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TEMPORAL DISCOUNTING: BASIC RESEARCH AND THE ANALYSIS OF SOCIALLY IMPORTANT BEHAVIOR

THOMAS S. CRITCHFIELD

ILLINOIS STATE UNIVERSITY

AND

SCOTT H. KOLLINS

DUKE UNIVERSITY MEDICAL CENTER

Recent basic research on human temporal discounting is reviewed to illustrate procedures, summarize key findings, and draw parallels with both nonhuman animal research and conceptual writings on self-control. Lessons derived from this research are then applied to the challenge of analyzing socially important behaviors such as drug abuse, eating and exercise, and impulsiveness associated with attention deficit hyperactivity disorder. Attending to the broader temporal context in which behavior occurs may aid in the analysis of socially important behavior. Applying this perspective to the study of behavior in natural environments also highlights the importance of combining methodological flexibility with conceptual rigor to promote the extension of applied behavior analysis to a broader array of socially important behaviors.

DESCRIPTORS: temporal discounting, delayed consequences, self-control, attention deficit hyperactivity disorder, drug abuse

Applied behavior analysts have expressed concern over whether their field is addressing an adequate range of socially important problems (e.g., Baer, Wolf, & Risley, 1968, 1987; Hawkins, Greene, & Fuqua, 1995; Hopkins, 1987; Kunkel, 1987). Socially important problems are easy to identify outside of the residential settings, day treatment programs, and laboratory-like environments in which many applied behavior analyses currently take place. Practical difficulties arise, however, when attention turns toward the behavior of individuals who are negotiating the world outside of controlled therapeutic settings. Among these difficulties are that behaviors of interest may not lend themselves readily to direct observation or experimental manipulation, and that these behaviors, as well as the environmental events that affect them, occur over such extended time frames that discrete relations between responses and consequences become difficult to discern. Modern applied behavior-analytic techniques often seem better suited to addressing discrete response–consequence relations of the sort that can be examined in controlled settings.

Hopkins (1987) suggested that applied behavior analysts might work to modify governmental and social systems to make them more accommodating, and appreciative, of existing approaches in the field, but acknowledged that the means for accomplishing this goal remain unclear. As will be discussed in the present article, another strategy is to select problems to address, and then develop methods of inquiry that are compatible with these problems, as a vehicle for

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Address correspondence to T. Critchfield, Department of Psychology, Illinois State University, Normal, Illinois 61790 (E-mail: tscritc@ilstu.edu), or S. Kollins, Department of Psychiatry, Duke University Medical Center, Box 3431, Durham, North Carolina 27710 (E-mail: kolli001@mc.duke.edu).

insinuating the field's strong conceptual foundations into new domains. Because nontraditional problems can spawn nontraditional methods, a challenge inherent in this strategy is to insure that one's efforts produce conceptually interpretable outcomes that are reconcilable with mainstream efforts in the field.

In the present article we argue that inspiration for this process of extension can be found in basic research on temporal discounting in humans, published recently in the *Journal of the Experimental Analysis of Behavior* (*JEAB*) and elsewhere. Like previous basic-to-applied articles in the *Journal of Applied Behavior Analysis* (*JABA*), the present essay seeks to summarize recent *JEAB* research and evaluate its applied relevance, although the present article breaks with precedent in two ways. First, previous articles have focused on a few *JEAB* studies, explaining their procedures and results in great detail. Recent human temporal discounting studies in *JEAB*, however, are better appreciated by examining the overall research agenda into which they fit. Therefore, we describe the rapidly growing temporal discounting research area, employing relatively brief descriptions of selected *JEAB* studies to illustrate some of its features. Second, previous articles have attempted to draw rather close parallels between the results of *JEAB* studies and the possible features of specific types of behavior-analytic interventions. We attempt instead to derive broad lessons from the temporal discounting literature that may be instructive regarding opportunities for growth in applied behavior analysis generally.

We begin with an introduction to research on temporal discounting in humans and some reasons why, despite the fact that this research employs unusual methods, it can be viewed as a useful accompaniment to more traditional experimental analyses of behavior. Next we provide some examples of how lessons derived from research on temporal discounting in humans might promote a behavior-analytic approach to some socially important problems, including attention deficit hyperactivity disorder (ADHD), alcohol abuse, and exercise. We conclude with a brief consideration of the relations between these efforts and more traditional efforts in applied behavior analysis.

BASIC RESEARCH ON HUMAN TEMPORAL DISCOUNTING

Behavior analysts assume that behavior is determined by past consequences, and they test this assumption in the laboratory via operant procedures in which behavior produces reinforcers and punishers after varying degrees of delay. Economists, cognitive psychologists, and many other social scientists assume that people plan their actions with respect to future consequences, and they test this assumption in the laboratory via procedures in which subjects indicate their response to future events, usually hypothetically described. Both traditions recognize that delays render consequences less effective in guiding behavior. *Temporal discounting,* therefore, refers to the weakening of consequence effects due to delay, and any procedure that promotes the investigation of delay effects can be called a temporal discounting procedure. The human temporal discounting procedures under discussion in the present article have their methodological roots in the tradition of economics and cognitive psychology, but they recently have been coopted and modified to address questions relevant to operant theory (e.g., see Rachlin, 1989).

Theoretically speaking, temporal discounting research has obvious links to consequence-based interpretations of *self-control.* Scholars have long regarded self-control as involving deferred gratification (e.g., Mischel & Gilligan, 1964). In operant terms, self-control means engaging in behavior that leads to large delayed reinforcers instead of behavior that leads to small, more immediate reinforcers. The converse is true when punishment is involved (e.g., Rachlin, 1976; Skinner, 1953). This conflict between immediate and delayed consequences has inspired many interpretations of everyday human affairs. For example, Nevin (1991) characterized the stockpiling of nuclear arms as a trade-off between short-term security and long-term risk of nuclear annihilation. Rachlin (1976) described visiting the dentist (which has mildly unpleasant short-term consequences) as being in conflict with response options that preclude regular dental care (leading to intensely unpleasant long-term consequences).

The results of operant experiments portray nonhuman animals as clearly impulsive, acting for short-term gain at the expense of more favorable long-term outcomes. Given a choice between small immediate reinforcers and large delayed ones, nonhuman animals usually show a preference for the former (e.g., Ainslie, 1974; Logue, 1995; Rachlin, 1995a; Rachlin & Green, 1972). Laboratory studies with humans, however, have not always revealed the same degree of impulsiveness (e.g., Flora & Pavlik, 1992; Forzano & Logue, 1995; Logue, King, Chavarro, & Volpe, 1990; Logue, Peña-Correal, Rodriguez, & Kabela, 1986; Millar & Navarick, 1984; Navarick, 1996; Tobin & Logue, 1994). Quite possibly, these discrepant outcomes reflect the use of weak reinforcers (e.g., small amounts of money) or trivial delays that pale in comparison to those that humans tolerate daily outside the laboratory (e.g., Hyten, Madden, & Field, 1994; Ragotzy, Blakely, & Poling, 1988). Because of practical constraints, arranging effective reinforcers and extended participation remain challenges in human operant research. As will be illustrated below, however, by stepping into the realm of the hypothetical, temporal discounting procedures may be able to manipulate meaningful magnitudes of delay and reward and thus provide a valuable missing link in the continuum of behavior-analytic research. If results obtained from these procedures depict familiar interactions between delay and magnitude of reward, then temporal discounting studies may help to affirm the generality of intertemporal choice patterns in humans and nonhuman animals and, in some cases, might also be considered valid estimates of human sensitivity to delay of reinforcement.

Temporal Discounting Procedures

The procedures of temporal discounting studies, as implemented recently within the experimental analysis of behavior, involve soliciting verbal responses to hypothetical choice scenarios. The consequences in these scenarios typically are amounts of money (which is easily scaled and quantified, unlike many other outcomes of long-term value, such as good health or happy relationships). In some studies the procedures are computerized; in others, an experimenter presents the choices on index cards and records the data manually. In all cases, however, the participant works individually with the aid of instructions like the following:

> The purpose of this experiment is to see how you make decisions concerning imaginary amounts of money. On each trial, two amounts of money will appear on your screen. The left side of your screen offers you one amount and indicates that is it to be paid right now. The right side of your screen offers you another amount to be paid at a later time indicated on your screen. Your job is to choose which of the hypothetical money amounts is most appealing to you. All choices are unrelated; please do not attempt to plan ahead. Just judge each amount based on what is most appealing to you. (based on Myerson & Green, 1995, and Simpson & Vuchinich, 2000a)

Table 1

Representative trials and hypothetical raw data from a portion of a temporal discounting experiment involving choices between imaginary money gains. Columns represent different delays to receipt of a large gain (in this case, $1,000). For each delay, the large delayed gain remains constant, and the amount of an alternative immediate gain (leftmost column) varies systematically across in ascending sequence. A complete experiment would also include a descending sequence of small gains for each delay (see text). A hypothetical response to each trial is indicated with a D (delayed money option selected) or an I (immediate money option selected). For each of the delays, switches from delayed to immediate options are highlighted with an asterisk.

Amount of immediate reward	Delay to large reward (in months)								
	0.25	1	6	12	36	60	120	180	300
1	D	D	D	D	D	D	D	D	D
5	D	D	D	D	D	D	D	D	I*
10	D	D	D	D	D	D	D	D	I
20	D	D	D	D	D	D	D	D	I
40	D	D	D	D	D	D	D	I*	I
60	D	D	D	D	D	D	D	I	I
80	D	D	D	D	D	D	I*	I	I
100	D	D	D	D	D	D	I	I	I
150	D	D	D	D	D	I*	I	I	I
200	D	D	D	D	D	I	I	I	I
250	D	D	D	D	D	I	I	I	I
300	D	D	D	D	D	I	I	I	I
350	D	D	D	D	D	I	I	I	I
400	D	D	D	D	D	I	I	I	I
450	D	D	D	D	D	I	I	I	I
500	D	D	D	D	I*	I	I	I	I
550	D	D	D	I*	I	I	I	I	I
600	D	D	D	I	I	I	I	I	I
650	D	D	D	I	I	I	I	I	I
700	D	D	I*	I	I	I	I	I	I
750	D	D	I	I	I	I	I	I	I
800	D	D	I	I	I	I	I	I	I
850	D	I*	I	I	I	I	I	I	I
900	D	I	I	I	I	I	I	I	I
920	D	I	I	I	I	I	I	I	I
940	D	I	I	I	I	I	I	I	I
960	D	I	I	I	I	I	I	I	I
980	D	I	I	I	I	I	I	I	I
990	D	I	I	I	I	I	I	I	I
1,000	I*	I	I	I	I	I	I	I	I

Thus, on each trial, subjects choose between a small amount of money, available immediately (smaller sooner reward, or SSR), and a larger amount, available at a later time (larger later reward, or LLR). Across many trials, the delay of the LLR and the amount of the SSR are manipulated, with the goal of identifying the *current subjective value* of delayed rewards, defined as the magnitude of SSR that generates indifference in a choice against the LLR. This value suggests the extent to which an LLR has been discounted because of delay.

In many studies, experimental conditions are defined by a constant LLR and the manipulation, across trials, of SSR magnitude, in ascending and descending sequences as per traditional psychophysical scaling procedures (Stevens, 1951). Table 1 summarizes a representative set of trials involving as-

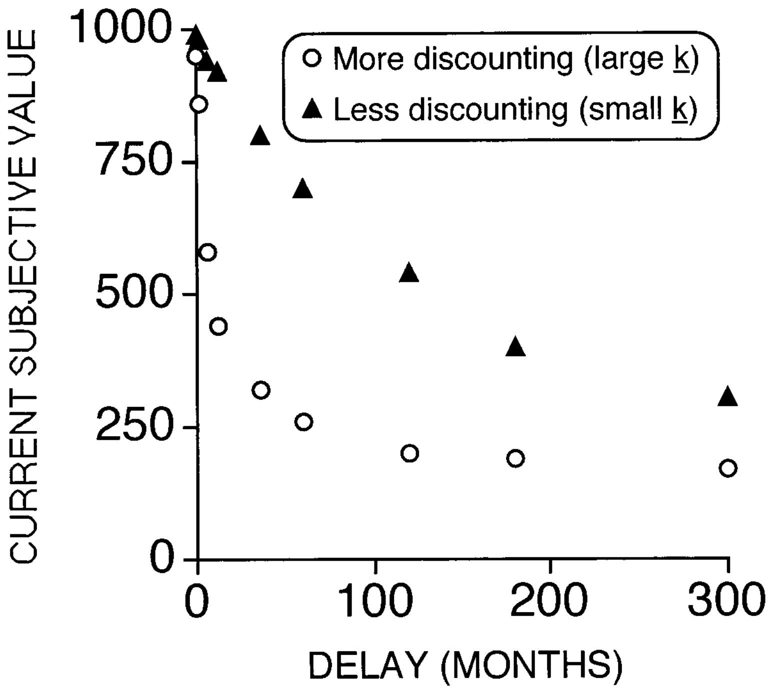

Figure 1. Hypothetical temporal discounting data, showing current subjective value of $1,000 as a function of delay to its receipt. See text for details.

cending choice sequences. In an ascending choice sequence, the LLR is likely to be preferred initially, with preference shifting to the SSR as its size increases, as shown in Table 1. In a descending choice sequence, the SSR is likely to be preferred initially, with preference switching to the LLR as the SSR shrinks. Current subjective value for each LLR is estimated by averaging the switch points in the ascending and descending choice sequences. The current subjective value is almost always less than the face value of the LLR.

As implemented by Rachlin, Raineri, and Cross (1991) and many others since, the temporal discounting procedure incorporates a range of conditions, across which the delay to receipt of the LLR varies (see Table 1). For example, Rachlin et al. used delays ranging from 1 week to 25 years. In data analysis, each condition is summarized by a single current subjective value, and collectively, the data points from various conditions describe a negatively decelerating curve in which current subjective value decreases as a function of increasing delay to the receipt of that reward. Figure 1 shows two examples of temporal discounting functions, to be explained below.

Quantitative description of results. Considerable interest has been invested in determining the precise shape of the temporal discounting function. In economics, discounting curves have been regarded as exponential (Kagel, Battalio, & Green, 1995), but many recent behavioral models are similar to, or based upon, a hyperbolic equation proposed by Mazur (1987) to account for delay-of-reinforcement data from nonhumans:

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

Here V, A, and D represent the current subjective value, amount, and delay, respectively, of the LLR, and k is a fitted parameter whose value can be interpreted as an index of sensitivity to delay. When k is large, the current subjective value of LLRs decreases substantially as a function of delay (open circles in Figure 1). Individuals produce large k values by forgoing LLRs to accept smaller rewards now, and thus are labeled as impulsive. When k is small, the subjective value of LLRs decreases little as a function of delay (filled triangles in Figure 1). Individuals produce small k values by forgoing small rewards now for more lucrative LLRs, and thus are considered to be self-controlled.

Equation 1 has fit the data well in many experiments (e.g., Madden, Bickel, & Jacobs, 1999; Myerson & Green, 1995; Rachlin et al., 1991; Simpson & Vuchinich, 2000a), but it should be viewed as a working model rather than the final statement on the form of the temporal discounting function. Theorists still debate the proper mathematical form of the discounting model.[1] Fortunately, resolution of this matter need not forestall the present discussion. For present purposes, what matters is that research in this area points to a negatively decelerating discounting function, and that all quantitative models currently under consideration produce an index of discounting that is useful in summarizing that function, thus yielding a quantitative estimate of sensitivity to delay. Hereafter, for economy of expression, we will refer to sensitivity to delay in terms of the k parameter in Equation 1 and its variants, although we acknowledge that other means of assessing and summarizing sensitivity to delay are worth considering.

Validation of the Procedures

There is no escaping that temporal discounting procedures with humans differ from traditional behavioral analyses in many ways, and thus these procedures are likely to promote skepticism in many *JABA* readers. Concerns worthy of attention include (a) in hypothetical procedures, subjects acquire no within-study experience with the "consequences" of interest, and demonstrate the "effects" of these consequences via verbal responses that bear no necessary relation to the behavior they supposedly describe (e.g., Skinner, 1957); (b) many studies have evaluated temporal discounting curves based on the central tendency of several individuals, raising questions about the applicability of the models to individual behavior; and (c) procedures like those just described are quite brief (as short as 30 min), raising questions about the long-term stability of the results. For these reasons, before considering any implications of temporal discounting research with humans, it is worthwhile to consider what evidence may exist to promote confidence in its findings.

Real versus hypothetical consequences. Although temporal discounting procedures often omit contact with real consequences, most adult subjects will have substantial prior experience with earning and spending money. There is no guarantee that verbal repertoires, as assessed in hypothetical tasks, will correspond to actual choice, but typical preexperimental histories provide the opportunity for ample self-observation of the sort that might inform a self-descriptive verbal repertoire (see Skinner, 1957, e.g., pp. 138–146). In addition, a few studies employing real, rather than hypothetical, consequences

[1] For example, Myerson and Green (1995) have proposed adding an exponent to Equation 1, and doing so accounts for marginally higher proportions of variance. Grace (1999) has pointed out that choices involving delayed reinforcers in the laboratory can be accounted for by exponential models based on the matching law. Models based on the matching law have not been routinely evaluated with respect to the hypothetical choices of temporal discounting tasks, but may confer certain mathematical and conceptual advantages. Thus, it is possible that the precise shape of the negatively decelerating temporal discounting function has been misjudged, and that the most appropriate parameter describing speed of discounting has yet to be agreed upon.

have produced results much like those described previously (e.g., Crean, de Wit, & Richards, 2000; Kirby & Marakovic, 1996). For example, Richards, Zhang, Mitchell, and de Wit (1999) allowed healthy volunteers to choose between various SSRs and an LLR of $10, available at delays up to 365 days. For each delay, the indifference points indicative of current subjective value were estimated in an adjusting procedure, rather than a fixed sequence of choices as in Table 1. A hyperbolic discounting function fit these indifference points well. Such results suggest direct parallels in human discounting of hypothetical and real money consequences.

Another point lending confidence to the interpretation of human temporal discounting data is the mathematical similarity of functions derived from hypothetical tasks with humans and those based on the behavior of nonhuman animals working for food or water. For example, Richards, Mitchell, de Wit, and Seiden (1997) employed a discrete-trials procedure in which rats chose between immediate and delayed sources of water. The magnitude of the delayed reinforcer remained constant while that of the immediate reinforcer was titrated across trials, increasing after delayed-reinforcer choices and decreasing after immediate-reinforcer choices. The delay to the fixed reinforcer varied across conditions. In each condition, the value of the titrating reinforcer at which performance stabilized represented an indifference point, much like the current subjective value measure in human temporal discounting tasks. When these indifference points were plotted against delay, Equation 1 (modified to account for position biases) accounted for between 76% and 99% of the variance in individual discounting functions (median = 98%).

Group versus individual analyses. Because many temporal discounting data sets have been analyzed at the group level, Myerson and Green (1995) examined whether individual-subject responses mirror functions based on group-aggregate data. Using hypothetical procedures like those described previously, Myerson and Green assessed college students twice, once with a relatively small LLR and once with a relatively large LLR. A modified Equation 1 accounted for about 92% and 94% of the variance in functions describing group-median data for the smaller and larger LLRs, respectively. The same model could be successfully applied to 21 of 24 individual functions (for the two LLRs combined), accounting for a median of 95% of the variance in these cases. Similarly impressive individual fits now have been reported in a number of studies (e.g., Green, Myerson, & McFadden, 1997; Madden et al., 1999; Rachlin et al., 1991; Richards et al., 1999; Simpson & Vuchinich, 2000a). Such findings suggest that models based on Equation 1 fit individual-subject functions as well as group ones, alleviating concerns about k values as an artifact of aggregating data across subjects.

Stability of temporal discounting patterns. Relatively little is known about the long-term stability of the index of temporal discounting (k). Simpson and Vuchinich (2000a), however, reported that k values for college students remained fairly constant across assessments separated by 1 week, and one of us (Critchfield) has collected pilot data suggesting stability over as long as 10 weeks. Bolstering the case for temporal discounting as an informative measure of impulsiveness are studies suggesting a relationship between k and relatively stable individual differences of obvious conceptual relevance.

Casual observation and clinical data testify to heightened impulsiveness of certain groups of individuals. For example, habitual drug users are often thought of as impulsive (e.g., Evenden, 1999) in the sense that they trade the short-term pleasures of intoxication against a variety of long-term costs (e.g., hangovers, lost job productivity, impaired relationships, etc.). Heavy alcohol or other drug consumption might be regarded as one measurable outcome in a pattern of impulsive choices. Consistent with this assumption, temporal discounting studies demonstrate that binge drinkers (Vuchinich & Simpson, 1998), cigarette smokers (Bickel, Odum, & Madden, 1999; Mitchell, 1999), and heroin addicts (Kirby, Petry, & Bickel, 1999; Madden, Petry, Badger, & Bickel, 1997) all tend to discount the value of delayed rewards at a faster rate than comparison groups. In addition, evidence for heightened impulsiveness, as measured by the temporal discounting procedure, has been found in intravenous drug users who are willing to share needles (Odum, Madden, Badger, & Bickel, 2000) and in substance abusers with concomitant gambling problems (Petry & Casarella, 1999).

Perhaps analogously, college students who eschew safe-sex practices appear to have higher *k* values than sexually active students who take precautions against disease and pregnancy (Farr, 1998). And, consistent with age-level stereotypes about impulsiveness, sixth graders tend to have higher *k* values than college students, who tend to have higher *k* values than elderly adults (Green, Fry, & Myerson, 1994). In all of the cases just described, the index of temporal discounting (*k*) appears to be correlated with relatively stable behavioral differences between groups of individuals.

The index of temporal discounting also has been found to reflect situational dynamics of conceptual relevance to a behavioral analysis. For example, individuals living in Poland's wildly inflated economy of the early 1990s, who became accustomed to rapid decline in the value of money, tended to have higher *k* values than individuals living in the less volatile economy of the United States. The between-nations difference disappeared, however, after Poland's inflation was brought under control a few years later (Ostaszewski, Green, & Myerson, 1998). In another study involving only participants from the United States, individuals with low annual incomes showed more pronounced temporal discounting than individuals with higher incomes (Green, Myerson, Lichtman, Rosen, & Fry, 1996). These between-groups comparisons suggest that individual sensitivity to delay may depend on establishing operations that are specific to the consequences under consideration, but apparently no research has addressed this problem experimentally with humans at the individual level.[2]

If *k* is a context-sensitive, experience-driven measure of impulsiveness, then it should vary with the specific hypothetical consequences under consideration. Indeed, larger rewards are discounted proportionally less than smaller ones (Green et al., 1997). In addition, *k* can differ within individuals for different types of hypothetical outcomes (e.g., money vs. health, Chapman, 1996; heroin vs. money in opioid-dependent individuals, Madden et al., 1997). The latter outcome makes sense if one assumes that *k* is affected by ongoing histories of experience with environmental contingencies, which could differ for different classes of consequences.

Summary. From the perspective of traditional behavior-analytic methods, temporal discounting laboratory procedures have some unusual features. Nevertheless, these procedures have spawned outcomes that nicely suit the conceptual framework of behavior analysis. The findings of temporal

[2] Several studies involving edible reinforcers have found no systematic effect of deprivation level on preference for delayed reinforcers in nonhuman animals (Logue, Chavarro, Rachlin, & Reeder, 1988; Logue & Peña-Correal, 1985; Richards et al., 1997). An obvious contrast between these studies and those in the human temporal discounting tradition involves the type of reinforcer (primary vs. conditioned or hypothetical). The recent development of self-control procedures in nonhumans involving conditioned reinforcers (Jackson & Hackenberg, 1996) may provide a means to shed further light on this issue.

discounting studies with humans are broadly consistent with nonhuman animals' choices involving real, briefly delayed consequences and humans' choices in many everyday situations. In bridging these observations, temporal discounting research bolsters confidence in interpretations of human affairs based on principles illuminated in animal self-control studies while simultaneously providing a reminder that the time scale on which important human events occur can be quite large.

THE TEMPORAL CONTEXT OF SOCIALLY IMPORTANT BEHAVIOR

Of what practical value are the findings of temporal discounting studies with humans? Below, we discuss two possibilities. First, as some of the studies cited previously suggest, special populations of individuals might be distinguished in terms of temporal discounting. Using ADHD as an example, we review some of the advantages of attempting to study temporal discounting in clinically relevant cases of impulsiveness. Second, temporal discounting research suggests that the consequences that affect behavior can be distributed over an extended time frame. Using substance abuse as an example, we consider some of the implications of this general perspective for the study of socially important behavior in the natural environment.

Functional Characteristics of Psychological Disorders

As those who provide behavior-analytic services are well aware, the topographical features of psychological disorders often provide little insight into the functional properties of problem behavior (e.g., Scotti, Morris, McNeil, & Hawkins, 1996). An important contribution of functional analysis methodology (Iwata, Dorsey, Slifer, Bauman, & Richman, 1982/1994) lies in highlighting the distinction between topography and function. To date, functional analysis procedures have been applied to fairly limited classes of problem behavior (e.g., self-injury and aggression) in relatively few diagnostic categories (e.g., developmental disorders). One way for applied behavior analysis to extend its scope is to address the problems associated with other disorders.

It has long been recognized that certain populations can be distinguished using laboratory procedures that tap fundamental behavior principles (e.g., Harzem, 1984). For example, violent criminals differ from nonviolent ones in their performance on an operant laboratory measure of aggression (Cherek, Schnapp, Moeller, & Dougherty, 1996). Individuals diagnosed with bipolar disorder show a different relation between reinforcement rate and response rate when manic than when depressed (Bradshaw & Szabadi, 1978). The temporal discounting literature makes clear that different groups of humans tend to discount delayed rewards more or less. Given their utility in distinguishing substance abusers from controls (e.g., Bickel et al., 1999; Madden et al., 1997; Vuchinich & Simpson, 1998), temporal discounting procedures might prove useful in assessing a variety of clinical populations in which impulsive choices typically are of concern.

Consider the behavior problems associated with a diagnosis of ADHD. ADHD, which incorporates developmentally inappropriate levels of impulsiveness and global activity, has received relatively little attention from applied behavior analysts.[3] This may

[3] An electronic keyword search of *JABA* contents conducted during preparation of this article found that ADHD, which occurs in 3% to 5% of school-aged children (American Psychiatric Association, 1994), was addressed in only 14 of 322 articles, whereas autism, which is estimated to be about 100 times less prevalent than ADHD, was the focus of over 100 articles. See the *JABA* web site at http://www.envmed.rochester.edu/wwwrap/behavior/jaba/jabahome.htm.

be explained, in part, by the fact that children with ADHD typically live at home, attend regular classes in public schools, and receive brief outpatient therapy, whereas applied behavior-analytic research often is conducted in controlled therapeutic settings that are amenable to long-term, single-subject investigations. Not surprisingly, ADHD usually is characterized using terms and constructs that are not functionally defined. It may not be widely known within behavior analysis, therefore, that ADHD has been has been conceptualized in ways that bring to bear the effects of environmental events, such as delay to consequences (Sonuga-Barke, Taylor, Sembi, & Smith, 1992) and sensitivity to reinforcement (Barkley, 1997; Kollins, Lane, & Shapiro, 1997; Murray & Kollins, 2000; Schweitzer, 1996).

Perhaps the most influential account of ADHD is that of Barkley (1997), who has attributed the disorder to a small constellation of factors, the most salient of which is behavioral inhibition, which can be conceptualized as the extent to which behavior is influenced by its consequences. For instance, Barkley has asserted that

> Inhibition and its related executive functions may be most obvious (and most needed) when a delay of a consequence is imposed in a task, when a conflict is confronted between the immediate and delayed consequences of a response, or when a problem arises that requires generating a novel response to resolve it. . . . Conditioned signals of punishment from experiences and prior socialization may be the determinants of when inhibition and self regulation are engaged. (p. 68)

Stated differently, Barkley's model suggests that the problems seen in children diagnosed with ADHD can be described in functional terms that relate measurable environmental events (like time and reward magnitude) to the problem behavior in question. Specifically, this model predicts that "a form of temporal myopia should exist in children with ADHD, in that behavior is more controlled by the temporal 'now' than by internally represented information pertaining to the past, the future, and the sense of time" (Barkley, 1997, p. 77).

ADHD behaviors have been explained in terms of sensitivity to reinforcement before (e.g., Douglas & Parry, 1994), but it is important to note that, in operant terms, this sensitivity can be conceptualized in many ways. Indeed, the testability of any consequence-based model of ADHD depends on clarifying the definition of *sensitivity.* For instance, sensitivity to reinforcement might suggest effects related, or unrelated, to temporal discounting. In the latter case, one form of sensitivity is evident in the degree to which behavior allocation reflects the discrepancies between two or more sources of immediate reinforcement, as per the matching law (Baum, 1974; Kollins et al., 1997). Barkley's (1997) model, its references to internal representations notwithstanding, places ADHD behaviors squarely in the context of immediate and delayed consequences. The model suggests that, in persons with ADHD, immediate reinforcers are unusually potent because competing reinforcers are heavily discounted due to delay. The model also suggests that people diagnosed with ADHD are relatively unaffected by delayed punishment. Because of its specificity, Barkley's theoretical model appears to be eminently testable. Unfortunately, tasks commonly used to evaluate impulsiveness associated with ADHD (Corkum & Siegel, 1993; Oosterlaan, Logan, & Sergeant, 1998) were not designed to isolate temporal discounting effects. Investigators who understand temporal discounting theory and related experimental procedures (e.g., behavior analysts) thus stand poised to make notable contributions to this rapidly growing area of clinical psychology.

Approaching the behavior problems associated with ADHD from the standpoint of temporal discounting allows some specific predictions to be generated. First, individuals with ADHD should discount the value of delayed rewards differently than undiagnosed controls (e.g., if impulsiveness reflects unusually rapid reinforcer discounting, then *k* should be larger for ADHD children). Second, individuals with ADHD should discount punishers (costs) more than reinforcers (gains). Third, across individual cases, the magnitude of temporal discounting effects (the size of *k* or the discrepancy between *k* for reinforcement and *k* for punishment) should be correlated with severity of behavior problems. Fourth, treatments that alleviate symptoms of ADHD should have conceptually interpretable effects on temporal discounting patterns. For example, because stimulant drugs like methylphenidate are among the interventions of choice for ADHD, one might expect them to reduce sensitivity to delay (i.e., result in smaller values of *k*) in persons diagnosed with ADHD. We are aware of no published studies that have explicitly examined these relations,[4] but data from a number of sources suggest that choices involving immediate consequences and delayed alternatives may play a significant role in the behavior of such individuals. For example, there appear to be links between ADHD behavior and substance use (Levin & Kleber, 1995), accidents (Schubiner et al., 2000), educational and occupational difficulties (Mannuzza, Klein, Bessler, Malloy, & Hynes, 1997), and aggression (e.g., Pliszka, 1998), all of which can be thought of as producing immediate reinforcers combined with delayed risks and costs.

An obvious opportunity exists to shed light on the functional properties of impulsiveness as exhibited by individuals with ADHD. Traditional operant laboratory tasks (e.g., those that emphasize self-control and sensitivity to reinforcement) could provide one valuable form of assessment, because they bring well-elaborated behavioral principles to bear on problems like those in ADHD (e.g., Kollins et al., 1997; Saldana & Neuringer, 1998; Sonuga-Barke et al., 1992). For practical reasons related to the settings in which ADHD children usually are encountered, however, many operant tasks may be difficult to apply widely. For example, it may be difficult to arrange meaningful delays to reinforcement in brief laboratory procedures, and substantial schedule exposure may be required to generate stable response patterns. Hypothetical temporal discounting tasks, which are relatively quick and easy to administer, could provide a convenient, alternative means of estimating discounting functions (at least in individuals who are old enough to understand the questions). Temporal discounting tasks thus might promote the goal of describing ADHD problem behavior patterns in functional and measurable terms, along dimensions defined by the independent variables known to influence choice generally. Moreover, because the procedures of temporal discounting seem so obviously related to behavioral characteristics (e.g., impulsiveness) already assumed to underlie ADHD, the procedures offer a degree of face validity that could help temporal discounting procedures find acceptance where traditional laboratory schedules do not.

Viewing ADHD partly as a problem in temporal discounting immediately suggests factors worthy of basic and applied investiga-

[4] Recent research suggests that the stimulant *d*-amphetamine reduces temporal discounting in pigeons (e.g., Hummel & Pitts, 2000). In addition, a number of laboratory studies suggest that methylphenidate tempers impulsiveness in ADHD children (e.g., Arnett, Fischer, & Newby, 1996; Casat, Pearson, Van Davelaar, & Cherek, 1995), but the procedures typically do not permit an analysis in terms of temporal discounting.

tion (e.g., reinforcer magnitude, type, and delay). A variety of benefits could accrue as the relation becomes clearer between these factors and the socially important problems associated with ADHD. Ultimately, the goal would be to understand relations between ADHD behaviors and temporal discounting well enough to inform individual interventions. It might be possible, for example, to distinguish subtypes of the disorder (e.g., based on the discounting of different types of consequences), and a clear functional description of individual cases will naturally suggest intervention strategies (e.g., Dixon et al., 1998), such as the shaping of tolerance for delay (e.g., Schweitzer & Sulzer-Azaroff, 1988, 1995). If this sequence of events sounds reminiscent of the process of functional analysis, the parallel is drawn intentionally.

Socially Important Behavior As Choice Over an Extended Time Frame

As the preceding example suggests, laboratory procedures can advance the conceptualization of clinical problems. Ultimately, however, efforts to understand socially important behaviors must draw applied behavior analysts into the natural environments in which problem behaviors occur. Basic research on temporal discounting can be broadly informative to these efforts in two ways. First, in portraying sensitivity to consequences as a problem of choice, temporal discounting procedures provide a reminder that, in a world of limited time and effort, all behavior occurs at the expense of other behavior. Competing contingencies usually loom large, and thus response strength is a function of the strength of alternative behaviors (e.g., Baum, 1974), as mediated by factors such as response effort and the frequency and magnitude of reinforcers and punishers (e.g., Friman & Poling, 1999; Madden, 2000).

Second, temporal discounting research places choice into an extended temporal context. Although operant consequences lose efficacy with delay, even delayed consequences can have an impact on behavior (e.g., Lattal & Gleeson, 1990; Stromer, McComas, & Rehfeldt, 2000). Behavior can be affected by events that occur over extended intervals, and this has important implications for attempts to understand behavior in natural environments. With the passage of time, responses and consequences aggregate, and as they do their relations grow ever more complex (e.g., a single consequence can influence a variety of responses preceding it; Dews, 1962). For this reason, it may prove difficult to fully characterize socially important behavior in terms of discrete response–consequence relations. Indeed, several temporal discounting studies point to the utility of thinking about consequences in more molar terms. For instance, in laboratory studies involving hypothetical outcomes, participants tend to respond differently to a single delayed reward than to a sequence of rewards spaced over time, even when total delay and total amount of reward are equated in the two cases (Hsee, Loewenstein, Blount, & Bazerman, 1999; Kudadjie-Gyamfi & Rachlin, 1996; Stevenson, 1993). Stevenson has described this outcome as analogous to conditioned reinforcement effects in chained schedules (although other interpretations exist; Hsee et al., 1999).

Molar sequences of responses may be just as important as sequences of consequences (Rachlin, 1995b). For example, Siegel and Rachlin (1995) allowed pigeons to respond for food in a typical discrete-trial self-control task. When choices were made with a single key peck, pigeons preferred the SSR. But when choices were made by completing a fixed ratio of 31 responses, the first 30 of which could be distributed in any way across the two keys, the LLR was preferred more often. This increased preference might arise because the time necessary to complete the ratio requirement created added delay for both alternatives; such a delay would be expected to differentially affect the subjective value of the SSR (e.g., Rachlin, 1989). Another possibility noted by Siegel and Rachlin is that the time and effort required to move from one operandum to another may have functioned like changeover cost, known to promote preference for the richer of two concurrent response alternatives (e.g., Aparicio & Baum, 1997). What is striking for present purposes is that the pigeons tended to initiate pecking on the LLR key and persist there until reinforcement had been earned, although switching between keys was allowed by the procedure. Whatever the explanation for this tendency, it is clear from these results that sequences of responses can sometimes function differently than discrete responses in choice situations.

The example of substance abuse. One type of socially important behavior to which these lessons might be applied is maladaptive alcohol and drug consumption. Most excessive drinking and drug use does not take place in a professional office or in a treatment program, and thus bears inspection in the natural environment. Some socially important aspects of substance use (e.g., abuse, recovery, relapse) are, by their nature, molar phenomena, not fully describable without referring to sequences of events over extended time periods.

Drug and alcohol abuse often has been examined within a choice framework, especially in laboratory research (e.g., Bickel, DeGrandpre, & Higgins, 1993). For example, the amount of responding maintained by drug reinforcers tends to vary with the availability and characteristics of alternative reinforcers (e.g., Bickel, DeGrandpre, & Higgins, 1995; Woolverton & Alling, 1999). Consistent with this corpus of research, Vuchinich and Tucker (e.g., Vuchinich, 1982, 1995; Vuchinich & Tucker, 1983, 1988) have applied a behavioral choice perspective toward understanding alcohol problems in the natural environment. In general, they have argued, drinking-related behavior produces favorable immediate consequences (such as intoxication) but unfavorable delayed ones (such as hangover and health problems). Drinking competes for time and resources with nondrinking behaviors, which tend to facilitate favorable delayed consequences (e.g., good health and relationships) but less tangible immediate benefits. The research program of Vuchinich and Tucker (e.g., 1996; Tucker, 1995; Tucker, Vuchinich, & Pukish, 1997) illustrates how behavioral choice concepts can be applied to behavior that occurs in the natural environment, where the time frames of interest can be quite extended. This research has addressed two specific problems in alcohol abuse: First, why do habitual heavy drinkers sometimes abstain from drinking, either independently (i.e., spontaneous recovery) or by seeking treatment? Second, why do alcohol abusers who have received treatment start drinking again (relapse)?

To answer questions about drinking habits, one needs a way to track the occurrence of drinking episodes, and environmental events that might contribute to them, over periods lasting weeks, months, or even years. Direct observation usually is not an option. Fortunately, extensive methodological research has identified conditions under which self-reports, as a form of behavioral assessment by proxy, yield valid data on the real-time distribution of drinking episodes and potentially important environmental events (e.g., Babor, Stephens, & Marlatt, 1987; Maisto, Sobell, Cooper, & Sobell, 1982; O'Farrell & Maisto, 1987; Sobell, Sobell, Leo, & Cancilla, 1988). Through interviews with problem drinkers, Vuchinich and Tucker examined the temporal patterning of drinking and its relation to a variety of environmental events that were presumed to reflect the reinforcing value of engaging in nondrinking alternative behaviors.

In general, individuals who ceased drinking had experienced a variety of drinking-related outcomes that appeared to threaten the availability of non-drinking-related reinforcers. These events, which tended to accumulate before help seeking or spontaneous recovery began, included difficulties in social, vocational, and intimate relationships, as well as in health and finances (George & Tucker, 1996; Tucker, 1995; Tucker et al., 1997). Thus, the costs of drinking had become temporally acute. Relapse among recovering alcohol abusers also was related to non-drinking-related events. For example, one study found that, in problem drinkers recently released from treatment, adverse social and vocational events tended to precede episodes of drinking. In addition, the degree of disruption in these areas experienced prior to treatment predicted the strength of the posttreatment association between life events and drinking (Vuchinich & Tucker, 1996).

Such findings, though readily understood in behavior-analytic terms, are difficult to describe in the language of discrete response–consequence relations. Instead, they depict a molar relation between overall patterns of drinking and aggregated consequences for alternative (nondrinking) behaviors, extending over a relatively lengthy time interval. This relation is important to note for at least three reasons. First, results like those just described parallel findings from laboratory drug self-administration research, indicating that drug use is integrally related to the availability of nondrug consequences. Second, such findings can inform the development of treatment protocols. For example, it seems obvious that addiction treatment should address the choice context in which drug consumption occurs, in particular by establishing and enhancing nondrug reinforcers (e.g., Higgins & Silverman, 1999; Hunt & Azrin, 1973). Within that context, if the reinforcing consequences of drinking are immediate, but those accruing from nondrinking alternatives may be deferred, then temporal discounting probably renders drug reinforcers especially powerful in relative terms. According to principles of behavioral momentum (e.g., Nevin, 1996), the more richly reinforced of two behaviors should be more difficult to change, making one common feature of drug treatment programs, abstinence training (i.e., extinction for drug-related behaviors) a difficult challenge. Therefore, it may be productive for treatment programs to focus initially on boosting reinforcement for alternative behaviors (e.g., Higgins & Silverman, 1999; Vuchinich & Tucker, 1998).[5] Finally, information about the choice and temporal context of socially relevant behavior can inform public policy decisions about which prevention, intervention, and interdiction programs are cost effective and worthy of public funding (e.g., Tucker, Donovan, & Marlatt, 1999), levels of analysis that behavior analysts rarely address.

Extension to other behaviors. The analysis of alcohol-related problems in the natural environment provides a useful model for inquiries into other kinds of behavior problems (e.g., see Simpson & Vuchinich, 2000b). Consider, for example, the challenges inherent in studying eating and exercise habits, which are important to understand because overeating promotes, and physical activity serves as a buffer against, a variety of problems ranging from cardiovascular disease to orthopedic difficulties (e.g., U.S. De-

[5] Admittedly, similar insights might be generated without reference to the temporal discounting literature. For example, the community reinforcement model of drug abuse treatment was pioneered before most of the research we describe was conducted (Hunt & Azrin, 1973). This model involves arranging alternative reinforcement by enhancing social and family relationships, job prospects, and other sources of immediate reinforcement unrelated to alcohol. Nevertheless, the success of this treatment model (e.g., Higgins et al., 1991) makes greater sense in light of a temporal discounting analysis.

partment of Health and Human Services, 1996). As is true for alcohol consumption, most eating and exercise do not take place in the laboratory.

Impetus for examining eating and exercise in the natural environment comes from laboratory research placing these activities squarely within a behavioral choice framework. Studies have found exercise rates to depend on response requirements (de Luca & Holborn, 1990, 1992) and on the cost of sedentary alternatives (Epstein, Smith, Vara, & Rodefer, 1991). Food choices have been shown to depend on the response cost for less preferred alternatives (Laipalainen & Epstein, 1990; Smith & Epstein, 1991). These patterns are broadly consistent with behavioral choice principles, and there is some evidence that they accurately model behavior in the natural environment. In one study, for example, children played a computer game that incorporated concurrent reinforcement schedules, in which one response alternative produced access to sedentary activities (such as watching videotapes) and the other produced access to physically demanding activities (e.g., riding an exercise bicycle). The response requirement for the physical activity remained constant while that for the sedentary activity was systematically varied to determine an indifference point. Indifference points proved to be a good predictor of global physical activity level at home, as measured through an accelerometer (Epstein, Kilanowski, Consalvi, & Paluch, 1999). Taken together, results like these provide encouragement that eating and exercise, when studied in the natural environment, may be understood in the terms of the present discussion. Further encouragement can be found in the success of behaviorally oriented programs for promoting healthier lifestyles (Marcus et al., 2000).

With the right measurement tools,[6] what might be learned about eating and exercise choices in the broader temporal context of the natural environment? Few relevant studies exist, but the framework under discussion yields several general predictions for which provisional support can be found. It may be assumed, for example, that molar reinforcement variables will predict entry into problems of overeating and too little exercise, recovery from these problems, and relapse in those who have established healthy eating and exercise habits. Indeed, using procedures like those described previously for alcoholism research, Tinker and Tucker (1997) examined the factors that predict natural recovery from obesity, and found that recovery was associated with molar life events (alternative reinforcers) similar to those found to influence alcohol consumption. It may also be assumed that eating and exercise choices will depend on delay to access of relevant reinforcers, including those for alternative behaviors. Laboratory research shows that the choice of active versus sedentary behavior is influenced by the proximity of exercise facilities (Raynor, Coleman, & Epstein, 1998). Similar findings were obtained in a community study that showed a negative relation between exercise and distance from home to public exercise facilities (Sallis et al., 1990). Presumably, more distant facilities impose a delay on access to activity-related reinforcers, thus discounting their value. De-

[6] Observational systems exist for coding children's eating and activity patterns in natural environments. For example, that of McKenzie et al. (1991) treats eating as behavior (rather than simply a route of administration for calories), and focuses on the antecedents and consequences of eating and exercise. Direct observation is not always an option, however, placing a premium on self-reports and other alternative measures. Unfortunately, researchers are still wrestling with how to generate reliable self-reports about eating and exercise (e.g., Neumark-Sztainer, Jeffery, & French, 1997). Behavior analysts who work in this domain might, therefore, need to engage in methods development to support their research.

lay also may play an important role in certain interventions for overeating. For example, it is common to recommend that snacks in the house be placed out of sight and out of reach to maximize the time and effort needed to obtain them (e.g., Stuart & Davis, 1974).

GENERAL IMPLICATIONS

In principle, a perspective grounded in temporal discounting concepts can inform the analysis of almost any behavior in the natural environment that incorporates delayed consequences or consequences that aggregate over time. Consider, as examples, relationship success, the allocation of time between work and family life, academic study patterns, child discipline habits of parents and teachers, actions that affect the likelihood of household accidents, consumer habits relevant to resource conservation and environmental pollution, selected behaviors of political candidates and elected officials, and corporate investment in research and development. Nothing known to date renders fundamental principles of behavior incompatible with such cases, leaving the field free, in principle, to choose among the many interesting topics awaiting a behavioral analysis. But the field's choice of topics necessarily reflects choices among methods of investigation. Understanding behavior in the natural environment will require valid means of examining the distribution over time of events that investigators do not control (including stable individual differences in patterns of responses to these events).

Few readers would reject ADHD behaviors, drug abuse, or eating and exercise problems as trivial topics for an applied science, but questions may linger regarding the present suggestions for examining problems like these in the natural environment. Is this really applied behavior analysis? In mounting a case for the relevance of temporal discounting research to applied behavior analysis, the present article has invoked self-report measurement, selected studies involving group-level or descriptive analyses, and an analytical framework in which the relation between individual responses and consequences may not always be evident. Standard conceptions of the field hold most of these practices in low regard (e.g., Baer et al., 1968, 1987; see also Derenne & Baron, 1999). Yet our approach is hardly novel. Proposals for extending the reach of applied behavior analysis into natural settings span most of the field's history (Baer et al., 1968; Carr, 1994; Nordquist & Wahler, 1973), and these proposals have acknowledged the utility of descriptive methods (Bijou, Peterson, & Ault, 1968; Epstein, Parker, McCoy, & McGee, 1976; Lalli, Browder, Mace, & Brown, 1993; Wahler & Fox, 1981), self-report methods (Finney, Putnam, & Boyd, 1998; Winnett & Neale, 1981), and molar-level descriptions of behavior (Wahler & Fox, 1981).

Baer et al. (1987) bemoaned the fact that "applied researchers increasingly transform questions to fit known designs and their rules, rather than constructing a design that answers the original question" (p. 319). Perhaps applied behavior analysis should be whatever it *must* be to allow behavior-analytic thinking to contribute to the solution of important problems. For instance, group-level analyses usually are eschewed in behavior analysis, but consider the problem of identifying life events relevant to alternative reinforcement effects in the individual course of alcohol abuse. Among the myriad possible life events not related to alcohol consumption, which should be measured? Group-level and descriptive analyses might permit the identification of candidate variables worthy of further experimental analysis at the individual level. Consider also that some problems, such as those involving diagnosis and classification of disorders like

ADHD, may be impossible to evaluate without some reference to a *population* of affected individuals (e.g., see Iwata et al., 1994). In such cases, group research methodology might well be appropriate to the research question. Of greater importance than the methods employed in a specific investigation, therefore, are the conceptual rigor invested in devising and answering the research question, and the capacity of the investigation to promote new analyses and interventions (including those at the individual level).

Applied behavior analysis can extend its influence by considering the broader context of behavior. To do this, the field must preserve its conceptual core while innovating methodologically. Opportunities to address new and important problems thus carry with them a burden of methods development, which is an effortful exercise with uncertain endpoints. An additional burden, that of disciplinary self-examination (Baer et al., 1987), may be encountered when strategies of practical appeal run afoul of long-held conceptions of what constitutes a behavioral analysis. Do the present examples, and the kinds of opportunities they exemplify, belong within applied behavior analysis, or are they something else? Some readers, inevitably, will view nontraditional approaches as the slippery slope toward a weaker science, but many decades of refinement have made applied behavior analysis strong and stable enough to safely admit some variability. Perhaps the more relevant question is whether applied behavior analysts can afford *not* to pursue topics like those discussed here. As the example of substance abuse illustrates, others are forging ahead with analyses of important behavior in the natural environment that bespeak operant principles. It seems logical that *JABA* and its contributors should be a part of this movement.

In summary, the natural environment is rife with opportunities for analyzing important, temporally extended behaviors. Seizing these opportunities can, ideally, promote growth in the field: new methods, new populations, and new conceptual emphases to complement existing ones. Yet the natural environment poses self-control problems for behavior analysts, not just for those whose lives they hope to enrich. Existing research programs can yield successes relatively quickly. New lines of investigation produce benefits only after much effort and delay. Fortunately, the rewards of solving behavior problems in the natural environment can be substantial, and laboratory research suggests that large rewards are discounted relatively little due to delay (e.g., Green et al., 1997). The present article has sought to magnify the discriminative features of those rewards.

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