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BASIC AND APPLIED RESEARCH ON CHOICE RESPONDING

WAYNE W. FISHER

KENNEDY KRIEGER INSTITUTE AND
JOHNS HOPKINS UNIVERSITY SCHOOL OF MEDICINE

AND

JAMES E. MAZUR

SOUTHERN CONNECTICUT STATE UNIVERSITY

Choice responding refers to the manner in which individuals allocate their time or responding among available response options. In this article, we first review basic investigations that have identified and examined variables that influence choice responding, such as response effort and reinforcement rate, immediacy, and quality. We then describe recent bridge and applied studies that illustrate how the results of basic research on choice responding can help to account for human behavior in natural environments and improve clinical assessments and interventions.

DESCRIPTORS: basic research, choice, matching theory, concurrent schedules

How one response is affected by consequences associated with concurrently available responses has been the topic of a considerable amount of basic behavior analysis research over the last few decades (see Williams, 1994 for a review). In addition, a number of discussion articles have been written on the potential applied significance of basic laboratory research on choice responding and the related theoretical accounts, most notably matching theory (e.g., McDowell, 1988, 1989; Meyerson & Hale, 1984; Pierce & Epling, 1995). Articles on this topic published in the 1980s had but a few available exemplars of clinical investigations that used the matching equation to account for, assess, or treat aberrant behavior (e.g., Carr & McDowell, 1980; Conger & Killeen, 1974; Martens & Houk, 1989). Since that time, however, the number of studies that have examined matching phenomena or choice responding with human participants in more natural settings has steadily increased. The primary goals of the current article are to describe and discuss (a) the variables that affect choice responding under laboratory and natural conditions with both nonhumans and humans, (b) the application of choice methods to the identification and assessment of reinforcers among individuals with developmental disabilities, and (c) the application of choice methods to analyzing and improving the effects of clinical interventions designed to reduce problem behavior. Before discussing the basic and applied studies on choice responding, it may be helpful to briefly describe how we categorized those investigations.

CATEGORIZING STUDIES ALONG THE BASIC–APPLIED CONTINUUM

Behavior-analytic investigations on choice responding and other phenomena vary along

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Requests for reprints should be addressed to Wayne W. Fisher, Neurobehavioral Unit, Kennedy Krieger Institute, 707 N. Broadway, Baltimore, Maryland 21205.

a continuum from basic to applied studies (for discussion of the basic–applied continuum, see Hake, 1982; Wacker, 1996). For heuristic purposes, it may be useful to segment that continuum into three broad categories: basic, applied, and bridge studies. A basic investigation on choice responding is one in which the primary goal is to elucidate the variables that determine how individuals allocate their responding or time across available options. By contrast, an applied investigation on choice responding is one in which the primary goal is to employ the principles derived from (or methods used in) basic investigations on choice to achieve a better clinical outcome (e.g., to identify more potent reinforcers or to produce more rapid or complete reductions in aberrant behavior). Finally, a bridge study is one in which the primary goal is to determine the extent to which the variables that affect choice responding under laboratory conditions in basic research operate in a similar manner with either clinical or normal populations under more naturalistic conditions.

Basic and applied studies are important because they improve our understanding of behavioral phenomena and help to solve real human problems, respectively. Bridge studies are also important because they help to determine the extent to which the behavioral phenomena observed in laboratory experiments (and the resultant explanations of those phenomena) also occur in and are applicable to natural human environments. Bridge studies that replicate laboratory findings may reveal novel and potentially useful applications of basic principles (e.g., Neef, Shade, & Miller, 1994). In addition, bridge studies that fail to replicate findings from basic research may raise new and important questions that could be a focus of subsequent laboratory research (Wacker, 1996). In the remainder of this article, we discuss the major findings from laboratory research on matching and choice responding and the related applied and bridge studies that illustrate how the results of basic research can help to account for human behavior in natural environments.

VARIABLES THAT INFLUENCE CHOICE RESPONDING IN BASIC INVESTIGATIONS

Studying Choice and Preference Using Concurrent-Operants Arrangements

The variables that influence choice responding are generally studied in a concurrent-operants arrangement in which two or more responses are simultaneously available (e.g., two keys in an operant chamber) and each is correlated with an independent schedule of reinforcement. One advantage of a concurrent arrangement is that it allows the experimenter to evaluate how manipulations of the three-term contingency (usually of the consequence) for one response affects the probability of other concurrently available responses. Said another way, a concurrent arrangement allows the experimenter to study choice (i.e., whether and why an individual emits one response over one or more alternatives at a given point in time). This has obvious significance to clinical behavior analysis because there are almost always multiple response options available to individuals in natural human environments.

A second advantage of a concurrent-operants arrangement (over a single-operant arrangement) is that it provides a much more sensitive method of assessing an individual's preference for one reinforcer over another. That is, when two reinforcers are concurrently available, the individual must choose between them. By contrast, when two reinforcers are compared using a single-operant arrangement, each one is available at different points in time, and thus the individual is not required to choose between them.

In a concurrent arrangement, two reinforcers are in direct competition, and individuals allocate or distribute their responding in accordance with how much they value each reinforcer. That is, choice responding provides an excellent measure of an individual's preferences for concurrently available reinforcers. An individual's preference for a given reinforcer is determined by how much responding is allocated to that reinforcer relative to the amount of responding allocated to other available reinforcers, a measure called relative response rate. That is, the relative rate of a response is its rate in proportion to the other concurrently available responses (e.g., the rate of Response A divided by the combined rate of Responses A and B in a two-operant arrangement). By contrast, the absolute rate of a response is its frequency (e.g., number per session) divided by some unit of time (e.g., the number of minutes in the session).

A clear preference for one reinforcer over another may be identified through differences in relative response rates observed in a concurrent arrangement, even when the two consequences produce equal absolute response rates in a single-operant arrangement. In general, relative response rate is a more sensitive measure of preference than is absolute response rate. For example, suppose that an individual with developmental disabilities did piecework in a sheltered workshop. On Mondays the individual could sort nuts for Company A, who paid 6 cents per bag; on Tuesdays the individual could sort nuts for Company B, who paid 7 cents per bag; and on Wednesdays the individual could sort for either Company A or B, or do some amount of both. A comparison of the work rates on Mondays and Tuesdays represents a single-operant arrangement (i.e., one response option and reinforcer was available on each day). A comparison of the work rates for Company A (6 cents per bag) and Company B (7 cents per bag) on Wednesdays, when both response options and corresponding reinforcers were simultaneously available, represents a concurrent-operants arrangement. The work rates on Mondays (6 cents per bag) and Tuesdays (7 cents per bag) might be similar, which would lead to the conclusion that the individual values each of the two consequences (6 or 7 cents per bag) about the same. However, a comparison of the work rates for Company A (6 cents) and Company B (7 cents) on Wednesdays, when both consequences were concurrently available, might clearly show that the individual preferred to earn 7 cents per bag rather than 6 cents per bag. This example is analogous to laboratory studies with both nonhuman and human participants that typically have found exclusive preference for the "better" of two concurrent ratio schedules (e.g., Herrnstein & Loveland, 1975; Shah, Bradshaw, & Szabadi, 1989).

Most basic investigations on choice responding have focused on how an individual's allocation of responding is affected by variables like response effort and reinforcement rate, magnitude, quality, and immediacy. In some cases, manipulations of these response and reinforcement parameters produce a phenomenon called matching, where response allocation matches the rate of reinforcement obtained from each available response option. In other cases, changes in these variables produce deviations from matching.

Matching Between Rate of Responding and Reinforcement

In basic investigations in which two or more responses are each correlated with independent reinforcement schedules, the rate or amount of reinforcement available on each schedule is often different (e.g., a variable-interval [VI] 30-s schedule for Response A and a VI 60-s schedule for Response B). When two concurrent VI schedules are in effect, individuals usually switch back and forth between the two schedules, emitting one of the responses for a while and then the other (e.g., Herrnstein, 1961). Only by frequently switching between the alternatives can an individual obtain all or almost all of the reinforcers available from both VI schedules. Over time (e.g., over several sessions), individuals often learn to distribute their responding such that the relative rate of a response will approximately equal its relative rate of reinforcement (e.g., with concurrent VI 30-s VI 60-s schedules, two thirds of the responses and reinforcers will occur on the VI 30-s schedule and one third of responses and reinforcers will occur on the VI 60-s schedule). The distribution of responding in proportion to the amount of reinforcement obtained from each response option during concurrent arrangements is called matching (Herrnstein, 1961).

When two concurrent-ratio schedules are in effect (e.g., a variable-ratio [VR] 100 for Response A and a VR 20 for Response B), there is no benefit to switching back and forth between the two response options. Over time, individuals typically learn to allocate all or almost all of their responding to the schedule that produces a higher rate of reinforcement (e.g., the VR 20 schedule). The matching equation holds for VR schedules, because when an individual learns to respond exclusively on the denser schedule, all responding is allocated to and all reinforcement is obtained from this schedule.

Deviations from Matching in Symmetrical and Asymmetrical Arrangements

Baum (1974, 1979) described three ways in which relative response rates may deviate from the predictions of the matching equation, which he called overmatching, undermatching, and bias.

Overmatching. The term *overmatching* is used to describe situations, like those observed by Baum (1982), in which the relative rate of the more frequent response is consistently greater than its relative rate of reinforcement (e.g., Response A accounts for 70% of responding but produces 60% of the reinforcers; Response B accounts for 30% of responding but produces 40% of the reinforcers). Overmatching occurs when relative response rates (Response A, 70%; Response B, 30%) are further away from the midpoint (50%) than are the corresponding relative reinforcement rates (Reinforcer A, 60%; Reinforcer B, 40%). Overmatching is sometimes observed when there is a substantial penalty for switching between alternatives. For example, Baum (1982) found that pigeons allocated increasingly more responding to the denser of two VI schedules than would be predicted by the matching equation as the response effort involved in switching between the two schedules was increased (by placing a barrier and hurdle between the two response keys).

Undermatching. Although overmatching is observed occasionally in basic investigations, undermatching is considerably more common. Undermatching describes situations in which the relative rate of the more frequent response is consistently lower than its relative rate of reinforcement (e.g., Response A accounts for 60% of responding but produces 70% of the reinforcers; Response B accounts for 40% of responding but produces 30% of the reinforcers). Undermatching occurs when relative response rates (Response A, 60%; Response B, 40%) are closer to the midpoint (50%) than are the corresponding relative reinforcement rates (Reinforcer A, 70%; Reinforcer B, 30%). One common explanation for undermatching is that individuals switch back and forth more frequently than would be predicted by matching because switching may be reinforced accidentally. This explanation is supported by the finding that undermatching can be reduced by including a changeover delay (COD), which prevents reinforcement until a fixed amount of time has elapsed after a switch from one response to the other.

CODs are therefore included in most laboratory studies with concurrent VI schedules.

Bias. The term *bias* is used to describe situations in which the individual consistently emits one response more than would be predicted by simple matching (e.g., 70% of responding occurs on the right key when it produces 60% of the reinforcers, whereas 50% of responding occurs on the left key when it produces 60% of the reinforcers). For example, Baum and Rachlin (1969) found that the pigeons in their study had a consistent bias for the right side of the operant chamber.

Symmetrical and asymmetrical arrangements. McDowell (1989) pointed out that deviations from matching are much more likely when concurrent arrangements are asymmetrical rather than symmetrical. He referred to concurrent arrangements as being symmetrical when identical response options (pecking Key A vs. Key B) produce qualitatively identical reinforcers (e.g., 2 s of access to food). By contrast, asymmetrical concurrent arrangements are ones in which either the responses (e.g., communication vs. aggression) or the type of reinforcers (e.g., a toy vs. attention) are different. In natural human environments, the response options available to an individual are often qualitatively different (e.g., mow the lawn vs. watch television), as are the reinforcers associated with each response. As a result, individuals may often allocate responding in ways that deviate from matching. Although deviations from matching may be more likely in asymmetrical concurrent arrangements, significant deviations from matching also may occur under symmetrical ones.

BRIDGE STUDIES ON CHOICE

One major purpose of bridge studies on choice is to determine the extent to which the variables that affect response allocation in basic studies with nonhumans (e.g., reinforcement rate and immediacy) produce similar effects with humans under more naturalistic conditions.

Matching and Self-Control Choice with Humans

A number of laboratory experiments with concurrent VI schedules have been conducted with human subjects, and some have obtained results that closely conform to the predictions of the matching law. For example, Schroeder and Holland (1969) instructed subjects to watch four dials on a panel and to try to detect as many needle deflections as possible. Needle deflections on the two dials on the left were programmed by one VI schedule, and needle deflections on the two right dials were programmed by a second VI schedule. Subjects were told to press one of two buttons whenever they saw a needle deflection. However, the operant responses in this task were the subject's eye movements, which were recorded by a camera throughout the experiment. Each subject was exposed to two or more conditions with different pairs of VI schedules. Schroeder and Holland found that their subjects' eye movements varied considerably depending on whether there was a COD. With no COD, there was substantial undermatching, but with a 2.5-s COD, the results were well described by the matching law: The percentage of eye movements toward the left dials was approximately equal to the percentage of needle deflections on the left dials. In a similar study, subjects played a video game in which they could detect and destroy two types of enemy missiles by pressing two response keys, and their key-press percentages closely matched the percentages of the two types of missiles (Baum, 1975).

Other studies with human subjects have also obtained close approximations to matching. Bradshaw and his colleagues conducted several experiments in which the operant responses were pressing levers or response keys and the reinforcers were points that could later be exchanged for money (e.g., Bradshaw, Ruddle, & Szabadi, 1981; Bradshaw, Szabadi, & Bevan, 1976). By using different lights on the control panel as discriminative stimuli for different VI schedules, Bradshaw and colleagues were able to present as many as five different pairs of VI schedules in a single session. In general, their results were similar to those obtained with nonhuman subjects, with some subjects exhibiting approximate matching, some undermatching, and some overmatching.

By contrast, some studies with human subjects using concurrent VI schedules have obtained results that did not conform to the matching law. For example, Horne and Lowe (1993) conducted studies that were patterned after Bradshaw's research, but some of their subjects displayed response patterns that deviated greatly from the matching law. Some subjects exhibited near indifference for two different VI schedules, whereas others showed exclusive preference for whichever VI schedule delivered more reinforcers. Lowe and Horne (1985) suggested that the approximate matching observed by Bradshaw and colleagues may have been the result of a fortuitous arrangement of the stimulus lights associated with the different VI schedules. The lights were arranged in a row, and the ordinal position of a light corresponded to the richness of the VI schedule. Therefore, subjects could have learned to distribute their choice responses according to a simple rule such as, "The further the light is to the right, the more I should respond on the right button." By questioning their own subjects about their response strategies, Horne and Lowe (1993) provided evidence that the participants' choices were influenced by the verbal rules they had formulated about how to respond. For example, a subject who showed extreme undermatching stated that random responding was the best strategy, and a subject who responded exclusively on one key said that he decided he could earn the most points by responding only on the key that delivered points more frequently. Based on such verbal reports, Horne and Lowe concluded that human choice is largely rule governed rather than contingency shaped. For this reason, human choice may frequently differ from nonhuman choice and thus from the principles derived from research with nonhumans, such as the matching law.

It should be noted that the results of Horne and Lowe (1993) are not as different from those of Bradshaw and colleagues as they may appear. Although some of Horne and Lowe's subjects showed gross departures from matching, others exhibited approximate matching. Nevertheless, Horne and Lowe presented evidence that there is often a strong correspondence between a human subject's verbal rules and his or her actual performance in choice situations. Perhaps the safest conclusion that can be drawn at this time is that both the current reinforcement contingencies and a subject's verbal rules can influence behavior in choice situations. The factors that determine which of these two sources of behavioral control will dominate in any particular choice situation are not well understood.

Another popular procedure in laboratory research on choice is the so-called *self-control choice* situation, in which subjects must choose between a small, fairly immediate reinforcer and a larger but more delayed reinforcer. Subjects are said to exhibit self-control if they choose the larger, more delayed reinforcer, and they are sometimes called impulsive if they choose the smaller, more immediate reinforcer. Numerous studies have shown that nonhuman subjects will frequently make the impulsive choice under these circumstances (e.g., Ainslie, 1974; Rachlin & Green, 1972), and several experiments have shown that humans often do so as well. Solnick, Kannenberg, Eckerman, and Waller (1980) had college students work on math problems in the presence of an aversively loud noise, and on each trial they could choose (a) an immediate 60-s period of silence followed by a 120-s period of noise or (b) a 90-s period of noise followed by a 90-s period of silence. In some conditions of this experiment, the students chose the immediate period of silence on nearly every trial, even though this meant that they would be exposed to more noise in the long run. In an experiment by Logue and King (1991), college students who had not eaten for several hours were given repeated choices between (a) a small amount of fruit juice after a 1-s delay and (b) a larger amount after a 60-s delay. Logue and King found large individual differences, with some subjects choosing the small immediate option and others the large delayed option. Eight of their 19 subjects chose the small immediate option on more than half of the trials. Other studies have obtained similar results with a variety of different reinforcers that could be delivered in small or large amounts, including snack items (Schweitzer & Sulzer-Azaroff, 1988), slides of sports and entertainment personalities (Navarick, 1986), and opportunities to play video games (Millar & Navarick, 1984).

Not all experiments with human subjects have found preference for the smaller, more immediate reinforcer. For example, in some studies in which the reinforcers were points that could be exchanged for money at the end of the session, subjects showed strong preferences for the larger, delayed reinforcer, and by doing so they increased the total amount of money they earned during the session (Logue, Forzano, & Tobin, 1992; Logue, Peña-Correal, Rodriguez, & Kabela, 1986). Why do human subjects exhibit self-control in some studies and impulsive choices in others? Some writers have suggested that an important variable is whether primary or conditioned reinforcers are used (Flora & Pavlik, 1992). The hypothesis is that impulsive choices are more likely to occur with primary reinforcers that can be consumed or used as soon as they are delivered. By contrast, when the large and small alternatives are conditioned reinforcers, such as points or tokens that can be exchanged for money or other tangible items only at the end of the session, subjects may consistently choose the larger, delayed alternative. This strategy seems reasonable because there is no advantage in choosing an immediate but smaller quantity of tokens that cannot be redeemed until the end of the session. This distinction between primary and conditioned reinforcers is certainly not the only factor that can affect whether a person will choose a small immediate reinforcer or a larger delayed one, but it may be an important factor.

The research on self-control choice has several potential implications for applied work with clinical populations. First, it suggests that if it is possible to impose a delay of just a few seconds before the delivery of a more preferred reinforcer (e.g., attention) for maladaptive behavior (e.g., self-injury), the subject's preference may switch to a less preferred reinforcer (e.g., a toy) that is delivered immediately for appropriate behavior (e.g., task completion). Second, there is some evidence that children can be taught to avoid making impulsive choices that are not in their best long-term interests. With preschool children who were identified by their teachers as impulsive, Schweitzer and Sulzer-Azaroff (1988) used a training procedure in which the delay for the larger of two reinforcers was gradually lengthened over many sessions. Five of the six children showed significant increases in the amount of time they chose to wait for the larger reinforcer. Third, children's choices in self-control situations might be useful as an assessment or screening measure, because choices in such situations change systematically as children get older (Sonuga-Barke, Lea, & Webley, 1989). In addition, several studies have found that impulsive choices are more likely in children with attention deficit hyperactivity disorder (ADHD; e.g., Schweitzer & Sulzer-Azaroff, 1995; Sonuga-Barke, Taylor, Sembi, & Smith, 1992). Therefore, it may be particularly important to develop treatments that are designed to train individuals with ADHD to choose larger, delayed reinforcers over smaller, more immediate reinforcers. Teaching individuals to respond more to quantity of reinforcement and less to immediacy of reinforcement is an effect that can often require many trials, but it may be time and effort well spent, especially for individuals who are particularly prone to impulsive responding.

Choice Responding and Matching in Natural Settings and Clinical Populations

A number of investigators have examined the extent to which the parameters that affect response allocation in basic experiments (e.g., response effort, reinforcement rate, delay, and quality) also do so in natural settings or with distinct clinical populations. For example, Conger and Killeen (1974) reported that college students in a group discussion spent more time talking to a confederate group member who frequently delivered positive statements (e.g., "good point") than to another confederate who issued such statements much less frequently. In fact, by the end of the group discussion, the proportion of time spent talking to each confederate closely matched the proportion of positive statements each delivered to the participant.

Neef, Mace, and colleagues have conducted a series of investigations on the effects of response effort and reinforcement rate, quality, and delay on students' time allocation to concurrently available sets of math problems (Mace, Neef, Shade, & Mauro, 1994, 1996; Neef, Mace, & Shade, 1993; Neef, Mace, Shea, & Shade, 1992; Neef et al., 1994). Neef et al. (1992) examined how special education students allocated their time across two concurrently available sets of math problems in relation to the rate and quality of reinforcement correlated with each set. A unique discriminative stimulus (a distinctly colored math sheet) and an independent VI schedule (i.e., concurrent VI 30-s VI 120-s schedules) were associated with each set of math problems. The experimenters included a prebaseline training condition in which kitchen timers were used to signal the time remaining until reinforcement was available on each VI component. This was done to increase the participants' sensitivity to the rates of reinforcement associated with each schedule. Interestingly, matching between the time allocation and reinforcement rates occurred only after the kitchen timers were added, but matching persisted in subsequent phases after they were removed.

In the formal experimental phases, Neef et al. (1992) alternated between phases in which the quality of the reinforcers delivered were equal (either program money or nickels on both schedules) or unequal (program money on the VI 30-s schedule and nickels on the VI 120-s schedule). Time allocation closely matched reinforcement rates (e.g., approximately 80% of responding on the VI 30-s schedule) when the quality of reinforcement associated with each schedule was the same. However, time allocation shifted toward the leaner schedule when it was associated with a higher quality reinforcer (nickels). That is, each participant displayed a preference for nickels over program money, which resulted in a deviation from matching in which the effects of reinforcer quality overrode the effects of reinforcement rate (time allocation was biased toward the higher quality reinforcer).

In subsequent studies, these investigators have used similar methods to evaluate the effects of (a) reinforcement delay, which (consistent with basic investigations) shifted responding away from matching toward more immediate reinforcement (Neef et al., 1993); (b) problem difficulty, which did not result in a deviation from matching (i.e., time allocation matched rate of reinforcement independent of problem difficulty; Mace et al., 1996); and (c) a variety of adjunctive procedures (changeover delays, demonstrations, limited holds, and timers), which were necessary to produce matching as the relative rates of reinforcement available from two concurrent VI schedules were systematically manipulated (Mace et al., 1994). These investigations are noteworthy in that the effects of response and reinforcement parameters on matching and deviations from matching were evaluated with a clinical population (students with severe emotional, learning, and behavioral disabilities) using a socially meaningful target response as the dependent variable (math problems).

APPLIED RESEARCH ON REINFORCER IDENTIFICATION

Recent applied investigations have begun to examine ways in which the principles and methods used in basic investigations to evaluate and influence choice responding may be used to improve clinical assessments and interventions. In the next three sections, we discuss how choice arrangements have been used (a) to improve stimulus preference assessments, (b) to compare reinforcer effects, and (c) to analyze and improve clinical interventions.

Choice and Stimulus Preference Assessments

One method of assessing an individual's preference for potential reinforcers is to present stimuli in pairs (e.g., Fisher et al., 1992). This method of assessing client preferences for potential reinforcers has been called a forced- or paired-choice assessment in the literature on developmental disabilities (e.g., DeLeon & Iwata, 1996; Fisher et al., 1992). For example, Stimulus A (e.g., a Slinky™) is presented with Stimulus B (e.g., a bite of pizza), and the client is asked to choose one stimulus over the other. Then Stimulus A is similarly presented with Stimuli C, D, E, and so on. This process continues until each stimulus has been presented with every other stimulus one or more times.

The basic approach of presenting stimuli in pairs has been used for years in other areas of psychology and in other disciplines. For example, this method has been used in psychophysiological research and neurological examinations to assess perception (e.g., measuring just noticeable differences; Fechner, 1860/1966). Presenting stimuli in pairs also has been used to quantify human judgments (e.g., the method of paired comparisons; Thurstone, 1927).

Fisher et al. (1992) applied the method of presenting stimuli in pairs to the stimulus preference assessment developed by Pace, Ivancic, Edwards, Iwata, and Page (1985). Fisher et al. (1992) compared the single-stimulus and paired-choice methods of assessing preference. The paired-choice assessment resulted in greater differentiation among the stimuli than did the single-stimulus method and better predicted which items functioned as more effective reinforcers when presented contingently in a concurrent-operants arrangement. Northup, George, Jones, Broussard, and Vollmer (1996) similarly found that the accuracy of children's verbal reports regarding their preferences were improved by presenting stimuli in pairs rather than singly (e.g., "Would you rather get _ or _?" rather than "Do you like _ a little, a lot, or not at all?"). In addition, Piazza, Fisher, Hagopian, Bowman, and Toole (1996) found that reinforcer effectiveness varied proportionally with the preference values derived from a paired-choice assessment; high-preference stimuli were more effective reinforcers than moderately preferred stimuli, which, in turn, were more effective than those assessed as low preference by the paired-choice assessment.

Increasing the efficiency of preference assessments. Several recent investigations have focused on further improving the efficiency of preference assessments. Two recent investigations by Windsor, Piche, and Locke (1994) and DeLeon and Iwata (1996) are particularly noteworthy in this regard. Windsor et al. assessed whether individuals with developmental disabilities could choose from a larger array of concurrently available stimuli (six stimuli at a time rather than two). The obvious advantage of presenting six or more stimuli at a time rather than two is that the stimuli can be presented in fewer trials and less time. However, Windsor et al. found that the paired-choice assessment produced more distinct rankings than did the multiple-stimulus method. In addition, the paired-choice assessment produced more stable preference rankings over repeated administrations.

DeLeon and Iwata (1996) hypothesized that the advantages of the paired-choice assessment (better differentiation and stability of preference rankings) may have been due to the fact that, with the multiple-stimulus method, an individual's highest preference stimuli were available during each trial. Thus, an individual might choose only one or a few stimuli during the entire assessment. Based on this hypothesis, DeLeon and Iwata developed a variation of the multiple-stimulus method that retained its efficiency (i.e., fewer trials and less time) but also included a component that required the individual to choose among lesser preferred stimuli, thus allowing better differentiation among these items. During the first trial, seven stimuli were present, and the individual was allowed to choose and have access to just one. On the second trial, the stimulus chosen on the first trial was omitted from the array of available stimuli (e.g., the highest preference stimulus from the first trial was not present during the second trial). On each subsequent trial, the stimuli that had been chosen on previous trials were omitted until the individual stopped choosing or chose between the last two stimuli. They called the procedure *multiple stimulus without replacement* (MSWO). The MSWO was more efficient than the paired-choice assessment (30 or fewer trials completed in about 22 min for the MSWO, 105 trials completed in about 53 min for the paired-choice assessment).

The most important clinical advancement offered by the MSWO may not be that the entire procedure was completed in about 22 min, but rather that an abbreviated version of the procedure could be used on an ongoing basis to select one or two potential reinforcers from an array of seven or more prior to each training session. Mason, McGee, Farmer-Dougan, and Risley (1989) used an abbreviated version of the paired-choice assessment prior to each training session and reported that preferences frequently changed from one session to the next. Thus, it may be beneficial to reassess an individual's preferences as frequently as possible.

Choice and Reinforcer Assessments

The purpose of a reinforcer assessment is to evaluate stimuli that have been identified as being preferred to determine whether they actually function as reinforcers (i.e., verifying reinforcer function). The ultimate goal for both stimulus preference and reinforcer assessments is to identify effective reinforcers that subsequently can be used in typical training situations.

Based in part on the supposition that it may be important to evaluate the effects of a given reinforcer relative to other competing reinforcers, Fisher et al. (1992) assessed preferred stimuli in a concurrent-operants arrangement. Two free-operant responses (e.g., sitting in Chair A vs. Chair B) were each correlated with different consequent stimuli. For example, when in-seat behavior was the dependent measure, the stimuli associated with Chair A were available to the participant as long as he or she remained in that chair; the stimuli associated with Chair B were available as long as the participant remained in that chair. Thus, the reinforcers were presented on concurrent fixed-ratio (FR) 1 schedules, but a reinforcement interval continued as long as the individual remained in a chair. For 3 of 4 participants with severe to profound mental retardation, clear preferences were established in the very first concurrent-operants session. Using similar procedures, Piazza, Fisher, Hagopian, Bowman, and Toole (1996) and Fisher, Piazza, Bowman, and Amari (1996) also found that this method showed fairly rapid and clear differences in relative reinforcement value. Taken together, these results suggest that this method was a rapid and sensitive means of establishing the relative reinforcement value of different stimuli among individuals with severe to profound mental retardation.

Behavioral economics and reinforcer assessments. One potential limitation of both the single and the concurrent arrangements described by Pace et al. (1985) and Fisher and colleagues, respectively, was the use of simple, free-operant responses (e.g., reaching, in-seat behavior) as dependent measures (Piazza, Fisher, Hagopian, Bowman, & Toole, 1996). A second and perhaps related limitation was that the schedule requirements for reinforcement delivery were low (e.g., FR 1 schedules; Tustin, 1994). Although use of simple responses and schedules permits comparisons of the effects of reinforcers in an efficient manner, their use may limit the generality of the results (i.e., efficiency at the expense of validity). A stimulus that has been shown to function as a reinforcer for a simple free-operant response during a reinforcer assessment may not increase or maintain more complex or socially meaningful responses in typical training situations. Similarly, a stimulus that maintains a response on a dense schedule (e.g., FR 1) may not do so on a leaner schedule (e.g., FR 20). Responding may decrease during leaner schedules not only because of increases in the ratio of responses to reinforcers but also because the amount of time that elapses between reinforcer deliveries is extended.

The extent to which reinforcement effects obtained with a simple free-operant response generalize to more complex and socially meaningful responses is an empirical question that remains largely untested. However, two recent applied investigations (DeLeon, Iwata, Goh, & Worsdell, 1997; Tustin, 1994) based on principles of behavioral economics illustrate how schedule density may affect an individual's preferences for two concurrently available reinforcers.

Within a behavioral economics framework, reinforcement is viewed as a transaction in which responding (or work) is exchanged for reinforcement (or payment; Tustin, 1994). Tustin used progressive FR schedules to determine whether an individual's preferences for two concurrently available reinforcers changed as the price (i.e., the number of responses per reinforcer) of one or both of them was systematically increased. The participants were adult men with moderate to severe mental retardation, autism, or both. The reinforcers were brief attention from the experimenter or computer-generated visual patterns and musical tones, either alone or in combination. Two reinforcers were available at a time, and each was correlated with a different response (two buttons on a joystick) and an independent FR schedule. In one arrangement, one of the reinforcers (e.g., visual) was always correlated with an FR 5 schedule, while the schedule for the other reinforcer (e.g., attention) varied between an FR 1 and an FR 20. As would be expected from a behavioral economics framework, the individual's preferences were a function of both the type of stimulus (i.e., reinforcer quality) and the cost (i.e., number of responses per reinforcer) associated with each option. For example, during one assessment, the participant showed a clear preference for attention when its cost was less than or equal to the visual stimulus. But the individual's preference shifted away from attention and toward the visual stimulus in a linear fashion as the price of attention increased.

In another arrangement in the Tustin (1994) investigation, the schedules for both stimuli varied together between an FR 1 and an FR 20 (i.e., the two schedules varied but were always equal to one another). Surprisingly, the participant had a slight preference for one stimulus (constant color over combined visual patterns and musical tones) when the schedule requirements for both stimuli were low (i.e., an FR 1). However, his preference reversed (combined over constant color) as the schedule requirements increased. In fact, the individual showed a near-exclusive preference for the combined stimulus when the price of both stimuli was 10 responses per reinforcer (FR 10) or higher.

Given that this arrangement (concurrent and equal progressive-ratio schedules) was implemented with only 1 of the participants in the Tustin (1994) investigation, it would be easy to discount this unusual finding as spurious or idiosyncratic. However, DeLeon et al. (1997) have similarly shown that an individual's preference for one item over another may be readily apparent when schedule requirements are relatively high (e.g., concurrent FR 10 schedules) but not when they are low (e.g., concurrent FR 1 schedules). In addition, they found that this effect (i.e., a shift from no apparent preference to a clear preference as schedule requirements increased) occurred with both participants when similar reinforcers were concurrently available (two food items) but not when dissimilar items were compared (a food and a leisure item).

Based on these findings, DeLeon et al. (1997) suggested that increased schedule requirements may magnify small differences in preference between similar but not dissimilar stimuli. This is because stimuli that share physical characteristics (e.g., food items) are more likely to share functional properties as well (e.g., hunger reduction). An individual can exclusively consume the more preferred (or less costly) item without experiencing deprivation when two concurrently available stimuli serve the same function (e.g., either food item reduces hunger). By contrast, when two stimuli serve separate functions, exclusive consumption of one reinforcer results in deprivation of the other (e.g., sustenance but no fun or leisure). If each function is important or valued, the individual will continue to allocate responding to both options as schedule requirements increase.

Given that the DeLeon et al. (1997) investigation involved just 2 participants, their findings and the accompanying explanation should be viewed as tentative. Further, it should be noted that these investigators specifically selected reinforcers for which the individuals showed no apparent preference under concurrent FR 1 schedules, which may be an uncommon occurrence. Fisher and colleagues have generally found that individuals with developmental disabilities show clear preferences on concurrent FR 1 schedules (Fisher et al., 1992, 1996; Piazza, Fisher, Hagopian, Bowman, & Toole, 1996). Nevertheless, stimuli that maintain responding as schedule requirements increase may be more likely to function as reinforcers when they are used as consequences in more typical training situations. Thus, it may be beneficial to assess potential reinforcers using schedule requirements similar to those the individual is likely to encounter in his or her training activities. The investigations by DeLeon et al. and Tustin (1994) are important because they illustrate how basic findings and principles from the field of behavioral economics can be relevant to clinical populations and how they may be used to improve assessments designed to identify potent reinforcers.

Choice as reinforcement. Up to this point, we have discussed choice in terms of (a) how individuals distribute responding among concurrently available reinforcers and (b) how knowledge of choice responding may improve our ability to predict and assess the effects of stimuli used as reinforcers. However, providing individuals with choice-making opportunities may actually produce reinforcement effects that are relatively independent of the consequences associated with each response option.

Catania and Sagvolden (1980) showed that pigeons displayed a small but consistent preference for a condition in which they could produce reinforcement through responding on any of three available keys (choice) over one in which only a single response key produced reinforcement (no choice), even though the programmed reinforcement (i.e., food pellets on equal fixed-interval [FI] schedules) was the same for the choice and no-choice conditions. Similarly, clinical investigations have shown that providing choice-making opportunities to individuals with developmental disabilities can result in marked increases in appropriate behavior or decreases in aberrant behavior (e.g., Dyer, Dunlap, & Winterling, 1990; Mason et al., 1989; Parsons, Reid, Reynolds, & Bumgarner, 1990). However, in most clinical investigations on this topic, the consequences in the choice and no-choice conditions were not equated. Thus, it is possible that the effects were partially or completely due to the fact that the stimuli available in the choice condition were more highly preferred than those presented in the no-choice condition. The investigations by Lerman et al. (1997) and Fisher, Thompson, Piazza, Crosland, and Gotjen (1997) are noteworthy because they equated the consequences delivered in the choice and no-choice conditions; however, one study used a single-operant arrangement (Lerman et al.) and the other used a concurrent arrangement (Fisher et al.).

Lerman et al. (1997) and Fisher et al. (1997) equated the consequences in the choice and no-choice conditions by yoking the reinforcers selected by the therapist in the no-choice condition to selections that had been previously made by the participant in the choice condition. In the choice condition, simple free-operant responses (e.g., stamping the date on paper, switch pressing) were reinforced on FR schedules (usually an FR 1 schedule). When the response requirement was completed, the therapist presented two reinforcers, and the participant was allowed to choose and consume one of them. The no-choice condition was similar to the choice condition except that the therapist selected the reinforcers for the participant (i.e., on a schedule that was yoked to choices the participant had made in the previous session).

Lerman et al. (1997) did not find an effect of choice (i.e., the rates of responding were equivalent in the two conditions). By contrast, Fisher et al. (1997) found a clear effect of choice, perhaps because a concurrent-operants arrangement was used. That is, participants showed almost exclusive responding on the option that allowed them to choose the reinforcers when the consequences in the choice and no-choice conditions were equated.

The participants in the Fisher et al. (1997) study were higher functioning than those in the Lerman et al. (1997) study, and this may have contributed to the differential findings. Thus, it is unclear whether a concurrent arrangement would have detected an effect of choice among the participants of the Lerman et al. investigation. On the other hand, it is doubtful that Fisher et al. would have detected an effect of choice with their participants had they used a single-operant arrangement, because choice affected relative but not absolute rates. As previously mentioned, relative response rates are often a more sensitive measure of reinforcement value than are absolute response rates. In a concurrent arrangement, relative response rates allow detection of a difference in reinforcement value above and beyond that which is necessary to maintain a response in a single-operant arrangement. In a concurrent arrangement, the relative response rates shift toward the response option associated with the more favorable outcome even when absolute response rates remain unchanged (because of a ceiling effect or other factors).

Assessing client preferences for different treatments. Schwartz and Baer (1991) suggested that allowing individuals to choose among concurrently available behavioral programs may be the most valid method of assessing the social acceptability of those programs. However, most investigations on the social acceptability of behavioral treatments used with persons with developmental disabilities have employed indirect measures (e.g., rating scales; Miltenberger, 1990). In addition, these tools have generally been used to assess caregiver (e.g., parents, teachers) rather than client preferences for the treatment. An investigation by Hanley, Piazza, Fisher, Contrucci, and Maglieri (1997) provided an example of how a modification of a concurrent-chains procedure can be used to directly assess a client's preference for one treatment over another.

A chain schedule consists of two or more simple schedules combined together in a fixed sequence (e.g., VI 30 s followed by VI 90 s). Each simple schedule is correlated with a unique discriminative stimulus (e.g., a VI 30-s schedule correlated with a green light followed by a VI 90-s schedule correlated with a red light). The first schedule in the chain is called the initial link, and the last one is called the terminal link. In a concurrent-chains procedure, two or more concurrent responses are each correlated with an independent chain schedule (e.g., a VI 30-s VR 10 chain schedule on the right key, and a VI 30-s FR 10 chain schedule on the left key).

Concurrent-chains procedures have been used to evaluate an individual's preferences for different schedules of reinforcement (e.g., do individuals prefer variable over fixed schedules?). This is done by making the initial links in each chain identical (both VI 30-s schedules) and presenting the schedules of interest in the two terminal links (VR 10 vs. FR 10 schedules). If the individual prefers one terminal-link schedule over the other (e.g., prefers a VR 10 to an FR 10), then more responding will occur on the initial link that produces the preferred schedule (cf. Herrnstein, 1964).

Hanley et al. (1997) used a variation of a concurrent-chains procedure to evaluate preferences for three different treatments developed to decrease the problem behavior of 2 individuals with developmental disabilities: functional communication training with extinction (FCT+EXT), noncontingent reinforcement with extinction (NCR+EXT), and extinction alone (EXT). All three treatments were based on the results of a functional analysis (Iwata, Dorsey, Slifer, Bauman, & Richman, 1982/1994), which indicated that the participants' problem behaviors were maintained by attention. During all three treatments, the contingency between problem behavior and attention was discontinued (i.e., extinction). In addition, attention was delivered contingent on an appropriate communication response during FCT and on a time-based schedule during NCR. In the initial links of the concurrent-chains procedure, three independent FR 1 schedules were each correlated with separate responses (pressing one of three switches) and with unique discriminative stimuli (three colors). Pressing one switch resulted in 2 min of FCT+EXT, pressing a second switch produced 2 min of NCR+EXT, and pressing the third led to 2 min of EXT. Differential rates of responding in the initial links demonstrated that both participants had a clear preference for FCT+EXT over either NCR+EXT or EXT alone.

The variation of a concurrent-chains procedure described by Hanley et al. (1997) represents a unique method of assessing social acceptability, one that allows individuals to have input into the selection of the behavioral treatments they receive, even if they are unable to express their preferences verbally. It also provides a means of assessing specific treatment components (differential reinforcement of other vs. alternative behavior) to determine which ones have the largest effect on an individual's preferences.

CLINICAL INTERVENTIONS THAT INVOLVE CHOICE ARRANGEMENTS

The focus of the clinical investigations reviewed thus far has been on assessing an individual's preferences for various stimuli or evaluating the reinforcing effects of a stimulus relative to the effects of other concurrently available stimuli. In the following section, we discuss studies that have incorporated choice arrangements into clinical interventions designed to reduce problem behavior.

Choice and Functional Communication Training

A number of behavior analysts have conceptualized the treatment of aberrant behavior using functional communication training (FCT) or similar differential reinforcement treatments in terms of concurrent operants (e.g., Carr, 1988; Fisher et al., 1993; R. H. Horner & Day, 1991; Mace & Roberts, 1993). FCT is designed to reduce problem behavior, is based on the results of a functional analysis, and is used primarily when the functional analysis determines that the aberrant behavior is maintained by social contingencies (e.g., attention, escape from demands). During FCT, the reinforcer that is responsible for behavioral maintenance is delivered contingent on an alternative (communicative) response. In most cases, FCT has been combined with extinction (i.e., discontinuation of reinforcement for aberrant behavior; e.g., Lalli, Casey, & Kates, 1995), but in other cases it has not (concurrent reinforcement of communication and aberrant behavior; e.g., Fisher et al., 1993; R. H. Horner & Day, 1991). There are certain clinical situations in which placing aberrant behavior on extinction is impractical or even dangerous (cf. Pace, Ivancic, & Jefferson, 1994; Piazza, Moes, & Fisher, 1996). In these cases, it may be critical to find alternative responses and corresponding reinforcers that compete effectively with aberrant behavior and its correlated reinforcer. The major goal of conceptualizing differential reinforcement procedures in terms of concurrent operants is to help to "stack the deck" in favor of the appropriate alternative response by making it less effortful and correlating it with denser, more immediate, or higher quality reinforcement (see Mace & Roberts, 1993, for a more in-depth discussion of how response effort and reinforcement rate, immediacy, and quality can affect treatment selection).

An investigation by R. H. Horner and Day (1991) provides a nice example of how a concurrent-operants arrangement may help to evaluate how response effort and reinforcement rate and immediacy can influence the effectiveness of differential reinforcement procedures like FCT. The participants were 3 individuals with severe to profound mental retardation; one also had cerebral palsy and another also had autism. In each of three experiments, participants received a break from work (e.g., 30-s break from toothbrushing) or assistance with the task (e.g., the therapist pointing to the correct answer) contingent on an appropriate mand (e.g., signing "break") or problem behavior.

In Experiment 1, the amount of effort required for the FCT response was systematically manipulated. In two experimental conditions, the individual could escape the work task for approximately 30 s to 45 s through either aggression or an appropriate mand (i.e., concurrent FR 1 FR 1 schedules). However, in one condition, the appropriate mand was a single word (signing "break") and, in the other, it was a longer sentence that required more effort (signing "I want to go, please"). The participant allocated his responding almost exclusively to problem behavior when the choice was between an effortful communication response and aggression. By contrast, when the less effortful mand was available, the individual allocated his responding almost exclusively to this option, and aggression was maintained at near-zero levels. These results differ from those obtained by Chung (1965), who manipulated response effort with pigeons by systematically altering the amount of physical force required to complete a key-peck response, and by Mace et al. (1996), who manipulated response effort by systematically altering the difficulty level of two concurrently available sets of math problems. This difference may be partially due to the fact that these latter two investigations used concurrent VI schedules, whereas ratio schedules were in effect in the R. H. Horner and Day (1991) study. The more effortful response (signing a complete sentence) in the Horner and Day investigation probably took more time to complete than the less effortful one (signing a single word), which probably lowered the rate of reinforcement, given that concurrent-ratio schedules were used.

In Experiment 2 of the R. H. Horner and Day (1991) study, the rate of reinforcement for the alternative mand was manipulated (FR 1 vs. FR 3), and predictable effects were obtained; responding was allocated to self-injurious behavior (SIB) when the schedule for the mand was an FR 3 and was allocated toward the mand when the schedule was an FR 1. Finally, in Experiment 3, the effects of shorter versus longer reinforcement delays for the FCT response (a break after 1 s vs. 20 s) were compared while problem behavior continued to produce immediate reinforcement in each condition. As expected, the rates of problem behavior were much higher when the alternative mand was associated with the longer delay than when it was associated with a shorter delay.

Peck et al. (1996) extended the findings of R. H. Horner and Day (1991) by showing that their participants displayed high rates of the FCT response and low rates of problem behavior when the former response was correlated with a better outcome (i.e., a higher quality reinforcer that was presented for a longer duration). Piazza et al. (1997) similarly found that participants allocated their responding toward compliance when it produced higher quality reinforcement than was produced by problem behavior. However, as the schedule of reinforcement for compliance was gradually thinned from an FR 1 to schedules more typical of most training situations (e.g., FR 10), it was necessary to include both higher quality reinforcement for compliance (e.g., escape plus attention) and extinction for aberrant behavior in all three cases.

Choice and Aberrant Behavior Maintained by Automatic Reinforcement

Certain aberrant behaviors (e.g., pica, stereotypies, some forms of SIB) persist in the absence of apparent social or environmental contingencies. One operant hypothesis for this phenomenon is that these behaviors produce their reinforcement automatically (Skinner, 1953; see Vollmer, 1994, for a review). For example, it has been suggested that pica and rumination may sometimes be maintained by the oral stimulation that is produced by these responses (Favell, McGimsey, & Schell, 1982; Rast, Johnston, Lubin, & Ellinger-Allen, 1988). Similarly, it has been hypothesized that blind individuals display SIB involving the eyes more often than do other populations because pressure to the eyes (e.g., through eye pressing or eye poking) can stimulate the visual cortex (Hyman, Fisher, Mercugliano, & Cataldo, 1990; Kennedy & Souza, 1995).

One approach to treating behavior hypothesized to be maintained by automatic reinforcement is to provide a way for the individual to obtain the putative reinforcer through a more appropriate response. For example, Favell et al. (1982) hypothesized that the pica of 3 clients was maintained by the oral stimulation it produced. They then provided the participants with materials that could be used to produce benign but similar forms of oral stimulation (popcorn and toys that could be mouthed and chewed but not swallowed). Consistent with the automatic reinforcement hypothesis, pica decreased when oral stimulation was available with these alternative materials. In addition, if the alternative materials produced additional forms of reinforcement (e.g., a higher quality reinforcement due to the taste of the popcorn), this may have increased the likelihood of switching from the aberrant to the more appropriate target behaviors.

A second approach to the treatment of aberrant behavior that persists in the absence of social consequences is to provide the individual with one or more alternative forms of stimulation that might effectively compete with the putative reinforcer for aberrant behavior. Viewed from a choice perspective, responding should shift toward an alternative form of stimulation if it produces a higher quality form of reinforcement than does the aberrant behavior (given that both forms of stimulation are available immediately and continuously and require similar amounts of effort). For example, Berkson and Mason (1965) showed that stereotypic behavior decreased when the participants were given toys and attention. R. D. Horner (1980) developed a similar treatment for aberrant behavior called *environmental enrichment* wherein multiple toys and objects were available noncontingently. Vollmer, Marcus, and LeBlanc (1994) showed that environmental enrichment more effectively reduced aberrant behavior that persisted in the absence of social contingencies when the toys and objects presented were ones that had been identified by a choice assessment (Fisher et al., 1992) as highly preferred relative to ones that were less preferred. Thus, a choice assessment may be used to identify high-quality reinforcers that may be more likely to compete with the putative automatic reinforcement associated with aberrant behavior.

Several recent investigations have examined the extent to which stimuli evaluated during a preference assessment effectively competed with aberrant behavior that persisted in the absence of social contingencies (Derby et al., 1995; Piazza, Fisher, Hanley, Hilker, & Derby, 1996; Ringdahl, Vollmer, Marcus, & Roane, 1997). In each investigation, there was one dependent measure (e.g., approach responses, duration of interaction) that was designed to assess the participants' preferences for the various stimuli presented. In addition, each investigation measured the level of aberrant behavior that occurred each time a stimulus or group of stimuli was presented. In most cases, the stimuli associated with high levels of interaction and low levels of SIB were more effective than other stimuli when used during treatment. However, an investigation by Shore, Iwata, DeLeon, Kahng, and Smith (1997) illustrates how relative response rates during a free-operant arrangement may not always predict the effects of differential reinforcement contingencies.

In the first of a three-experiment investigation, Shore et al. (1997) showed that SIB persisted in the absence of social contingencies and also that object manipulation competed with SIB when both were freely and continuously available. However, in Experiment 2, contingent access to the objects was not effective reinforcement for the absence of SIB during a differential-reinforcement-of-other-behavior (DRO) intervention, even when the length of the DRO interval was small (absence of SIB for 5 s) relative to the length of the reinforcement interval (60 s of access to the object). The authors then completed a third experiment that helped to clarify why a relatively large amount of a more preferred activity (60 s of object manipulation) did not function as reinforcement for the brief absence (5 s) of a less preferred response (SIB). In this experiment, both responses were concurrently and continuously available, but the amount of effort required to obtain the object was systematically manipulated while the response effort associated with SIB remained constant. This was accomplished by tying the object to a string, anchoring the other end of the string in front of the individual, and then systematically altering the length of the string. The length of the string determined how far the individual had to bend over in order to manipulate the object (i.e., the shorter the string, the more the individual had to bend). The results showed that just a small increment in response effort required to obtain the object resulted in a shift in preference away from object manipulation toward SIB.

It is worth noting that the results obtained by Shore et al. (1997) in Experiment 2 are inconsistent with the predictions of Premack's principle (1962) and the response deprivation hypothesis. Each of these theoretical formulations predicts reinforcement effects based on the relative rates of two concurrently available responses observed in a free-operant assessment (i.e., no programmed contingency for either response). This was also the approach used by Derby et al. (1995), Piazza, Fisher, Hanley, Hilker, and Derby (1996), and Ringdahl et al. (1997). However, relative response rates during a free-operant assessment may not predict the effects of treatments that involve manipulation of other response and reinforcement parameters (e.g., reinforcement delay, response effort).

Choice arrangements may be useful not only for identifying stimuli that effectively compete with aberrant behavior that persists in the absence of social consequences but also for identifying the specific source of automatic reinforcement. Piazza, Hanley, and Fisher (1996) conducted a series of analyses to indirectly assess whether a young man's pica of cigarette butts was maintained by the effects of nicotine consumption. A functional analysis showed that the response was maintained without social consequences. Using a choice assessment, the authors confirmed that the participant preferred tobacco over the other components of the cigarettes (e.g., paper, filter, butts with herbs instead of tobacco). This assessment also helped to rule out the alternative hypothesis that his pica was maintained by the oral stimulation it produced, because the herbal butts would have served this function equally well. Finally, a treatment that was designed to interrupt the hypothesized response–reinforcer relationship reduced pica.

CONCLUDING COMMENTS

Basic studies have produced both conceptual and mathematical formulations of how several key variables (e.g., reinforcement rate, immediacy, quality) influence choice responding under laboratory conditions. The extent to which these formulations can be used to predict or control human responding in natural settings has been the topic of some debate (e.g., Fuqua, 1984; Horne & Lowe, 1993; Meyerson & Hale, 1984).

Fuqua (1984) argued that there are a number of differences between laboratory settings and natural human environments that limit the relevance of findings from basic research on matching to applied settings. For example, Fuqua contended that CODs are often necessary to produce matching but are rarely present in applied settings. However, the results of more recent applied and bridge studies suggest that the effects and necessity of CODs for matching to occur under laboratory and natural conditions may be more similar than Fuqua suggested. CODs have often (but not always) been required to produce matching, but their necessity does not seem to depend on whether (a) the participants are human or nonhuman (cf. Conger & Killeen, 1974; Herrnstein, 1961; Schroeder & Holland, 1969; Rachlin & Baum, 1972), (b) the setting is a laboratory or a natural human environment (cf. Baum, 1975; Conger & Killeen, 1974), or (c) the target response is contrived or more socially meaningful (cf. Horne & Lowe, 1993; Mace et al., 1994).

In basic and bridge studies on matching, CODs and other adjunctive procedures (e.g., instructions, timers) are often used to facilitate discrimination of the relative reinforcement rates that are associated with concurrent VI schedules or to penalize adventitious reinforcement of switching from one response to the other. CODs have similarly been used during applied studies on FCT with extinction to prevent adventitious reinforcement of problem behavior (e.g., Lalli et al., 1995). When problem behavior is treated with FCT, participants will sometimes rapidly switch from the inappropriate (e.g., SIB) to the appropriate (e.g., signing "break") target response, and a response chain consisting of these two responses may be adventitiously reinforced if a COD is not used (e.g., Fisher et al., 1993). CODs are usually unnecessary in both basic and applied studies when the schedules associated with each concurrent response are easily discriminated by the participants. For example, Fisher et al. (1997) used concurrent VI schedules to evaluate preferences for choice over no-choice conditions, and a COD was not necessary (presumably because the contingencies associated with each response were clear to the participants). Thus, based on currently available data, it appears that the arrangement (e.g., concurrent schedules that are not readily discriminated) rather than the setting (laboratory vs. natural), participant (human vs. nonhuman), or type of response (contrived vs. socially meaningful) determines whether CODs or other adjunctive procedures are necessary.

Fuqua (1984) also argued that the applied relevance of matching theory may be limited because the concurrent responses evaluated in basic studies were almost always topographically identical and mutually exclusive. By contrast, humans often allocate their time among different response topographies and can emit multiple responses and consume the corresponding reinforcers simultaneously (e.g., carry on a conversation while listening to music). However, in the majority of the applied investigations reviewed above, participants allocated their responding to one of two topographically distinct response options even though it was possible for both responses to occur simultaneously (e.g., R. H. Horner & Day, 1991; Piazza et al., 1997; Shore et al., 1997; Vollmer et al., 1994). Thus, it appears that there may be many situations in which matching theory is applicable to concurrent arrangements in natural human settings even when the target responses are dissimilar and not mutually exclusive.

Fuqua (1984) also pointed out that the reinforcers and corresponding schedules that maintain responding in applied settings may not be easily identified, thus making it difficult to apply the quantitative formulations of matching theory. As a result, Fuqua suggested that basic research on concurrent responses may have greater applicability on a qualitative rather than on a quantitative level. In fact, only a few of the studies reviewed above included mathematical analyses of the extent to which relative response rates matched relative reinforcement rates, and those that did were specifically designed to test the applicability of the matching equation to human responding (e.g., Horne & Lowe, 1993; Mace et al., 1994). Instead, most of the applied studies reviewed here used matching and choice principles on a more qualitative level. In general, the goals of these investigations were to identify preferred stimuli (e.g., DeLeon & Iwata, 1996; Piazza, Fisher, Hagopian, Bowman, & Toole, 1996), to evaluate reinforcer and schedule preferences or effects (e.g., Fisher et al., 1997; Hanley et al., 1997), or to treat problem behavior (e.g., R. H. Horner & Day, 1991; Shore et al., 1997). The application of matching or choice principles on a qualitative level clearly facilitated accomplishment of these goals; whether a more quantitative approach would have provided additional benefit remains uncertain.

There are undoubtedly many ways in which laboratory analogues fail to capture all of the complexities of human choice responding in more natural settings, and Fuqua's (1984) general admonition regarding the need to exercise caution when applying matching theory outside of the laboratory remains prudent. In fact, even in the applied studies reviewed above, choice responding was evaluated under analogue conditions in which the experimenters programmed specific reinforcers and schedules for each target response (e.g., DeLeon et al., 1997; Fisher et al., 1997). Thus, the extent to which the concurrent arrangements used in these applied studies accurately mimicked the schedules that maintained the target responses in the participants' natural environments remains unknown. Nevertheless, the applied and bridge studies reviewed above provide considerable empirical evidence regarding the applied relevance of choice and matching formulations of responding. More specifically, the results of these studies suggest that the variables that affect choice responding with nonhumans in the laboratory (i.e., response effort and reinforcement rate, immediacy, and quality) often operate in a similar manner in applied settings and with socially meaningful human responses. Thus, although Fuqua's concerns regarding factors that distinguish laboratory conditions from applied settings are quite reasonable, the data now available suggest that what could be, in principle, important differences between the two settings are, in practice, often not serious problems.

The applied literature on choice responding and matching is still relatively small in comparison with the corresponding basic literature on this topic. As the principles derived from basic research receive additional field testing in natural human environments, the applied technology of choice responding that develops will in some ways be similar to and in other ways be different from the basic knowledge base on this topic. We hope that the similarities will lead to more accurate and effective clinical procedures, and that the differences will spark additional basic and bridge studies that further our understanding of human choice responding.

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