defined in terms of interlocking social contingencies—where the behavior of each person supports the behavior of other members of the community. The pattern of behavior that arises from the interlocking contingencies is the type of practice (i.e., what people do in that culture).

Cumulative record. A cumulative record is a real-time graphical representation of operant rate. Each response produces a constant upward increment on the y-axis, and time is indexed on the x-axis. The faster the rate of response is, the steeper the slope or rise of the cumulative record. See also **cumulative recorder**.

Cumulative recorder. Refers to a commonly used laboratory instrument that records the frequency of operant behavior in real time. For example, paper is drawn across a roller at a constant speed, and each time a lever press occurs a pen steps up one increment. When reinforcement occurs, this same pen makes a downward deflection. Once the pen reaches the top of the paper, it resets to the bottom and starts to step up again. See also **cumulative record**.

Delayed imitation. Imitation of a modeled stimulus after a delay and in the absence of the model or modeled stimulus. Delayed imitation is considered to require more cognitive abilities than direct imitation (i.e., delayed imitation involves remembering the modeled stimulus).

Delay-reduction hypothesis. Stimuli that signal a decrease in time to positive reinforcement, or an increase in time to an aversive event, are more effective conditioned reinforcers. Generally, the value of a conditioned reinforcer is attributed to its delay reduction—how close it is to reinforcement or how far it is from punishment.

Delayed conditioning. A respondent conditioning procedure in which the CS is presented a few seconds before the US occurs.

Delayed matching to sample. On a matching-to-sample task, the comparison stimuli are presented some time after the sample stimulus is turned off. See also **matching to sample**.

Dependent variable. The variable that is measured in an experiment, commonly called an effect. In behavior analysis, the dependent variable is a measure of the behavior of an organism. One common dependent variable is the rate of occurrence of an operant (e.g., the rate of lever pressing for food).

Deprivation operation. Refers to the procedure of restricting access to a reinforcing event. Withholding an event or stimulus increases its effectiveness as a reinforcer.

Differential reinforcement. In *discrimination procedures*, differential reinforcement involves reinforcement in the presence of one stimulus (S^D) but not in other settings (S^Δ). The result is that the organism comes to respond when the S^D is presented and to show a low probability of response in settings that have not resulted in reinforcement (S^D). A differential response in S^D and S^Δ situations is called a discrimination and an organism that shows this differential response is said to discriminate the occasion for reinforcement.

   Differential reinforcement may be based on a property of operant behavior and in this case results in *response differentiation*. For example, when reinforcement is based on short interresponse times or IRTs (2–5 s) the distribution of IRTs becomes centered around short intervals. Changing the contingencies to reinforce longer IRTs (20–25 s) produces a new distribution centered around long intervals. See **response differentiation**.

Differential reinforcement of other behavior (DRO). Refers to reinforcement for any behavior other than a target operant. For example, after a period of time the applied behavior analyst delivers reinforcement for any behavior other than "getting out of seat" in a classroom. The target behavior is on extinction and other behavior is reinforced.

Differential response. When an organism makes a response in one situation but not in another, we say that the animal discriminates between the situations and makes a differential response.

Direct replication. Repeating the procedures and measures of an experiment with several subjects of the same species (e.g., pigeons) is called direct replication. If each pigeon is exposed to a fixed interval 30-s schedule of food reinforcement and each bird shows a scalloping pattern of pecking the key (i.e., a low rate of response following reinforcement that increases to a high rate at the moment of reinforcement) then the experimental procedures show direct replication.

Discriminated avoidance. This is avoidance behavior emitted as a function of a warning stimulus. For example, a dog stops barking when its owner shouts, "Shut up!"

Discriminated extinction. Refers to a low rate of operant behavior that occurs as a function of an S^Δ. For example, the probability of putting coins in a vending machine with an "out of order" sign on it is very low.

Discrimination. When an organism makes a differential response to two or more stimuli (or events), we can say the animal discriminates between them. This process is called discrimination.

Discriminative function. When an organism's behavior is reinforced, those events that reliably precede responses come to have a *discriminative function*. These events are said to *set the occasion* for behavior and are called discriminative stimuli. Discriminative stimuli acquire this function because they predict (have been followed by) reinforcement.

Discrimination index (I_D). This index compares the rate of response in the S^D component to the sum of the rates in both S^D and S^Δ phases:

$$I_D = (S^D \text{ rate})/(S^D \text{ rate} + S^\Delta \text{ rate}).$$

The measure varies between 0.00 and 1.00. Using the I_D measure, when the rates of response are the same in the S^D and S^Δ components, the value of I_D is 0.50, indicating no discrimination. When all responses occur during the S^D phase, the S^Δ rate is zero and I_D equals 1. Thus, a discrimination index of 1 indicates a perfect discrimination and

maximum stimulus control of behavior. Intermediate values of the index signify more or less control by the discriminative stimulus.

Discriminative stimulus (S^D). Refers to an event or stimulus that precedes an operant and sets the occasion for operant behavior.

Discriminative-stimulus account of conditioned reinforcement. Refers to the hypothesis that it is necessary for a stimulus to be an S^D in order for it to be a conditioned reinforcer. The hypothesis has been largely discounted, and the weight of the evidence supports Edmond Fantino's (1969b) delay-reduction hypothesis. See **delay-reduction hypothesis**.

Displacement behavior. Displacement behavior is observed in the natural environment and is characterized as irrelevant, incongruous, or out of context. That is, the behavior of the animal does not make sense given the situation, and the displaced responses do not appear to follow from immediately preceding behavior. Like adjunctive behavior (see definition in this glossary), displacement activities arise when consummatory activities like eating are interrupted or prevented.

Duration recording. When behavior is continuous, duration recording is a method of observation. An observer may use a stopwatch or other timing device to record the duration of behavior. When a person is sitting in a chair, the watch is timing; and when the person leaves the chair, the watch is stopped.

Echoic behavior. When there is point-to-point correspondence between a stimulus and response, verbal behavior may be classified as echoic. A further requirement is that the verbal stimulus and the echoic response must be in the same mode (auditory, visual, etc.) and have exact physical resemblance (e.g., same sound pattern). An echoic is a class of verbal operants regulated by a verbal stimulus in which there is correspondence and topographic similarity between the stimulus and response. Saying "this is a dog" to the spoken stimulus "this is a dog" is an example of an echoic response in human speech.

Elicited. Respondent (CR) or reflexive (UR) behavior is elicited in the sense that the behavior is drawn out (or made to occur) by the presentation of a stimulus (CS or US).

Emitted. Operant behavior is emitted in the sense that it occurs at some probability in the presence of a discriminative stimulus, but the S^D does not force its occurrence.

Emotional response. Refers to a response such as "wing flapping" in birds that occurs with a change in contingencies from reinforcement to extinction. One common emotional response is called aggression (attacking another organism or target).

Environment. The functional environment is all of the events and stimuli that affect the behavior of an organism. The environment includes events "inside the skin" like thinking, hormonal changes, and pain stimulation.

Errorless discrimination. In errorless discrimination, the trainer does not allow the organism to make mistakes by responding to the extinction stimulus. Initially S^D and S^Δ are very different, but differences between the stimuli are gradually reduced as training progresses. The procedure eliminates the aversive effects of extinction that are generated by other discrimination-training methods. For example, pigeons flap their wings in an aggressive manner and will work for an opportunity to attack another bird during the presentation of the S^Δ on a multiple schedule. This behavior does not occur when errorless discrimination is used in training.

Escape. See **negative reinforcement**.

Establishing operation. Formally, an establishing operation is defined as any change in the environment that alters the effectiveness of some stimulus or event as reinforcement and simultaneously alters the momentary frequency of the behavior that has been followed by that reinforcement. Thus, an establishing operation has two major effects: (a) It increases the momentary effectiveness of reinforcers supporting operant behavior, and (b) it increases the momentary probability of operants that have produced such reinforcement.

For example, the most common establishing operation is food deprivation for primary reinforcement. This procedure has two effects. First, food becomes an effective reinforcer for any operant that produces it. Second, behavior that has previously resulted in getting food becomes more likely.

Evolution. In terms of biology, a change in the genetic make-up of a species, as observed in the expressed characteristics of its members.

Experimental analysis of behavior. The method of investigation most commonly used in behavior analysis. The method involves breaking down complex environment–behavior relations into component principles of behavior. The analysis is verified by arranging experimental procedures that reveal the underlying basic principles and controlling variables. This involves intensive experimentation with a single organism over an extended period, rather than statistical assessment of groups exposed to experimental treatments.

External validity. External validity refers to the extent that experimental findings generalize to other behaviors, settings, reinforcers and populations. That is, does the cause-and-effect relationship found in an experiment occur at different times and places, when the original conditions are in effect?

Extinction. The procedure of extinction involves the breaking of the contingency between an operant and its consequence. For example, a bar press that was followed by food reinforcement no longer produces food. As a behavioral process, extinction refers to a decline in the frequency of the operant when an extinction procedure is in effect. In both instances, the term extinction is used correctly.

Extinction burst. A rapid burst of responses that occurs when extinction is first implemented.

Extinction stimulus (S^Δ). An S^Δ (pronounced S-delta) is a stimulus that sets the occasion for a decrease in operant responses. For example, an "out of order" sign on a vending machine decreases the probability of putting money in the machine. See S-delta.

Extraneous sources of reinforcement (R_e). Involves all nonprogrammed sources of reinforcement that regulate alternative behavior, reducing the control of behavior on a specified schedule of reinforcement. Extraneous sources of reinforcement include any unknown contingencies that support the behavior of the organism. For example, a rat that is pressing a lever for food on a particular schedule of reinforcement could receive extraneous reinforcement for scratching, sniffing, and numerous other behaviors. The rate of response for food will be a function of the programmed schedule as well as the extraneous schedules controlling other behavior. In humans, a student's mathematical performance will be a function of the schedule of correct solutions as well as extraneous reinforcement for other behavior from classmates or teachers, internal neurochemical processes, and changes to the physical/chemical environment (e.g., smell of food drifting from the cafeteria). See also **quantitative law of effect**.

Facultative behavior. Collateral behavior generated by properties of a schedule of reinforcement. See also **adjunctive behavior**.

Fading. The procedure involves transferring stimulus control from one value of a stimulus to another. This is done by gradually changing a controlling stimulus from an initial value to some designated criterion.

Findley procedure. A method used to present concurrent schedules in the operant laboratory. Separate schedules are programmed on a single key, and the organism may switch schedules (and associated S^Ds) by making a response on a CO or changeover key.

First-order conditioning. In first-order respondent conditioning, an apparently neutral stimulus is paired with an unconditioned stimulus. When this occurs, the control of the response to the US is transferred to the neutral stimulus, which is now called a conditioned stimulus (CS).

Fixed action pattern (FAP). A sequence or chain of behavior set off by a specific stimulus. The component responses are repeated almost identically with each presentation of the stimulus. Fixed action patterns are based on a "genetic blueprint," and the environment simply initiates the sequence. For example, the male stickleback fish will aggressively defend its territory from male intruders during mating season. The fish shows a fixed sequence of threatening actions that are elicited by the red underbelly of an intruding male.

Fixed interval (FI). A schedule of reinforcement in which an operant is reinforced after a fixed amount of time has passed. For example, on a fixed-interval 90-s schedule (FI 90), one bar press after 90 s results in reinforcement. Following reinforcement, another 90-s period goes into effect; and after this time has passed, another response will produce reinforcement.

Fixed ratio (FR). A response-based schedule of reinforcement that delivers reinforcement after a fixed number of responses are made. For example, on a fixed ratio 10 (FR 10), the organism must make 10 responses for each reinforcement.

Fluency. In Precision Teaching, the use of rate (frequency/time) focuses instruction on *fluency* or accuracy *and* high frequency. When a performance becomes fluent, the behavior is retained longer, persists during long periods on the task, is less affected by distractions, and is more likely to be available in new learning situations (i.e., to combine with other well-learned behaviors).

Force of response. Reinforcement can be made contingent on the force or magnitude of response. Force or magnitude is a property or dimension of behavior.

Formal similarity. A term used in verbal behavior to define echoic behavior. Formal similarity requires that the verbal stimulus and the product of the response be in the same mode (auditory, visual, etc.) and have exact physical resemblance (e.g., same sound pattern).

Free operant method. In the free operant method, an organism may repeatedly respond over an extensive period of time. The organism is "free" to emit many responses or none at all. More accurately, responses can be made without interference from the experimenter (as in a trials procedure).

Function-altering event. Verbal stimuli such as rules and instructions can alter the function of other stimuli and, thereby, the strength of relations among stimuli and behavior. For example, an instruction about what to do in an airline emergency can establish stimulus control by a "dangling yellow mask" over the behavior of "placing the mask over your face and breathing normally."

Functional analysis of behavior. An analysis of behavior in terms of its products or consequences. Functionally, there are two basic types of behavior, operant and respondent. The term respondent defines behavior that increases or decreases because of the presentation of a stimulus (or event) that precedes the response. Such behavior is said to be elicited, in the sense that it reliably occurs when the stimulus is presented. There is a large class of behavior that does not depend on an eliciting stimulus. This behavior is called emitted and spontaneously occurs at some frequency. When emitted behavior is strengthened or weakened by the events that follow the response, it is called operant behavior. Thus, operants are emitted responses that increase or decrease depending on the consequences they produce.

Functional independence. A term used in verbal behavior to describe the independence of the operant classes of manding and tacting. Formally, each operant class is controlled by separate contingencies of reinforcement; training mand relations would not necessarily affect the training of tact relations or vice versa.

Generality. An experimental result has generality when it is observed in different environments, organisms, and so on. For example, the principle of reinforcement generalizes over species, settings, responses, and reinforcers. In a pigeon, the peck-for-food relationship

depends on the establishing operation of deprivation for food in the immediate past. For humans, who have an extensive capacity for operant conditioning, going to a soda machine to get a cold drink on a hot afternoon is an effective contingency. In both examples, establishing operations and reinforcement are the operating principles.

Generalization gradient (operant). Generalization occurs when an organism responds to values of the S^D (or fewer responses to the S^Δ) that were not trained during acquisition. A generalization gradient is the function (graph) that relates values of the $S^{D\,\text{(intensity of light)}}$ to a measure of response strength (operant rate).

Generalization gradient (respondent). Generalization occurs when an organism shows a conditioned response (CR) to values of the CS that were not trained during acquisition. A generalization gradient is the function (graph) that relates values of the CS (loudness of tone) to a measure of response strength (amount of CR).

Generalized conditioned reinforcer. A conditioned reinforcer that is backed up by many other sources of reinforcement. Money is a good example of a generalized conditioned reinforcer. Cash may be exchanged for a large variety of goods and services.

Generalized imitation. A reinforcement procedure used to teach the generalized response class "do as I do." The procedure involves reinforcement of correspondence between modeled performance and imitative operants. After training a number of exemplars, a novel modeled stimulus is presented without reinforcement and a new imitative response occurs that matches the modeled performance. Generalized imitation involves both stimulus generalization of the class of modeled stimuli and response generalization of the class of imitative responses.

Generalized matching law. Proportion equations like $B_a/(B_a + B_b) = R_a/(R_a + R_b)$ describe concurrent performance when alternatives differ only in rate of reinforcement. However, in complex environments, other factors also contribute to choice and preference. These factors arise from the biology and environmental history of the organism. For example, sources of error may include different amounts of effort for the responses, qualitative differences in reinforcement such as food versus water, a history of punishment, a tendency to respond to the right alternative rather than the left, and sensory capacities.

To include these and other conditions within the matching law, it is useful to express the law in terms of ratios rather than proportions (i.e., $B_a/B_b = R_a/R_b$). When relative rate of response matches relative rate of reinforcement, the ratio equation is simply a restatement of the proportional form of the matching law. A generalized form of the ratio equation may, however, be used to handle the situation in which unknown factors influence the distribution of behavior. These factors produce systematic departures from ideal matching but may be represented as two constants (parameters) in the generalized matching equation

$$B_a/B_b = k(R_a/R_b)^a.$$

In this form, the matching equation is known as the generalized matching law. In the equation, the coefficient k and the exponent a are values that represent two sources of error for a given experiment. When these parameters are equal to 1, the equation is the simple ratio form of the matching law. See also **matching law**.

Generalized social reinforcement. A generalized conditioned reinforcer that is also a social reinforcer. Praise is a social reinforcer backed up by many sources of reinforcement. See also **generalized conditioned reinforcer**.

Genotype. Genotype refers to the genetic make-up of the organism. Some observable characteristics are largely determined by genotype, other features are strongly influenced by experience, but most result from an interaction of genes and environment. Thus, the height of a person is attributable to both genes and nutrition.

Habituation. Habituation occurs when an unconditioned stimulus repeatedly elicits an unconditioned response. The frequent presentation of the US produces a gradual decline in the magnitude of the unconditioned response. When the UR is repeatedly elicited it may eventually fail to occur at all.

Heterogeneous chains schedule. A heterogeneous chain requires different responses for each link of the schedule. Dog trainers make use of heterogeneous chains when they teach complex behavioral sequences to their animals. In going for a walk, a seeing-eye dog stops at intersections, moves forward when the traffic is clear, pauses at a curb, avoids potholes, and finds the way home. Each of these different responses is occasioned by specific stimuli and results in conditioned reinforcement. See also **chain schedule of reinforcement**.

History as a source of invalidity. One kind of threat to internal validity is called history. History refers to conditions that are changing at the same time as the manipulation of the independent variable. For example, an experiment that assesses the effects of changes in pay for work performance within an automotive plant may be confounded by the effects of history. A history effect would occur if the economic conditions of the community were changing at the same time as the changes in pay within the plant. See also **internal validity**.

History of reinforcement. The reinforcement contingencies that an organism has been exposed to during its lifetime, including the resulting changes in behavior due to such exposure.

Homogeneous chains schedule. Operant chains are classified as homogeneous when the topography or form of response is similar in each link of the schedule. For example, a bird pecks the same key in each component of the chain. Each link in the schedule produces a discriminative stimulus for the next link, and the S^D is also a conditioned reinforcer for the behavior that produces it. See also **chain schedule of reinforcement**.

Hypothetical constructs. Unobservable events or processes that are postulated to occur and that are said to explain behavior are called hypothetical constructs. For example, Freud's mental device "ego" is a hypothetical construct that is used to explain self-gratifying behavior. In cognitive psychology, terms like "cognitive representation" or "mental imagery" are hypothetical terms that are said to explain the behavior of knowing and observing the world. From a behavioral perspective, the difficulty is that the mental constructs are easily invented, are inferred from the behavior they are said to explain, and are inherently unobservable with direct observation. That is, there is no objective way of getting information about such events except by observing the behavior of people or other organisms.

Identity discrimination. In identity discrimination, the researcher presents a sample stimulus (e.g., vertical line) and two side-key options (e.g., vertical line and horizontal line). The organism is reinforced for selecting the comparison stimulus that corresponds to the sample (e.g., pecking the side key with a vertical line when the sample is a vertical line). See also **matching to sample**.

Imitation. True imitation requires that the learner emit a novel response that could only occur by observing a model emit a similar response.

Innate imitation. See spontaneous imitation.

Impulsive behavior. When a person (or other animal) selects a smaller, immediate payoff over larger, delayed benefits, we may say that he or she shows impulsive behavior.

Independent variable. The variable that is manipulated, changed, or controlled in an experiment, commonly called a cause. In behavior analysis, a change in the contingencies of reinforcement or the arrangement of events that precede and follow the behavior of an organism (e.g., changing the rate of reinforcement).

Information account of conditioned reinforcement. A hypothesis suggesting that a stimulus will become a conditioned reinforcer if it provides information about the occurrence of primary reinforcement. This notion has been largely discounted and replaced by Edmond Fantino's (1969b) delay-reduction hypothesis. See also **delay-reduction hypothesis**.

Instinctive drift. Species-characteristic behavior patterns that become more and more invasive during operant training.

Instrument decay. One threat to internal validity is instrument decay. In behavioral research, instrument decay refers to observers becoming better or worse at measuring the dependent variable. Such an effect can occur in reversal designs where repeated observations are made. See also **internal validity**.

Interim behavior. See **adjunctive behavior**.

Interlocking contingencies. In social episodes involving manding or tacting, each person (speaker and listener) completes a behavioral sequence or chain ($S^D : R \rightarrow S^r + S^D : R \rightarrow S^r \ldots$), and the verbal relations involve the intermingling of these chains or the interlocking contingencies. In an interlocking contingency the behavior of one person causes stimulation and reinforcement for the behavior of the other, and vice versa.

Intermittent reinforcement effect. Intermittent reinforcement schedules generate greater resistance to extinction than continuous reinforcement (CRF). The higher the rate of reinforcement the greater the resistence to change; however, the change from CRF to extinction is disriminated more rapidly than between intermittent reinforcement and extinction.

Intermittent schedule of reinforcement. A schedule in which some rather than all operants are reinforced. In other words, an intermittent schedule is any schedule of reinforcement other than a continuous one (CRF).

Internal validity. When many extraneous variables are ruled out by an experimental design, the research has high internal validity. That is, changes in the dependent variable may be reasonably attributed to changes in the independent variable (cause $\rightarrow$ effect). Internal validity is the minimum requirement for all experiments.

Interreinforcement interval (IRI). The interreinforcement interval (IRI) is the time between any two reinforcers. It is well established that the postreinforcement pause (PRP) is a function of the IRI. As the time between reinforcements becomes longer, the PRP increases. On fixed-interval schedules, in which the time between reinforcement is controlled by the experimenter, the PRP is approximately one-half the IRI. For example, on a FI 300-s schedule (in which the time between reinforcements is 300 s), the average PRP will be 150 s. On fixed ratio, the evidence suggests similar control by the IRI; as the ratio requirement increases, the PRP becomes longer. See **postreinforcement pause (PRP)**.

Interresponse time (IRT). The time between any two responses. The interresponse time may be treated as a conditionable property of operant behavior; for example, the IRTs on a VI schedule of reinforcement are much longer than on a VR schedule. Variable interval schedules are said to differentially reinforce long IRTs while VR schedules differentially reinforce short interresponse times.

Interval recording. A measurement strategy used in applied behavior analysis to assess the rate of target behavior. A block of time is selected and divided into short equal intervals, and if the target behavior occurs it is recorded once in an appropriate time bin. For example, a 30-min segment of mathematics class may be divided into 10-s bins. Regardless of the number of responses, if the behavior occurs in a given 10-s segment, then the observer records it as a single event.

Interval schedules. Schedules of reinforcement that are based on the passage of time and one response after that time has elapsed.

Intraverbal behavior. Intraverbal behavior involves a class of verbal operants regulated by verbal discriminative stimuli. In everyday language, thematically related words (or sentences) are examples of intraverbal relations. For example, the verbal response "fish" to the spoken words "rod and reel" is an intraverbal response; saying "water" to the written word LAKE is also intraverbal behavior. Thus, intraverbal relations arise from verbal behavior; a previous verbal response by a speaker is a stimulus for a subsequent verbal operant.

Latency. The time from the onset of one event to the onset of another. For example, the time it takes a rat to reach a goal box after it has been released in a maze.

Law of effect. A paraphrase of this law may be stated as the principle of reinforcement: Operants may be followed by events or stimuli that increase the probability or rate of the behavior.

Law of intensity magnitude. As the intensity of an US increases, so does the magnitude or size of the unconditioned response.

Law of the latency. As the intensity of the US increases, the latency (time to onset) of the UR decreases.

Law of the threshold. At very weak intensities a stimulus will not elicit a response, but as the intensity of the eliciting stimulus increases there is a point at which the response is elicited. That is, there is a point below which no response is elicited and above which a response always occurs.

Learned helplessness. In the phenomenon called learned helplessness, an animal is first exposed to inescapable and severe aversive stimulation (shocks). Eventually the animal gives up and stops attempting to avoid or escape the situation. Next, an escape response, which under ordinary circumstances would be acquired easily, is made available but the animal does not make the response. The organism seems to give up and become helpless when presented with inescapable aversive stimulation.

Limited hold. A limited hold is a contingency where a reinforcer is available for a set time after an interval schedule has timed out. Adding a limited hold to a VI schedule will increase the rate of responding by reinforcing short interresponse times.

Learning. Refers to the acquisition, maintenance, and change of an organism's behavior as a result of lifetime events (the ontogeny of behavior). In everyday language, learning often is used to refer to transitional changes in behavior (e.g., from not knowing to knowing one's ABC's), but conditions that maintain behavior in a steady state are also part of what we mean by learning (e.g., continuing to recite the alphabet).

Log-linear matching equation. To write the matching law as a straight line, we may write the log-linear equation:

$$\log(B_a/B_b) = \log k + [a * \log(R_a/R_b)].$$

Notice that in this form, $\log(B_a/B_b)$ is the Y variable and $\log(R_a/R_b)$ is the X variable. The constants a and log k are the slope and intercept, respectively.

Magazine training. Establishing an association (in time) between stimuli that precede reinforcement (click of the feeder) and the reinforcing event (food in the mouth). For example, a rat is placed in an operant chamber and a microcomputer periodically turns on a feeder. When the feeder is turned on, it makes a click and a food pellet falls into a cup. Because the click and the appearance of food are associated in time you would, after training, observe a typical rat staying close to the food magazine and quickly moving toward it when the feeder was operated (see conditioned reinforcer).

MammaCare. A behavioral program used to teach women effective self-examination of their breasts.

Manding. The word manding comes from the common English word *commanding*, but commanding is only part of this operant class. Manding is a class of verbal operants whose form is regulated by specific establishing operations (e.g., deprivation, aversive stimulation, etc.). When you say "give me the book," "don't do that," "stop," and so on, your words are regulated by motivational conditions or establishing operations (e.g., deprivation for the book, or by another person doing something unpleasant). The establishing operation (no ketchup) regulates the topography of manding ("give ketchup") and ensures that a particular event functions as reinforcement (getting ketchup).

Matching law. When two or more concurrent-interval schedules are available, relative rate of response matches (or equals) relative rate of reinforcement. More generally, the matching law states that the distribution of behavior between (or among) alternative sources of reinforcement is equal to the distribution of reinforcement for these alternatives. See **relative rate of response** and **relative rate of reinforcement.**

Matching to sample. A procedure used to investigate recognition of stimuli. For example, in a simple recognition procedure, a pigeon may be presented with three keys. A triangle is projected onto the center key. The triangle is the sample stimulus. To ensure that the bird attends to the sample, it is required to peck the sample key. When this happens, two side keys are illuminated with a triangle on one and a square on the other, called the comparison stimuli. If the bird pecks the comparison stimulus that corresponds to the sample, this behavior is reinforced and leads to the presentation of a new sample. Pecks to the noncorresponding stimulus result in extinction and the next trial. See **identity discrimination**.

Maturation. One source of internal invalidity in experiments is called maturation; the term refers to biological or psychological processes that change over time (e.g., aging or developing). If these maturational changes occur at the same time as the manipulation of the independent variable, they (rather than the experimental treatment) could be responsible for the findings. See also **internal validity**.

Maximization. In this economic view of behavior, humans and other animals are like organic computers that compare their behavioral distributions with overall outcomes and eventually stabilize on a response distribution that maximizes overall rate of reinforcement.

Maximum associative strength. A given CS can acquire only so much control over a conditioned response. This is the maximum associative strength for the CS. Thus, a tone (CS) that is paired with 1 g of food will have maximum associative strength when the amount of conditioned salivation (CR) is about the same as the unconditioned salivation (UR) elicited by the gram of food (US). That is, an unconditioned stimulus elicits a given magnitude of the unconditioned response. This magnitude sets the upper limit for the conditioned response. The CS cannot elicit a greater response than the one produced by the unconditioned stimulus.

Mechner notation. A notation system that describes the independent variables that produce operant behavior. For example, Mechner notation represents the way that schedules of reinforcement are arranged.

Melioration. An explanation of how organisms come to produce matching on concurrent schedules of reinforcement. In contrast to overall maximizing of reinforcement, Herrnstein (1982) proposed a process of melioration (doing the best at the moment). Organisms, he argued, are sensitive to fluctuations in the momentary rates of reinforcement rather than to long-term changes in overall rates of reinforcement.

Metacontingencies. Contingent relations between cultural practices and the effects of those practices for a group. For example, competence in science is important for people who live in a technologically advanced culture. Scientific research produces a range of benefits for the general society. These include better medicine, more productive crop yields, new and better building materials, more efficient and longer lasting appliances, and superior

regulation of human behavior. Thus, a positive metacontingency exists between educational practices that increase scientific competence and long-term benefits to the group.

Mixed schedule of reinforcement. A mixed schedule is two or more basic schedules (CRF, FR, FI, VI, VR) presented sequentially in which each link ends with primary reinforcement (or in some cases extinction) and the component schedules are not signaled by discriminative stimuli. In other words, a mixed schedule is the same as an unsignaled multiple schedule. See **multiple schedule**.

Molar accounts of schedule performance. Molar accounts of behavior are concerned with large-scale factors that regulate responding over a long period of time—for example, the average time between reinforcers for an entire session.

Molecular accounts of schedule performance. Molecular accounts of behavior focus on small moment-to-moment relationships between behavior and its consequences—for example, the time between any two responses (IRT) or the response–shock interval (R–S).

Multiple baseline across behaviors. A multiple baseline research design across behaviors is used when a reinforcement procedure is applied progressively to several operants. In this case, the subject, setting, and consequences remain the same, but different responses are modified sequentially.

Multiple baseline across stimulus conditions. In this research design, a reinforcement procedure is applied in one situation but is withheld in other settings. When behavior changes in the situation where it is reinforced, the contingency is applied to the same response in another setting.

Multiple baseline across subjects. A research design in which an intervention is introduced progressively for different subjects who exhibit similar target behavior. The same behavior (e.g., stealing) is first modified for subject 1, and baselines are collected for subjects 2 and 3. Next, the behavior of subject 2 is changed while the rate of target behavior for subjects 1 and 3 continues to be assessed. Finally, the treatment procedure is applied to subject 3.

Multiple baseline design. A class of research designs used primarily in applied behavior analysis. See **multiple baseline across behaviors, multiple baseline across stimulus conditions**, and **multiple baseline across subjects**.

Multiple functions of events. A given event such as a student saying "The ball is red" can have several functions in the control of behavior (e.g., $S^r + S^D$). For example, the response can function as reinforcement for a teacher's question "What color is the ball?" and, at the same time, function as a discriminative stimulus for the teacher saying "Yes."

Multiple schedule. A multiple schedule is two or more basic schedules (CRF, FR, FI, VI, VR) presented sequentially in which each link ends with primary reinforcement (or in some cases extinction) and the component schedules are signaled by discriminative stimuli. In other words, a multiple schedule is the same as a chain schedule, but each link produces primary reinforcement. See **chain schedule of reinforcement**.

Natural selection. Differential reproduction of the members of a species and their genetic endowment. Based on a thorough analysis of life forms, Darwin concluded that reproductive success was the underlying basis of evolution. That is, individuals with more offspring pass on a greater number of their characteristics to the next generation.

Negative automaintenance. Birds are autoshaped to peck a key, but in negative automaintenance food is not presented if the bird pecks the key. This is also called an omission procedure or training because food reinforcement is omitted if key pecking occurs.

Negative contrast. See **behavioral contrast**.

Negative punishment. A procedure that involves the removal of an event or stimulus following behavior that has the effect of decreasing the rate of response.

Negative reinforcement. A procedure where a stimulus or event following behavior is removed (or prevented) and the rate of response increases. If the operant increases by

removing an ongoing event or stimulus (shock) the contingency is called *escape*. When the operant increases by preventing the onset of the event or stimulus the contingency is *avoidance*. Both escape and avoidance involve negative reinforcement.

Negative reinforcer. Any event or stimulus that increases the probability (rate of occurrence) of an operant when it is removed (or prevented). See also **negative reinforcement**.

New-response method for conditioned reinforcement. First, a nonreinforcing stimulus is associated with a reinforcing event (sound of feeder is followed by food), and following this the stimulus (sound of feeder) is shown to increase the frequency of some operant behavior.

Nondiscriminated avoidance. A procedure used to train avoidance responding in which no warning stimulus is presented; also called Sidman avoidance. See also **negative reinforcement**.

Observing response. The observing response is a topographically different operant that functions to produce an S^D or S^Δ depending on whether reinforcement or extinction is in effect. In other words, an observing response changes a mixed schedule of reinforcement to a multiple schedule. See **mixed schedule of reinforcement** and **multiple schedule**.

Omission procedure (training). See **negative automaintenance**.

Ontogenetic. Each organism has a unique life history (ontogeny) that contributes to its behavior. Ontogenetic changes in behavior (or learning) are caused by events that occur over the lifetime of an individual. Ontogenetic history builds on species history (phylogeny) to determine when, where, and what kind of behavior will occur at a given moment. See also **phylogenetic**.

Ontogenetic selection. The selection of operant behavior during the lifetime of an organism is ontogenetic selection. The process involves operant variability during periods of extinction and selection by contingencies of reinforcement. An organism that alters its behavior (adaptation) on the basis of changing life experiences, is showing ontogenetic selection. In this ontogenetic form of adaptation, the topography and frequency of behavior increase when reinforcement is withheld (increase in operant variability). These behavioral changes during extinction allow for the selection of behavior by new contingencies of reinforcement. Thus, a wild rat that has been exploiting a compost heap may find that the home owner has covered it. In this case, the rat emits various operants that may eventually uncover the food. The animal may dig under the cover, gnaw a hole in the sheathing, or search for some other means of entry. A similar effect occurs when food in the compost heap is depleted and the animal emits behavior that results in getting to a new food patch. In the laboratory, this behavior is measured as an increase in the topography and frequency of bar pressing as the schedules of reinforcement change.

Operant. An operant is behavior that operates on the environment to produce a change, effect, or consequence. These environmental changes select the operant appropriate to a given setting or circumstance. That is, particular responses increase or decrease in a situation as a function of the consequences they produce. Operant behavior is said to be *emitted* (rather than elicited) in the sense that the behavior may occur at some frequency before any known conditioning.

Operant aggression. Aggressive operant behavior that is reinforced by the removal of an aversive event. See also **negative reinforcement**.

Operant chamber. A laboratory device used to investigate operant conditioning. An operant chamber for a rat is a small, enclosed box that typically contains a lever with a light above it and a food magazine or cup connected to an external feeder. The feeder delivers a small food pellet when electronically activated.

Operant class. A class or set of responses that vary in topography but produce a common environmental consequence or effect.

Operant conditioning. An increase or decrease in operant behavior as a function of the consequences that follow responses.

Operant imitation. Imitative behavior that is a function of its consequences. See **imitation**.

Operant level. The rate of an operant before any known conditioning—for example, the rate of key pecking before a peck-food contingency has been established.

Operant variability. Operant behavior becomes increasingly more variable as extinction proceeds. From an evolutionary view, it makes sense to try different ways of acting when something no longer works. That is, behavioral variation increases the chances that the organisms will reinstate reinforcement or contact other sources of reinforcement.

Operant rate. See **rate of response**.

Overmatching. In the generalized matching equation, a value of *a* greater than 1 indicates that changes in the response ratio (B_a/B_b) are larger than changes in the ratio of reinforcement (R_a/R_b). This outcome occurs because relative behavior increases faster than predicted from relative rate of reinforcement. See also **generalized matching law**.

Overshadowing. This effect occurs when a compound stimulus is used as the CS in a respondent conditioning experiment. For example, a light + tone (CS) may be presented at the same time and be associated with an unconditioned stimulus (US) such as food. The most *salient* property of the compound stimulus comes to regulate exclusively the conditioned response. Thus, if the tone is more salient than the light, only the tone will elicit salivation.

Pain-elicited aggression. Respondent aggression or attack elicited by an aversive event. The same as respondent aggression.

Partial reinforcement effect. See **intermittent reinforcement effect**.

Peak shift. A shift in the peak of a generalization gradient away from an extinction (S^Δ) stimulus. See **generalization gradient (operant)** and **generalization gradient (respondent)**.

Personalized system of instruction (PSI). A college teaching method based on principles of operant conditioning and designed by Fred Keller (Keller, 1968). Keller called his teaching method a personalized system of instruction or PSI. Basically, PSI courses are organized so that students move through the course at their own pace and they are reinforced for completing small course units.

Phenotype. An organism's phenotype refers to anatomical and behavioral characteristics observed during the lifetime of the individual. For example, an individual's size, color, and shape are anatomical aspects of phenotype. Behavioral features include taste preferences, aggressiveness, and shyness. Different phenotypic attributes of individuals may or may not reflect underlying genetic variation.

Phylogenetic. Behavior relations that are based on the genetic endowment of an organism are called phylogenetic and are present on the basis of species history. Behavior that aids survival or procreation is often (but not always) unlearned. This is because past generations of organisms that engaged in such behavior survived and reproduced. These animals passed (to the next generation) the characteristics that allowed similar behavior. Thus, species history provides the organism with a basic repertoire of responses that are elicited by environmental conditions. See also **ontogenetic**.

Phylogeny. The species history of an organism.

Placebo effect. Concerns the effect of an inert substance such as a sugar pill on the "physiological well-being" of a patient. That is, patients treated with sugar pills show improvements relative to a no-treatment control group.

Polydipsia. Polydipsia or excessive drinking is adjunctive behavior induced by the time-based delivery of food. For example, a rat that is working for food on an intermittent

schedule may drink as much as half its body weight during a single session. This drinking occurs even though the animal is not water-deprived. See also **adjunctive behavior**.

Positive contrast. See **behavioral contrast**.

Positive punishment. A procedure that involves the presentation of an event or stimulus following behavior that has the effect of decreasing the rate of response.

Positive reinforcement. A procedure that involves the presentation of an event or stimulus following an operant that has the effect of increasing the rate of response.

Positive reinforcer. A positive reinforcer is any stimulus or event that increases the probability (rate of response) of an operant when presented.

Postreinforcement pause (PRP). The pause in responding that occurs after reinforcement on some intermittent schedules (e.g., FR, FI).

Power law for matching. See **generalized matching law**.

Precision teaching. In what became known as *Precision Teaching*, Ogden Lindsley devised a method of systematic instruction that encouraged students and teachers to target specific behaviors, count, time, and graph them, and revise instructional procedures based on the charted data. The use of the Standard Celeration Chart for graphing change in response rate over days is a prominent feature of this teaching method.

Precurrent behavior. Operant behavior that precedes a current response. Precurrent behavior often functions to establish stimulus control over subsequent operant behavior, as when a person sets the alarm for 6:00 a.m. (precurrent behavior) to ensure stimulus control by the clock over waking up and going to an appointment or job (current behavior). In this example, both the precurrent and current behavior are maintained by the reinforcement contingency (e.g., avoiding the consequences of being late). When precurrent behavior is private, as in thinking about chess moves, the behavior provides S^D control over the actual movement of the chess pieces. Thinking about chess moves and actual moves are maintained by the contingency of reinforcement involving getting a momentary advantage and ultimately winning the game. See **construction of S^Ds**.

Preference. When several schedules of reinforcement are available concurrently, one alternative may be chosen more frequently than others. When this occurs, it is called preference for an alternative source of reinforcement.

Preference reversal. The change in value of a reinforcer as a function of time to the choice point (as in self-control). For example, people make a commitment to save their money rather than spend it because the value of saving is greater than spending when far from the choice point (getting paid). See **Ainslie–Rachlin principle**.

Premack principle. A higher frequency behavior will function as reinforcement for a lower frequency behavior.

Preparedness. Some relations between stimuli, and between stimuli and responses, are more likely because of phylogenetic history. This phenomenon has been called preparedness. For example, a bird that relies on sight for food selection would be expected to associate the appearance of a food item and illness, but rats that select food on the basis of taste quickly make a flavor–illness association.

Preratio Pause. The number of responses required and the size of the reinforcer have both been shown to influence PRP. Calling this pause a "post" reinforcement event accurately locates the pause, but the upcoming requirements are what control it. Hence, many researchers refer to the PRP as a preratio pause. See **postreinforcement pause (PRP)**.

Primary aversive stimulus. An aversive stimulus that has acquired its properties as a function of species history. See **aversive stimulus**.

Primary laws of the reflex. The primary laws of the reflex include (1) the law of the threshold, (2) the law of intensity magnitude, and (3) the law of the latency. These law govern the US $\rightarrow$ UR relationship.

Private behavior. Behavior that is only accessible to the person who emits it (e.g., thinking).

Probability of response. The probability that an operant will occur on a given occasion (measured as rate of response).

Progressive ratio schedule. A schedule where the number of responses for reinforcement increases (or decreases) after each reinforcement. For example, a pigeon on an increasing progressive ratio may be required to make 2 responses for access to food, then 4, 8, 16, 32, and so on. In a foraging model, the increasing progressive ratio schedule simulates a depleting patch of food.

Punisher. A stimulus that decreases the frequency of an operant that produces it.

Punishment. As a procedure, punishment involves following an operant with a punisher. Usually, the operant is maintained by positive reinforcement, so that punishment is superimposed on a baseline of positive reinforcement. Punishment also refers to a decrease in operant behavior when it is followed by a punisher or when reinforcement is withdrawn contingent on responding. See **positive** and **negative punishment**.

Quantitative law of effect. The law states that the absolute rate of response on a schedule of reinforcement is a hyperbolic function of rate of reinforcement on the schedule relative to the total rate of reinforcement, both scheduled and extraneous. That is, as the rate of reinforcement on the schedule increases the rate of response also rises, but eventually further increases in rate of reinforcement produce less and less of an increase in rate of response (hyperbolic). Also, the rise in rate of response with increasing rate of reinforcement is modified by extraneous sources of reinforcement. The greater the extraneous reinforcement the less the increase in rate of response with increasing rate of scheduled reinforcement. One implication is that control of behavior by a schedule of reinforcement is reduced as the sources of extraneous reinforcement increase.

A matching equation is a mathematical expression of quantitative law of effect. The equation relates absolute response and reinforcement rates, using alternative sources of reinforcement as the context. The equation may be derived from a restatement of the proportional matching law and is written as $B_a/(B_a + B_e) = R_a/(R_a + R_e)$. In this equation, B_e refers to all behavior directed to extraneous sources of reinforcement, and R_e represents these sources. The term B_a represents rate of response on the programmed schedule, and R_a is the rate of scheduled reinforcement.

Rate of response (operant rate). The number of responses that occur in a given interval. For example, a bird may peck a key for food two times per second.

Ratio schedules. Response-based schedules of reinforcement. These schedules are set to deliver reinforcement following prescribed a number of responses. The ratio specifies the number of responses for each reinforcer.

Ratio strain. A disruption of responding that occurs when a ratio schedule is increased rapidly. For example, faced with a change in the schedule from CRF to the large FR value, an animal will probably show ratio strain in the sense that it pauses longer and longer after reinforcement. This occurs because the time between successive reinforcements contributes to the postreinforcement pause (PRP). The pause gets longer as the interreinforcement interval (IRI) increases. Because the PRP makes up part of the interval between reinforcements and is controlled by it, the animal eventually stops responding. Thus, there is a negative-feedback loop between increasing PRP length and the time between reinforcements (IRI). See **postreinforcement pause (PRP)** and **interreinforcement interval (IRI)**.

Reaction chains. Reaction chains are phylogenetic sequences of behavior. An environmental stimulus sets off behavior that produces stimuli that set off the next set of responses in the sequence; these behaviors produce the next set of stimuli and so on. Presenting stimuli that prompt responses ordinarily occurring in the middle part of the sequence

will start the chain at that point rather than at the beginning. Reaction chains are much like consecutive sets of reflexes where the stimulus that elicits the next response in the sequence is produced by the previous reflex.

Reactive measurement. Reactive measurement limits the generality of a treatment (or intervention) to situations where the dependent variable is being measured or counted. For example, a person in a weight-control program (treatment) may lose weight just because he or she is weighed daily by a researcher. Daily weighing may focus attention on being overweight, and the program is only effective under these conditions. See **external validity**.

Reflex. When an unconditioned stimulus elicits an unconditioned response (US → UR), the relationship is called a reflex.

Reflexivity. A one-to-one relationship (A = A) between stimuli. For example, a pigeon is presented with the color red on a sample key and the bird responds to a comparison key with the identical color (red). A child who is given a picture of a cat and then finds a similar picture in a set of photographs is showing reflexivity.

Reinforcement. An increase in the rate of operant behavior as a function of its consequences. Also, the procedure of presenting a reinforcing event when a response occurs.

Reinforcement function. Any event (or stimulus) that follows a response and increases its frequency is said to have a reinforcement function. If an infant's babbling increases due to touching by the mother, we can say that maternal touching has a reinforcement function.

Relative rate of reinforcement. When two or more sources of reinforcement are available (as on a concurrent schedule), relative rate of reinforcement refers to reinforcement delivered on one alternative divided by the sum of all alternatives. Relative rate of reinforcement is a measure of the distribution of reinforcement between or among alternatives.

Relative rate of response. When two or more sources of reinforcement are available (as on a concurrent schedule), relative rate of response refers to rate of response on one alternative divided by the sum of the rates on all alternatives. Relative rate of response is a measure of the distribution of behavior between or among alternative sources of reinforcement.

Relative stimulus control. Relative stimulus control means that an organism responds to differences among the values of two or more stimuli. For example, a pigeon may be trained to peck in response to the presence of the larger of two triangles rather than to the absolute size of a triangle. See also **absolute stimulus control**.

Relativity of punishment. The Premack principle states that a lower frequency operant will punish a higher frequency behavior. For example, when wheel running is a lower frequency operant, drinking is punished when followed by wheel running. In contrast, drinking is reinforced by wheel running when running in a wheel is a higher frequency operant. We cannot make an absolute statement about whether wheel running is a punisher or a reinforcer.

Reliability of observation. In applied behavior analysis, reliability of observation involves the amount of agreement among observers who independently record the same behavior. One way to assess reliability is to count the number of times two observers agree that a target behavior did (or did not) occur. This can be expressed as a percentage of agreement that varies from 0 to 100%. Generally, applied behavior analysts strive for reliability of greater than 80% agreement.

Remembering. The verb remembering (or forgetting) is used to refer to the effect of some event on behavior after the passage of time (as opposed to the noun "memory," which seems to refer to something stored in the brain).

Repertoire. All the behavior an organism is capable of emitting on the basis of species and environmental history.

Replication of results. Replication of results is used to enhance both internal and external validity of an experiment. If results replicate over time and place, it is likely that the

original findings were due to the experimental variable and not due to extraneous conditions (internal validity). Replication also establishes that the findings have generality in the sense that the effects are not limited to specific procedures, behaviors, or species (external validity). See also **direct** and **systematic replication**.

Rescorla–Wagner model. The basic idea of the Rescorla–Wagner model of respondent conditioning is that a conditioned stimulus acquires a limited amount of associative strength on any one trial. The term associative strength describes the relation between the CS and the magnitude of the conditioned response. In general, associative strength increases over conditioning trials and reaches some maximum level. A given CS can acquire only so much control over a conditioned response. This is the maximum associative strength for the CS. Thus, a tone (CS) that is paired with 1 gram of food will have maximum associative strength when the amount of conditioned salivation (CR) is about the same as the unconditioned salivation (UR) elicited by the gram of food (US). This magnitude sets the upper limit for the conditioned response. The CS cannot elicit a greater response than the one produced by the unconditioned stimulus.

Resistance to extinction. The perseverance of operant behavior when it is placed on extinction. Resistance to extinction is substantially increased when an intermittent schedule of reinforcement has been used to maintain behavior. See **partial reinforcement effect**.

Respondent. A respondent is behavior that increases or decreases by the presentation of a conditioned stimulus (CS) that *precedes* the response (CR). We say that the presentation of the CS regulates or controls the respondent (CR). Respondent behavior is said to be elicited, in the sense that it reliably occurs when the CS is presented. The notation system used with elicited behavior is CS → CR. The CS causes (arrow) the CR.

Respondent acquisition. The procedure of repeatedly pairing a CS with an US over trials and the increase in magnitude of the conditioned response (CR).

Respondent aggression. Aggression elicited by the presentation of an aversive stimulus or event. The same as pain-elicited aggression.

Respondent conditioning. Respondent conditioning occurs when an organism responds to a new event based on a history of association with a biologically important stimulus. The Russian physiologist Ivan Pavlov discovered this form of conditioning at the turn of the century. He showed that dogs salivated when food was placed in their mouths. This relation between the food stimulus and salivation is called a reflex and occurs because of the animal's biological history. When Pavlov rang a bell just before feeding the dog, it began to salivate at the sound of the bell. In this way, new features (sound of bell) controlled the dog's respondent behavior (salivation). Thus, presenting stimuli together in time (typically CS then US) is the procedure for respondent conditioning. If a CS comes to regulate the occurrence of a conditioned response (CR), respondent conditioning has occurred.

Respondent discrimination. Respondent discrimination occurs when an organism shows a conditioned response to one stimulus but not to other similar events. A discrimination procedure involves positive and negative conditioning trials. For example, a positive trial occurs when a CS$^+$ such as a 60-dB tone is associated with an unconditioned stimulus like food. On negative trials, a 40-dB tone is presented (CS$^-$) but never paired with food. Once a differential response occurs (salivation to 60 dB but not to 40), we may say that the organism discriminates between the tones.

Respondent extinction. The procedure of respondent extinction involves the presentation of the CS without the US after conditioning has occurred. As a behavioral process, extinction refers to a decline in the strength of the conditioned response when an extinction procedure is in effect. In both instances, the term extinction is used correctly.

Respondent generalization. Respondent generalization occurs when an organism shows a conditioned response to values of the CS that have not been trained. For example, if a

tone of 375 Hz is paired with food, a dog will salivate at maximum level when this tone is presented. However, the animal may salivate to other values of the tone. As the tone differs more and more from 375 Hz, the CR decreases in magnitude.

Respondent level. The magnitude of the CR to the presentation of the CS before any known conditioning has taken place. For example, the amount of salivation (CR) to a tone (CS) before the tone has been paired with food in the mouth (usually no salivation).

Response class. A response class refers to all the forms of a performance that have a similar function (e.g., putting on a coat to keep warm). In some cases, the responses in a class have close physical resemblance, but this is not always the case. For example, saying "Please open the door" and physically opening the door are members of the same response class if both result in an open door.

Response differentiation. A property of operant behavior can be differentiated by making reinforcement contingent on that property (differential reinforcement). For example, the force or magnitude of response can be differentiated; if the contingencies of reinforcement require a forceful response in a particular situation then that form of response will occur. In another example, when reinforcement is based on short interresponse times or IRTs (2–5 s) the distribution of IRTs becomes centered around short intervals. Changing the contingencies to reinforce longer IRTs (20–25 s) produces a new distribution centered around long intervals. See **differential reinforcement**.

Response–shock interval (R–S). On an avoidance schedule, the time from a response that postpones shock to the onset of the aversive stimulus, assuming another response does not occur.

Rule-governed behavior. The effects of verbal stimuli or contingency-specifying stimuli on a listener's behavior. When instructions, rules, advice, maxims, and laws regulate operant behavior, the behavior is said to be rule-governed. Control by instructions can make operant behavior insensitive to the operating contingencies of reinforcement.

Run of responses. A fast burst of responding. For example, after the postreinforcement pause on a fixed-ratio schedule, an organism will rapidly emit the responses required by the ratio.

Resurgence. The increase in topographic variablility during extinction after a period of reinforcement is referred to as resurgence.

Salience. The symbol S in the Rescorla–Wagner equation is a constant that varies between 0 and 1 and may be interpreted as the salience (e.g., dim light versus bright light) of the CS based on the sensory capacities of the organism. The constant S (salience) is estimated after conditioning and determines how quickly the associative strength of the CS rises to maximum. That is, a larger salience coefficient makes the associative strength of the CS rise more quickly to its maximum.

S-delta (S^Δ). When an operant does not produce reinforcement, the stimulus that precedes the operant is called an S-delta (S^Δ). In the presence of an S-delta, the probability of emitting an operant declines. See **extinction stimulus**.

S-S account of conditioned reinforcement. The hypothesis that it is necessary for a stimulus to be paired with a primary reinforcer in order for it to become a conditioned reinforcer. The hypothesis has been largely discounted, and the weight of the evidence supports Edmond Fantino's (1969b) delay-reduction hypothesis. See **delay-reduction hypothesis**.

Satiation. Repeated presentations of a reinforcer weaken its effectiveness, and for this reason rate of response declines. Satiation refers to this effect, and the repeated presentation of a reinforcer is called a satiation operation.

Scalloping. The characteristic pattern of response, seen on a cumulative record, that is produced by a fixed-interval schedule. There is a pause after reinforcement, then a few probe responses, and finally an increasingly accelerated rate of response until reinforcement.

Schedule of reinforcement. In relation to responses, a schedule of reinforcement is the arrangement of the environment in terms of discriminative stimuli and behavioral consequences.

Schedule-induced behavior. See **adjunctive behavior**.

Science of behavior. See **behavior analysis**.

Second-order conditioning. Second-order conditioning pairs two CSs ($CS_1 + CS_2$), rather than pairing a CS and US (CS + US). Pavlov (1960; originally published 1927) conducted experiments that demonstrated second-order conditioning. The tick of a metronome was paired with food. The sound of the metronome came to elicit salivation. Once the ticking sound reliably elicited salivation, Pavlov paired it with the sight of a black square ($CS_1 + CS_2$). Following several pairings of the metronome beat with the black square, the sight of the black square elicited salivation.

Selection by consequences. The causative principle for biology, behavior, and culture is selection by consequences. With regard to biology, mutation and sexual reproduction ensure a range of variation in genes that code for the features of organisms. Some physical attributes meet the requirements of the environment. Organisms with these adaptive features survive and reproduce, passing their genetic material to the next generation. Organisms without these characteristics do not survive as well and their genes are less represented in the subsequent population. Natural selection is therefore a form of selection by reproductive consequences that occurs at the biological level.

   Selection by consequences has been extended to the level of behavior. Operant behavior is an expressed characteristic of many organisms, including humans. Organisms with an extensive range of operant behavior adjust to new environmental situations on the basis of the consequences that follow behavior. This kind of selection occurs over the life of the individual. Operant responses are the units selected at the behavioral level. The process of the selection and change of operant behavior is analogous to evolution and natural selection at the genetic level. Reinforcement is therefore an ontogenetic process that extends selection by consequences to the level of behavior.

   A third level of evolution and selection occurs at the cultural level. The unit of selection at this level is the cultural practice. A cultural practice involves the interlocking operant behavior of many people. As with operant behavior, cultural practices vary in form and frequency. Different ways of doing things are more or less successful in terms of efficiency, productivity, and survival of group members. Generally, cultural practices are selected by aggregate outcomes, increasing or decreasing the rate of adoption of the practice.

Self-control behavior. From a behavioral perspective, self-control occurs when a person emits a response that affects the probability of subsequent behavior in the following way: giving up immediate gains for greater long-term benefits or accepting immediate negative consequences for later positive outcomes. When people (and other organisms) manage their behavior in such a way that they choose the more beneficial long-range consequences, they are said to show self-control.

Sensory preconditioning. In respondent compound conditioning, two stimuli such as light and tone are repeatedly presented together (light + tone) without the occurrence of a US (preconditioning). Later, one of these stimuli (CS_1) is paired with an unconditioned stimulus (US) and the other stimulus (CS_2) is tested for conditioning. Even though the second stimulus (CS_2) has never been directly associated with the US, it comes to elicit the conditioned response (CR).

Shaping. The method of successive approximation or shaping may be used to establish a response. This method involves the reinforcement of closer and closer approximations to the final performance. For example, a rat may be reinforced for standing in the vicinity of a lever. Once the animal is reliably facing the lever, a movement of the head toward

the bar is reinforced. Next, closer and closer approximations to pressing the lever are reinforced. Each step of the procedure involves reinforcement of closer approximations and nonreinforcement of more distant responses. Many novel forms of behavior may be shaped by the method of successive approximation.

Shock–shock interval (S–S). The scheduled time between shocks on an avoidance schedule.

Sign tracking. Sign tracking refers to approaching a sign (or stimulus) that signals a biologically relevant event. For example, dogs are required to sit on a mat and a stimulus that signals food is presented to the animal. When the food signal is presented, the dogs approach the stimulus and make food-soliciting responses to it.

Simultaneous conditioning. A respondent conditioning procedure in which the CS and US are presented at the same moment. Compared with delayed conditioning, simultaneous conditioning produces a weaker conditioned response (CR).

Simultaneous discrimination. In simultaneous discrimination, the S^D and S^Δ are presented at the same time and the organism is reinforced for responding to the relative properties of one or the other. For example, a pigeon may be presented with two keys, both illuminated with white lights, but one light is brighter than the other. The bird is reinforced for pecking the dimmer of the two keys. Pecks to the other key are placed on extinction. After training, the pigeon will peck the darker of any two keys. See also **relative stimulus control**.

Single-subject research. Experimental research that is concerned with discovering principles and conditions that govern the behavior of single or individual organisms. Each individual's behavior is studied to assess the impact of a given experimental variable. In behavioral research, a change in the contingencies of reinforcement is assessed for each bird, rat, or human (e.g., changing the schedule of reinforcement, the operant, or the discriminative stimuli).

Social disruption. A negative side effect of punishment in which the person who delivers punishment and the context become conditioned aversive stimuli. Individuals will attempt to escape from or avoid the punishing person or setting.

Spontaneous imitation. Imitation based on evolution and natural selection (a characteristic of the species) rather than experiences during the lifetime of the individual. See **imitation** and **generalized imitation**.

Spontaneous recovery (operant). After a period of extinction, an organism's rate of response may be close to operant level. After some time, the organism is again placed in the setting and extinction is continued. Responding initially recovers, but over repeated sessions of extinction the amount of recovery decreases. Repeated sessions of extinction eliminate stimulus control by extraneous features of the situation and eventually "being placed in the setting" no longer occasions the operant.

Spontaneous recovery (respondent). An increase in the magnitude of a CR after respondent extinction has occurred and after some time has passed. A behavioral analysis of spontaneous recovery suggests that the CS–CR relation is weakened by extinction, but the context or features of the situation maintain some level of the conditioned response. During respondent conditioning, many stimuli not specified by the researcher as the CS, but present in the experimental situation, come to regulate behavior.

Steady-state performance. Behavior that is stable in the sense that it does not change over time. For example, after transition from CRF to VI 30 s, a rat may press a lever at approximately the same rate day after day.

Stimulus class. Stimuli that vary across physical dimensions but have a common effect on behavior belong to the same stimulus class.

Stimulus control. A change in operant behavior that occurs when either an S^D or an S^Δ is presented. When an S^D is presented, the probability of response increases; and when an S^Δ is given, operant behavior has a low probability of occurrence.

Stimulus equivalence. The presentation of one class of stimuli (e.g., flags) occasions responses made to other stimulus classes (e.g., countries). This seems to be what we mean when we say that the flag stands for, represents, or signifies the country. Equivalence relations such as these are an important aspect of human behavior. For example, in teaching a child to read, spoken words (names of animals) are trained to visual stimuli (pictures of animals) and then to written symbols (written words for animals). Eventually, the written word is said to stand for the actual object, in the same sense that a flag stands for a country.

Stimulus function. When the occurrence of an event changes the behavior of an organism, we may say that the event has a stimulus function. Both respondent and operant conditioning are ways to create stimulus functions. During respondent conditioning, an arbitrary event like a tone comes to elicit a particular response, like salivation. Once the tone is effective, it is said to have a conditioned-stimulus function for salivation. In the absence of a conditioning history, the tone may have no specified function and does not affect the specified behavior.

Stimulus generalization. Stimulus generalization occurs when an operant that has been reinforced in the presence of a specific discriminative stimulus also is emitted in the presence of other stimuli. The process is called stimulus generalization because the operant is emitted to new stimuli that presumably share common properties with the discriminative stimulus.

Stimulus substitution. When a CS (e.g., light) is paired with an US (e.g., food) the conditioned stimulus is said to substitute for the unconditioned stimulus. That is, food elicits salivation and by conditioning the light elicits similar behavior.

Structural approach to classifying behavior. In the structural approach, behavior is analyzed in terms of its form or topography. For example, many developmental psychologists are interested in the intellectual growth of children. These researchers often investigate what a person does at a given stage of development. The structure of behavior is emphasized because it is said to reveal the underlying stage of intellectual development. See also **functional analysis of behavior**.

Successive approximation. See **shaping**.

Successive discrimination. A procedure used to train differential responding. The researcher arranges the presentation of S^D and S^Δ so that one follows the other. For example, a multiple schedule is programmed such that a red light signals VI food reinforcement, and this is followed by a green light that indicates that extinction is in effect.

Superstitious behavior. Behavior that is accidentally reinforced. For example, a parent may inadvertently strengthen aggressive behavior when a child is given his or her allowance just after fighting with a playmate. Switching from one alternative to another may be accidentally reinforced on a concurrent schedule if the alternative schedule has a reinforcement setup. In this case, the organism is accidentally reinforced for a change from one schedule to another.

Symbolic matching. In a matching-to-sample task, symbolic matching involves the presentation of one class of stimuli as the sample (e.g., geometrical forms) and another set of stimuli (e.g., different line angles) as the comparisons. Reinforcement depends on an arbitrary relation (e.g., triangle = vertical).

Symmetry. When stimulus class A is shown to be interchangeable with stimulus class B (if A = B then B = A), we may say that the organism shows symmetry between the stimulus classes. After a form-to-angle discrimination (e.g., triangle = vertical) is trained, a reversal test is conducted without reinforcement using line angles as the sample and

geometric shapes as the comparisons (e.g., vertical = triangle). An organism that passes the reversal test is said to demonstrate symmetry of angles and forms.

Systematic replication. A way to increase the generality of an experimental finding by conducting other experiments in which the procedures are different but are logically related to the original research. An experiment is conducted with rats to find out what happens when food pellets are presented contingent on lever pressing. The observation is that lever pressing increases when followed by food pellets. In a systematic replication, elephants step on a treadle to produce peanuts. The observation is that treadle pressing increases. Both experiments are said to show the effects of positive reinforcement contingencies on operant behavior. See also **direct replication**.

Tacting. A class of verbal operants whose form is regulated by specific nonverbal discriminative stimuli. For example, a child may see a cat and say, "kitty." The word tact comes from the more familiar term *contact*. Tacting is verbal behavior that makes contact with the environment.

Tandem schedule. A tandem schedule is two or more basic schedules (CRF, FR, FI, VI, VR) presented sequentially in which only the final link ends with primary reinforcement (or in some cases extinction) and the component schedules are not signaled by discriminative stimuli. In other words, a tandem schedule is the same as an unsignaled chain schedule.

Taste aversion learning. When a distinctive taste (e.g., flavored liquid) is paired with nausea or sickness induced by a drug, X-ray, or even physical activity, the organism shows suppression of intake of the paired flavor.

Temporal pairing. In respondent conditioning, the pairing of the CS and US in time.

Terminal behavior. On a schedule of reinforcement, as the time for reinforcement gets close, animals engage in activities related to the presentation of the reinforcer. For example, a rat will orient toward the food cup.

Textual beahvior. A class of verbal operants regulated by verbal stimuli where there is correspondence between the stimulus and response, but no topographical similarity. The most common example of textual behavior is reading out loud. The child looks at the text SEE DICK, SEE JANE and emits the spoken words "See Dick, see Jane." The stimulus and response correspond, but the stimulus is visual and the response is vocal.

Time sampling. A method of recording used mostly in applied behavior analysis. Behavior is sampled over a long time scale. The idea is to make observations at specified times throughout the day. For example, a patient on a psychiatric ward may be observed every 30 min, as a nurse does the rounds, and instances of psychotic talk may be recorded.

Token economy. A reinforcement system based on token reinforcement; the contingencies specify when, and under what conditions, particular forms of behavior are reinforced. The system is an economy in the sense that tokens may be exchanged for goods and services, much like money is in our economy. This exchange of tokens for a variety of back-up reinforcers ensures that the tokens are conditioned reinforcers. Token economies have been used to improve the behavior of psychiatric patients, juvenile delinquents, pupils in remedial classrooms, medical patients, alcoholics, drug addicts, prisoners, nursing home residents, and retarded persons.

Tolerance. When more of a drug (US) is needed to obtain the same drug effects (UR), we talk about drug tolerance. In respondent conditioning, the counteractive effects to CSs are major components of drug tolerance.

Topography. The physical form or characteristics of the response. For example, the way that a rat presses a lever with the left paw, the hind right foot, and so on. The topography of response is related to the contingencies of reinforcement in the sense that the form of response can be broadened or restricted by the contingencies. The contingency of reinforcement may require only responses with the left paw rather than any response that

activates the microswitch–under theses conditions left paw responses will predominate. Generally, topography is a function of the contingencies of reinforcement.

Total behavioral output. To solve the matching equation for the absolute rate of response (B_a), it is important to recognize that $B_a + B_e$ is equal to the total behavioral output for a given situation. Because B_a represents lever pressing and B_e represents all other activity, the sum must equal all the behavior of the animal in the experimental setting. It is convenient to express this sum as the value k or the total behavioral output. The quantity k may now be substituted into the matching equation

$$B_a/k = R_a/(R_a + R_e).$$

When each side of the equation is multiplied by k, the absolute response rate (B_a) is expressed as

$$B_a = k(R_a)/(R_a + R_e).$$

In this equation, rate of response rises as a hyperbolic function of the rate of reinforcement (R_a) and rate of extraneous reinforcement (R_e); the value k sets the limit or maximum on this function. See **quantitative law of effect**.

Trace conditioning. A respondent conditioning procedure in which the CS is presented for a brief period, and after some time the US occurs. Generally, as the time between the CS and US increases, the conditioned response becomes weaker. When compared to delayed conditioning, trace conditioning is not as effective.

Transition-state performance. Behavior that is changing from one state to another as a function of a change in contingencies of reinforcement. For example, when CRF contingencies are changed to FR 10, responding is at first erratic but eventually stabilizes. See also **steady-state performance**.

Transitivity. When stimulus A = stimulus B and B = stimulus C, if an organism responds to stimulus A as equal to stimulus C, it is said to show transitivity. For example, if the written numbers one, two, three are equivalent to the arithmetic numbers 1, 2, and 3, the words and these arithmetic numbers are equivalent to sets {X}, {X,X}, and {X,X,X}, it logically follows that one, two, and three are equivalent to sets {X}, {X,X}, and {X,X,X} and the relationship is transitive. An organism is said to show transitivity when it passes tests for transitivity after training for symbolic matching of stimulus class A (angles) to stimulus class B (geometric forms) and B (geometric forms) to C (intensity of illumination).

Trend, as in baseline drift. A trend is a systematic decline or rise in the baseline values of the dependent variable. A drift in baseline measures can be problematic when the treatment is expected to produce a change in the same direction as the trend.

Trial-and-error learning. A term coined by Thorndike (1898, 1911) that he used to describe results from his puzzle box and maze learning experiments. Animals were said to make fewer and fewer errors over repeated trials, learning by trial and error.

Two-key procedure. On a concurrent schedule of reinforcement, the alternative schedules are presented on separate response keys.

Unconditioned reinforcer. A reinforcing stimulus that has acquired its properties as a function of species history.

Unconditioned response (UR). All organisms are born with a set of reflexes (US → UR). These relationships are invariant and biologically based. The behavior elicited by the US is called the unconditioned response (UR).

Unconditioned stimulus (US). All organisms are born with a set of reflexes (US → UR). These relationships are invariant and biologically based. The eliciting event is called the unconditioned stimulus (US).

Undermatching. In the generalized matching equation, the exponent *a* takes on a value less than 1. This result is described as undermatching and occurs when changes in the response ratio are less than changes in the reinforcement ratio. See also **generalized matching law**.

Variable interval (VI). A schedule of reinforcement in which one response is reinforced after a variable amount of time has passed. For example, on a VI 30-s schedule, the time to each reinforcement changes but the average time is 30 s.

Variable ratio (VR). A response-based schedule of reinforcement in which the number of responses required for reinforcement changes after each reinforcer is presented. The average number of responses is used to index the schedule. For example, a rat may press a lever for reinforcement 50 times, then 150, 70, 30, and 200. Adding these response requirements for a total of 500, then dividing by the number of separate response runs (5), yields the schedule value, VR 100.

Verbal behavior. Verbal behavior refers to the vocal, written, and gestural performances of a speaker, writer, or communicator. This behavior operates on the listener, reader, or observer, who arranges for reinforcement of the verbal performance. Verbal behavior often has indirect affects on the environment. This contrasts with nonverbal behavior, which usually results in direct and automatic consequences. When you walk toward an object, you come closer to it. Verbal behavior, on the other hand, works through its affects on other people. To change the position of a lamp, the speaker states "Lift the lamp at the back of the room" to a listener, who is inclined to respond. Although verbal behavior is usually equated with speaking, vocal responses are only one of its forms. For example, a person may emit gestures and body movements that indirectly operate on the environment through their effects on others. A frown sets the occasion for others to remove some aversive event, while a smile may signal the observer to behave in ways that produce positive reinforcement.

Verbal community. The contingencies that regulate verbal behavior arise from the practices of people in the verbal community. The verbal community refers to the customary ways that people reinforce the behavior of the speaker.

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