JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 2011, **96,** 427–439 NUMBER 3 (NOVEMBER)

DELAY DISCOUNTING: I'M A K, YOU'RE A K

Amy L. Odum

UTAH STATE UNIVERSITY

Delay discounting is the decline in the present value of a reward with delay to its receipt. Across a variety of species, populations, and reward types, value declines hyperbolically with delay. Value declines steeply with shorter delays, but more shallowly with longer delays. Quantitative modeling provides precise measures to characterize the form of the discount function. These measures may be regarded as higher-order dependent variables, intervening variables, or hypothetical constructs. I suggest the degree of delay discounting may be a personality trait. In the end, the ontological status of measures of delay discounting is irrelevant. Whatever delay discounting may be, its study has provided the field of behavior analysis and other areas measures with robust generality and predictive validity for a variety of significant human problems. Research on moderating the degree of delay discounting has the potential to produce substantial societal benefits.

Key words: review, delay discounting, impulsivity, self control, pigeon, rat, human

---

Given a choice, most of us would rather have rewards sooner rather than later, and to have more of them rather than less. Choices are less straightforward, and more interesting, when these dimensions are in tension: less now, or more later. For example, many of us would prefer to have a healthy body weight rather than eat a piece of cake. The problem is that the piece of cake, although worth less to us overall, is available right now with little effort beyond lifting our fork, whereas the healthy body weight may require time and exertion. Although in this example there are multiple factors to be considered, we can feel the basic issue at work. Immediate rewards weigh disproportionately in our decision making: The failing student goes out to party the night before an exam; the smoker relapses after swearing off cigarettes; the obese person eats another bag of chips. Behavior analysts term the smaller sooner reward the *impulsive* choice, and the larger later reward the *self-controlled* choice (e.g., Ainslie, 1974).

One factor the above examples of maladaptive behavior share is delay discounting: the tendency for more remote outcomes to have less value (e.g., Mazur, 1987). Value may be measured in different ways. One measure of value is the rate of behavior a consequence will support. In general, behavior with immediate consequences occurs at a higher rate than behavior with delayed consequences (see Lattal, 2010, for review). Another measure of value, which will be the focus of this Perspective, is choice or preference. In general, immediate rewards are preferred to delayed rewards (e.g., Chung & Herrnstein, 1967).

Delay discounting is a burgeoning area of research with implications for many socially important issues including obesity, drug abuse, and gambling. The number of papers on the topic has been growing rapidly in recent years (see Madden & Bickel, 2010), and PubMed lists over 60 articles published in 2010 (the last complete year) with the key words ''delay discounting''. The *Journal of the Experimental Analysis of Behavior* has been historically and continues to be a frequent publisher of delay discounting research (see Calvert, Green, & Myerson, 2010; Eppolito, France, & Gerak, 2011; Green, Myerson, & Calvert, 2010; Jones & Rachlin, 2009; Locey & Dallery, 2009; Mazur & Biondi, 2009, 2011; Valencia Torres et al., 2011, for a variety of recent examples). At this point in the development of the field, I thought it would be interesting to reflect on what delay discounting is, and what it might mean. After reviewing, in brief, procedures for assessing delay discounting, I will focus on techniques for analyzing data from delay discounting procedures and what the resulting analyses show. I will give some notion of the generality and scope of the empirical literature

---

Preparation of this manuscript was supported in part by grant R01DA029100 from the National Institute on Drug Abuse. I would like to thank Tim Shahan, Greg Madden, and my laboratory group for helpful discussion.

Correspondence regarding this article may be addressed to Amy Odum, Department of Psychology, 2810 Old Main Hill, Utah State University, Logan, UT, 84322 (e-mail: Amy.Odum@usu.edu).

doi: 10.1901/jeab.2011.96-423

on delay discounting, as well as conclusions and potential future directions.

HOW TO ASSESS DELAY DISCOUNTING

At their heart, delay-discounting procedures are about finding the point at which two rewards, one relatively immediate and one delayed, have approximately the same value. For example, in Mazur's (1987) adjusting-amount procedure, pigeons chose between 2 s access to grain available after 2 s and 6 s of grain available after a delay. The duration of the delay changed based on the choice. If the pigeon chose the smaller sooner option, then the delay to the larger later option decreased. If the pigeon chose the larger later option, then the delay to the larger later option increased. Importantly, the duration of the intertrial interval (ITI) varied depending on the choice so as to keep the overall time between choices constant, so that the pigeon could not increase the overall rate of food deliveries by choosing the smaller sooner option. The adjustment process continued across trials until a pigeon was essentially indifferent between the two options: About 50% of the time it chose the smaller sooner grain, and about 50% of the time it chose the larger later grain. The duration of the delay to the larger later grain is a dependent variable, called the *indifference point*, which represents the value of the delayed outcome. For example, for a pigeon 2 s of food delayed by 2 s might be equivalent to 6 s of food delayed by 4 s. Mazur (1987) assessed the value of the larger later option at a range of delays to the smaller sooner option and found that as the delay to the 2 s of grain increased across conditions, the adjusted duration of the delay to the 6 s of grain (the indifference point) increased. He used the specific form of this function to decide between different quantitative models of how delay affects value (to be discussed below in DATA ANALYTIC TECHNIQUES).

A variety of other procedures can be used to assess how delay affects the value of an option for nonhuman animals. For example, rather than adjusting the delay to one of the options, the amount of an option can be adjusted across trials while the delay is held constant (e.g., Richards, Mitchell, de Wit, & Seiden, 1997). The two procedures (adjusting delay and adjusting amount) produce similar estimates of the degree of discounting (Green, Myerson, Shah, Estle, & Holt, 2007). The most prevalent way to determine how delay affects value in nonhumans is using a procedure developed by Evenden and Ryan (1996). Animals are offered a set list of choices between a smaller sooner option and a larger later option. The delay to the larger later option increases across blocks within the experimental session, making this procedure the most efficient. The procedure does not determine indifference points, however, but instead uses percent of choices for the larger later option as a dependent measure. Madden and Johnson (2010) provide extensive description and consideration of the procedures available for determining discount functions in nonhuman animals as well as in humans.

In assessing how delay affects the value of outcomes with humans, researchers commonly ask people to make a series of choices between hypothetical options, rather than giving them the consequences associated with each choice as is done with nonhumans. For example, Rachlin, Raineri, and Cross (1991) asked college students to choose between $1,000 available today and $1,000 available in a month. The amount of the immediate option decreased across trials until it reached $1, then increased back up to $1,000. The indifference point was the average amount at which the participant switched preference. So for example, a participant would prefer $1,000 today over $1,000 in a month, but then at $960 today might switch to choosing the delayed option through the rest of the trials as the immediate amount continued to decrease. When the immediate amount then increased across trials, the participant would initially prefer the delayed $1,000, but then at perhaps $940, would switch to choosing the immediate amount again. In this example, the indifference point would be $950. Across blocks, Rachlin et al. increased the delay to the larger later amount, up to 50 years, and determined indifference points at each delay. In general, the indifference points decreased as the delay to the larger amount increased. This is the empirical demonstration of delay discounting: The value of money is degraded systematically as the money becomes more remote.

Delay discounting by human participants can be assessed using a wide variety of techniques (see Madden & Johnson, 2010).

In another procedure that uses hypothetical outcomes, indifference points are determined by adjusting the amount of the immediate outcome based on the participant's choice (Du, Green, & Myerson, 2002), rather than by moving through a fixed list of options as in Rachlin et al. (1991). In a short version of the task developed by Kirby and colleagues (Kirby & Marakovic, 1996; Kirby, Petry, & Bickel, 1999), participants are asked relatively few questions, and the degree of discounting is interpolated from their choices. In this procedure, researchers sometimes select one choice to consequate (see ''potentially real rewards'', below). The majority of publications in the area of human delay discounting, however, use purely hypothetical outcomes.

Asking people to imagine what they think they would prefer is of course not the same as having them make a choice and receive the consequences. The hypothetical money choice tasks described in the paragraphs above have generated skepticism and attempts to develop other procedures with better face validity. In the Experiential Discounting Task (EDT; Reynolds & Schiffbauer, 2004), for example, participants experience the delays and amounts of money that they choose. On each trial, participants decide between a delayed and uncertain standard amount of money ($ 0.30) and an immediate adjusting amount. Across blocks of trials, the delay to the standard amount is changed to determine a discount function. The EDT differs from other delay discounting procedures by making the standard reward probabilistic in addition to delayed, and thus examines the simultaneous effects of delay and certainty on reward value. Additionally, unlike in the procedures used commonly with nonhumans (e.g., Mazur, 1987), the ITI in the EDT is the same duration for smaller sooner choices and larger later choices, so that participants could conceivably maximize local reinforcer rate by choosing the smaller option (see Madden & Johnson, 2010, for further discussion of the EDT). It can be argued that these features of the EDT make it correspond more closely to situations that people experience in their lives outside the laboratory (Reynolds, 2006). In some cases, behavior on the EDT could be more sensitive than other delay discounting measures to short-term state changes (e.g., acute drug intoxication, see Reynolds, 2006).

A number of articles have been devoted to comparing how choices made under tasks with hypothetical money compare to behavior in procedures that deliver some or all of the rewards people choose. For example, in what may be referred to as a ''potentially real rewards'' procedure, Johnson and Bickel (2002) gave participants the consequences (i.e., real money after a real delay) for one randomly selected choice they had made in each delay discounting assessment across a range of standard delayed monetary amounts. The degree of discounting did not differ between the potentially real rewards procedure and a purely hypothetical money choice task. Madden and colleagues (Lagorio & Madden, 2005; Madden, Begotka, Raiff, & Kastern, 2003; Madden et al., 2004) also found no substantial differences between discounting for real and/or potentially real rewards and hypothetical rewards using a variety of procedures, including one in which each delay and reward delivery was experienced. In some instances there could be differences in conclusions reached using real versus hypothetical rewards (e.g., Paloyelis, Asherson, Mehta, Faraone, & Kuntsi, 2010). The possibility remains that future studies, perhaps using larger sample sizes, could detect a small but consistent difference in discounting with real and hypothetical rewards, but at this juncture there appears to be good consistency across the techniques.

Doubtless, the similarity between choices made when the consequences are real (or potentially real) and when the consequences are purely imaginary has come as a surprise to many behavior analysts, including those who now use hypothetical money choice tasks in their own research. Asking participants to say what they think they would want sounds like a self-report procedure, and each student in a beginning research methods course should be able to describe the pitfall of self-report procedures: People may not accurately report their own behavior. In the case of delay discounting, however, people appear to be fairly good at describing what they would do (or at least what they would do in another type of delay discounting task). Why?

There are several reasons why people may be more accurate in reporting their preference for immediate versus delayed rewards than they are in reporting other things about themselves. One reason may be that in many self-report situations, people are being asked to describe something they have done in the past (e.g., ‘‘How often did you take your medicine as prescribed?’’). In delay discounting, people are not reporting on what they have done in the past, but instead are making a choice between which of two things they prefer at that moment. To choose, arguably, is to behave. The choice is not hypothetical, only the rewards. A second reason may be, unlike taking medication as prescribed, in delay discounting there is no obvious ‘‘right’’ or ‘‘wrong’’ option (and participants are usually explicitly instructed in this regard). Thus, the socially desirable answer is less obvious, and thus perhaps less likely to bias (whether consciously or unconsciously) participants' choices. Furthermore, there are no punitive contingencies associated with accurate reporting of behavior in delay discounting assessments, unlike in some perennially thorny self-report situations (e.g., ‘‘Who broke this lamp?’’).

Third, in many self-report instruments (e.g., the Barratt Impulsivity Scale; Barratt, 1985), people are asked to rate themselves, and perhaps implicitly to compare themselves to others. For example, imagine a simplified questionnaire in which I am asked to evaluate how well the word ‘‘self-controlled’’ describes me, with my options being ‘‘Rarely’’, ‘‘Sometimes’’, and ‘‘Often’’. I might think of myself in relation to my close friends, and decide I am about average. My friends may in general be highly self-controlled, or perhaps my friends are in general poorly self-controlled (whatever that might mean to me). If I think I am average with respect to my peers, my answer to the question would be the same in both cases: ‘‘Sometimes’’. I would answer this way despite the fact that in the first case, I might be more self-controlled than the average person in society at large, and in the second case, I might be less self-controlled than the average person in society at large. Unlike with some self-report instruments, however, in a delay-discounting task, I can report which of two things I would want without implicitly having to think how I compare to others. In short, I am not being asked to describe and judge myself in a delay-discounting task. This difference could be one of the factors underlying the inconsistent relations in the literature (see de Wit, Flory, Acheson, McCloskey, & Manuck, 2007; Reynolds, Ortengren, Richards, & de Wit, 2006) between self-report measures of impulsivity and the degree of delay discounting.

The strong correspondence between the degree of delay discounting as assessed with hypothetical and real rewards is but one example of the generality of delay discounting (see Odum, 2011, for a review). Another striking generality about delay discounting is that the same quantitative model accounts for indifference points as assessed across a variety of procedures, human populations, and species.

DATA ANALYTIC TECHNIQUES

Figure 1 shows examples of indifference points plotted as a function of delay to the larger later reward. These data, taken from individual participants who contributed to median values shown in Bickel, Odum, and Madden (1999), were generated using a procedure similar to that of Rachlin et al. (1991) described above. The participants were regular cigarette smokers and nonsmokers matched on a variety of demographic characteristics (ex-smokers were also tested, but no data from them are presented here for the sake of simplicity). They answered questions about which of two amounts of hypothetical money they would prefer, a delayed $1000 (the larger later option) or a reduced immediately available amount (the smaller sooner option). The delays ranged from 1 week to 25 years. In addition, cigarette smokers answered questions about delayed versus immediate hypothetical cigarettes. They were asked how much they paid for a carton of cigarettes, and the amounts were framed in terms of number of cartons (and fractions thereof) of their regular brand of cigarettes rather than in dollars. For further details, please refer to Bickel et al. (1999).

One notable feature of these data shown in Figure 1 is that as delay to the larger later reward increases, the indifference points decrease. These data are an empirical demonstration of delay discounting: As the reward becomes more remote, it has less value in the present. Another notable feature is that the indifference points differ for the 2 individuals shown. The squares in Figure 1 show

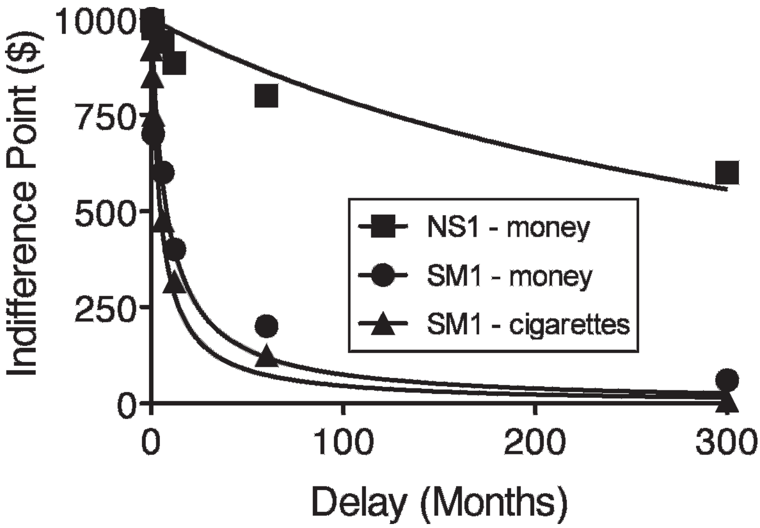

Fig. 1. Indifference points as a function of delay for an individual nonsmoking participant (NS1) and a smoking participant (SM1) for hypothetical money (NS1 & SM1) and hypothetical cigarettes (SM1). These participants were the first smoker and nonsmoker tested in a study by Bickel, Odum, and Madden (1999), who reported median data across groups. See Bickel et al. for details of the procedure. Lines show the best fit of Equation 1 to the data using GraphPad Prism®.

indifference points for money from an individual who did not smoke cigarettes (NS1), and the circles at lower values show indifference points for money from an individual who regularly smoked cigarettes (SM1). Steeper discounting by people who use drugs of abuse is a robust individual difference across a variety of substance use disorders (see Yi, Mitchell, & Bickel, 2010, for a recent review).

Another common feature in the delay discounting literature is also is also shown in Figure 1: The cigarettes (triangles) are discounted even more steeply than money (circles). In general, money is discounted less steeply than other types of rewards (see Estle, Green, Myerson, & Holt, 2007; Odum, 2011; Odum & Rainaud, 2003; Tsukayama & Duckworth, 2010). This effect extends beyond drugs of abuse, and to relatively small amounts of commodities, like $10 worth of food versus $10 (Odum, Baumann, & Rimington, 2006).

One relatively simple and atheoretical way to summarize the indifference points is to use the Area Under the Curve (AUC; Myerson, Green, & Warusawitharana, 2001). To calculate AUC, delays and indifference points are first normalized (i.e., expressed as a proportion of the maximum value). The area underneath the curve is then computed by summing the results of the following equation for each delay and indifference point pair: $x_2 - x_1 [(y_1 + y_2)/2]$, where x_1 and x_2 are successive delays and y_1 and y_2 are the indifference points associated with those delays (see Myerson et al. for more detail). The AUC can range from 1 (no discounting) to 0 (maximum discounting). Larger AUCs thus represent less discounting by delay (less impulsivity, or conversely, more self-control). For the indifference points shown in Figure 1, for money the AUC is .732 for the nonsmoking participant (NS1), and .176 for the smoking participant (SM1). For cigarettes, the AUC is .109 for the smoking participant (SM1). The AUC thus provides a useful single number to characterize how much delay degrades present value.

Often indifference points are fitted to a theoretical model using nonlinear regression. Quantitative analysis of this kind is useful because it describes a phenomenon succinctly and can lead to unambiguous and even unintuitive tests of theory (see Killeen, 1999; Mazur, 2006; Nevin, 1984; Shull, 1991). There is some relation in nature between how much value a reward has and how delayed it is, and that is what mathematical modeling is attempting to characterize. The most common model used to characterize the effects of delay on value is some version of a hyperbola. Hyperbolic discounting refers to the fact that, as can be seen in Figure 1, the effect of delay on value is not the same across the range of delays. At short delays, value is decreased proportionally more so than at long delays. Mazur (1987) evaluated several different possible quantitative models to describe the indifference points as a function of delay and determined that the following equation provided the best fit to the data from the pigeons in his experiment:

$$V = A/(1 + kD) \quad (1)$$

This equation states that the present value of a reward (V, the indifference point) is equal to the amount of the reward (A) divided by the delay to the reward (D). The numeral 1 appears in the denominator of the equation to prevent present value from approaching infinity as the delay approaches 0. The delay (D) is multiplied by a scaling factor, *k*, which describes how much value is affected by delay. If *k* is relatively large, then the effect of delay (D) on degrading value is bigger than if *k* is small. In Equation 1, *k* is a free parameter, determined by the fit of the model to the data; all other terms are dependent variables (the left-hand side) or independent variables (the right-hand side).

Across a variety of populations, species, and rewards (e.g., Bickel et al., 1999; Johnson & Bickel, 2002; Madden et al., 2003; Mazur, 1987; Mazur & Biondi, 2009), Equation 1 accounts for more variance in delay discounting data as compared to an exponential model historically favored by economists that also has one free parameter (Samuelson, 1937; see McKerchar et al., 2009):

$$V = Ae^{-kD} \quad (2)$$

In Equation 2, as in Equation 1, V is the indifference point, A is the undiscounted amount of the reward, D is the delay to the reward, and *k* is the derived discounting parameter that describes how steeply delay degrades value. The mathematical constant *e* is approximately equal to 2.718 and is the base of the natural logarithm. Unlike Equation 1 (the hyperbola), Equation 2 predicts that for each unit of time that constitutes the delay to the receipt of a reward, the value of the reward will decrease by a fixed proportion. For example, if half of the immediate value of a reward is lost with a 6-month delay, then half of the value remaining at 6 months will be lost at 1 year.

The two models have important differences with respect to one of the most perplexing of choice phenomena: preference reversal. For example, a person may say quite adamantly at the end of a day that he will quit smoking, and destroy his cigarettes. Despite his resolve, however, he may then begin smoking again before the next day is through. Although this example may seem extreme, a substantial proportion of smokers' quit attempts are sustained less than 24 hours (Hughes & Callas, 2010). Preference reversals can occur with respect to many types of rewards and over many time frames (e.g., deciding at the beginning of dinner not to eat dessert, but then at the end having desert nonetheless) and are shown by nonhumans as well as humans (e.g., Green, Fisher, Perlow, & Sherman, 1981). Equation 1 (the hyperbolic model) predicts preference reversals straightforwardly, but Equation 2 requires additional assumptions that may not always hold (see Mazur, 2006, for detailed discussion).

As in prior studies, Equation 1 provides a superior fit compared to that of Equation 2, accounting for a larger proportion of the variance in the data. Table 1 shows the R^2 values for the two models for each data set. The variance accounted for by both is good, but even with just three comparisons, the R^2 values are significantly different for the two models, paired $t(2) = 18.25$, $p = .003$. This difference with a few illustrative data sets mirrors the findings in the literature at large (see McKerchar et al., 2009).

The curves in Figure 1 show the fit of Equation 1 to the indifference points for the nonsmoking participant for money and for the smoking participant for money and cigarettes. Although the fit of Equation 1 to the indifference points is good overall, there are systematic deviations from the data that are also common in the literature (e.g., Odum et al., 2006). At shorter delays, Equation 1 tends to overpredict the indifference points, whereas at longer delays, it tends to underpredict the indifference points. This feature can be seen most clearly in the indifference points for money from participant NS1 in

Table 1

Goodness of fit (R^2) for Equation 1 (the hyperbolic model) and Equation 2 (the exponential model) for the data shown in Figure 1.

Participant (reward)	Model	
	Eq. 1	Eq. 2
NS1 (money)	.876	.830
SM1 (money)	.940	.886
SM1 (cigarettes)	.980	.934

Figure 1. In response to this type of systematic deviation from the data, there are alternative models that add an additional free parameter to Equation 1 (Green & Myerson, 1995; Rachlin, 2006; see Green & Myerson, 2004; McKerchar, Green, & Myerson, 2010). Substantial interest exists in more complex models of delay discounting (see e.g., Killeen, 2009; McKerchar et al. 2009, 2010; Takahashi, 2007). Despite its shortcomings, Equation 1 is the most parsimonious hyperbolic model and remains widely used, and so I will focus on it. The other models also include *k*, or a similar parameter, so what I say applies to them as well. Which model is best to use will depend on your purposes (see Killeen, 1999).

The fit of Equation 1 to each set of indifference points as shown in Figure 1 yields an estimate of the degree of delay discounting, *k*. For money, *k* is 0.00265 for the nonsmoking participant (NS1), and 0.123 for the smoking participant (SM1). For cigarettes, *k* is 0.208 for the smoking participant (SM1). The size of *k* thus tracks the degree of discounting shown in the indifference points: Steeper discounting is associated with a larger *k*. The findings in the examples shown here in Figure 1 parallel those in the extensive empirical literature: drug addiction (see Yi et al., 2010) and nonmonetary rewards (see Odum, 2011) are associated with steeper discounting.

INTERPRETATION OF THE ANALYSES

The parameter *k* has been used in hundreds of published articles to characterize delay discounting, but what is *k* exactly? In what follows, I will describe several possible (and nonexclusive) interpretations. First, *k* is a free parameter in an equation and describes how steeply value is degraded by delay. The term on the left-hand side of the equation is a dependent variable (the indifference points), and the terms on the right-hand side of the equation besides the free parameter *k* are the independent variables (delay and amount). Free parameters serve as higher-order dependent variables that describe in part how the other terms interact (see Nevin, 1984; Shull, 1991).

One objection that behavior analysts might make about *k* (or AUC as well) is that is does not represent a direct measure of behavior. Rather, *k* requires the integration of behavior over multiple observations, and is not equivalent to the set of observations. This argument can be also applied to common behavior analytic measures such as response rate, however, which is also not equivalent to the set of observations from which it is derived (see Nevin, 1984; Zuriff, 1985). On these grounds then, the use of *k* to characterize behavioral data should not be problematic.

In other respects, however, the parameter *k* from Equation 1 could be perceived by behavior analysts as controversial. Free parameters from mathematical models are often given names and theoretical interpretations (Shull, 1991), and *k* is widely referred to as representing ''impulsivity''. Unlike ''degree of discounting'', which is consistent with the interpretation of *k* as a higher-order dependent variable as described two paragraphs above, ''impulsivity'' could be interpreted to suggest something more than the way in which the independent and dependent variables are related. ''Impulsivity'' could be strictly defined as well as choice of a smaller sooner reward over a larger later reward (e.g., Ainslie, 1974), but the word has multiple meanings and is often considered to encompass more (see de Wit, 2008; Reynolds et al., 2006).

It may be useful at this juncture to consider MacCorquodale and Meehl's (1948) distinction between intervening variables and hypothetical constructs. Behavior analysts commonly prefer intervening variables over hypothetical constructs in their theory (see Zuriff, 1985). Intervening variables are constructs ''which merely abstract the empirical relationships'', whereas hypothetical constructs ''involve the supposition of entities or processes not among the observed'' (pp. 106–107). More specifically, MacCorquodale and Meehl suggest that the term 'intervening variable' should be used to refer to

> a quantity obtained by a specified manipulation of the values of empirical variables; it will involve no hypothesis as to the existence of nonobserved entities or the occurrence of unobserved processes; it will contain, in its complete statement for all purposes of theory and prediction, no words which are not definable either explicitly or by reduction sentences in terms of the empirical variables; and the validity of empirical laws involving only observables will constitute both the necessary and sufficient conditions for the validity of the laws involving these intervening variables (p. 103).

'Hypothetical constructs', in contrast,

> involve terms which are not wholly reducible to empirical terms; they refer to processes or entities that are not directly observed (although they need not be in principle unobservable); the mathematical expression of them cannot be formed simply by a suitable grouping of terms in a direct empirical equation; and the truth of the empirical laws involved is a necessary but not a sufficient condition for the truth of these conceptions (p. 104).

On one hand, when used as a higher-order dependent variable, *k* from Equation 1 undoubtedly meets the definition of an intervening variable and thus should be regarded as unproblematic in behavioral theory. Every term in Equation 1 is explicitly and empirically defined. Moreover, *k* (degree of discounting) is obtained by the specific manipulation of those empirical variables (fitting Equation 1 to the data). Thus, *k* clearly can be used in a way that should not concern Skinnerian psychologists. Skinner's (1950) objection was to explanation that ''appeals to events taking place somewhere else, at some other level of observation, described in different terms, and measured, if at all, in different dimensions'' (p. 193). There is nothing about *k*, or Equation 1, that requires that it be used in that manner.

On the other hand, *k* could also easily be used as a hypothetical construct. MacCorquodale and Meehl (1948) refer to cases in which a concept is initially introduced into the literature as an intervening variable, but eventually may be used as a hypothetical construct. In such cases,

> What began as a name for an intervening variable is finally a name for a ''something'' which has a host of causal properties. These properties are not made explicit initially, but it is clear that the concept is to be used in an explanatory way which requires that the properties exist (p. 105).

If I were to say, for example, that a person is impulsive *because* they have a high *k*, I would be using *k* as a hypothetical construct. Certainly *k* is used in this manner in common academic discourse. In this regards, though, *k* (the degree of delay discounting) does not appear to be any different than the concept of a reinforcer. When behavior produces a reinforcer, the reinforcer increases the likelihood that behavior will occur again (Ferster & Skinner, 1957). If I were to say that a behavior occurs again *because* it produced a reinforcer, I would be using reinforcer as a hypothetical construct.

Degree of discounting (*k*) may also be used as a hypothetical construct in more formal discourse. For example, I recently suggested (Odum, 2011) that *k* could be a personality trait. A personality trait may be considered ''a relatively enduring pattern of thoughts, feelings, and [other] behaviors that reflects the tendency to respond in certain ways under certain circumstances'' (Roberts, 2009). In Odum (2011), I present empirical evidence that *k* meets at least some aspects of this definition of a personality trait: It is relatively enduring, and may reflect the general tendency to respond certain ways in certain circumstances.

Two types of evidence from repeated testing indicate that *k* has relative endurance (Odum, 2011). First, consider same-form test–retest reliability. When tested up to one year later with an identical discounting assessment, people have a similar degree of discounting (e.g., Jimura et al., 2011; Kirby, 2009; Simpson & Vuchinich, 2000). Second, there is also generally good alternate-form test–retest reliability between a *k* obtained with one procedure and the *k* obtained with another delay discounting procedure. For example, Rodzin, Berry, and Odum (2011) found a strong correlation ($r = .81$) between the degree of discounting obtained with a procedure that used a fixed reward amount presentation sequence (as in Rachlin et al., 1991, described above in HOW TO ASSESS DELAY DISCOUNTING) and the degree of discounting obtained with a procedure that used a titrating reward amount sequence (as in Du et al., 2002, also described above). Together, these types of evidence show that *k* is relatively stable over modest time frames and with different testing methods.

Other evidence indicates that *k* may also reflect a tendency to respond certain ways under certain circumstances. For example, Odum (2011) examined the relation between discounting for one type of reward (e.g., money) and another type of reward (e.g., food). The degree of discounting for one reward was in all cases positively related to the degree of discounting for another reward across a number of archival data sets with different participant characteristics and reward types. These findings expanded and replicated those of prior studies (e.g., Charlton & Fantino, 2008; Johnson et al., 2010; Jones & Rachlin, 2009; Tsukayama & Duckworth, 2010). These findings also complement the well-established result that people with drug abuse problems (i.e., people who by definition behave impulsively with respect to a substance) discount money more steeply than people with similar demographic characteristics but without drug abuse problems (e.g., Bickel et al., 1999; see Yi et al., 2010, for a review). In sum, a person who is relatively impulsive for one reward may also be relatively impulsive when it comes to other types of rewards.

Two recent exceptions indicate this general finding will have limiting conditions. Jimura et al. (2011) found weak and unreliable correlations across two studies between the degree of discounting a person showed for 16 ml of (real) juice and a hypothetical $80. Similarly, in Odum (2011), although the correlations between discounting for $10 and $10 worth of cigarettes or food (all hypothetical) were positive, the relations were weak and not statistically robust. These cases of ''domain independent'' discounting may be due to the size of the reward under consideration. Choices made regarding small rewards, such as in these two studies, may not be particularly related to decisions regarding other small rewards or to a person's overall decision-making style.

The number of studies is too small to draw any firm conclusions, but given the data so far, it appears that domain independence may not be related to two other features of the reward—whether it is directly consumed and whether it is real. Odum (2011) found strong correlations between discounting for two consumable rewards (e.g., alcohol and food) as well as for consumable and nonconsumable rewards (e.g., alcohol and money). Furthermore, domain independence has been found between real and hypothetical rewards (Jimura et al., 2011) as well as between two hypothetical rewards (Odum, 2011). This will be an interesting area for future research. Overall there does thus appear to be good evidence that *k* could be considered a personality trait in terms of its relative endurance and consistency across rewards, small rewards not withstanding.

As with *k*, whether a personality trait is an intervening variable or hypothetical construct depends on the manner in which it is defined and used. Essentially, the issue may hinge on whether the term is used to summarize or explain. For example, both behaviorists (e.g., Skinner, 1953; 1974) as well as personality psychologists (e.g., Buss, 1989; Buss & Craik, 1983; Pervin, 1994) have considered personality to be essentially a repertoire of behavior (see Odum & Baumann, 2010, for review). In this case, the term ''personality'' simply summarizes a general pattern of behaving, and would be an intervening variable. If, however, personality traits are seen as underlying tendencies that cause and explain behavior (e.g., McCrae & Costa, 1995), then a personality trait, and by inference *k* as a personality trait, would be a hypothetical construct.

SUMMARY AND CONCLUSIONS

The degree of discounting by delay (*k* from Equation 1 and related measures like AUC) is extensively used to summarize the results of experiments on sensitivity to delayed rewards. Equation 1 and other quantitative models of choice between immediate and delayed rewards capture a large degree of variability in data from across species, populations, and reward types. This type of quantitative analysis of behavior can provide useful summary measures and precise descriptions of theoretical models of behavior. In addition, it can inspire and guide research as a heuristic and as a general, flexible construct. Thus, the ontological status of measures of delay discounting in the end may not be important. These measures can readily be used in multiple ways depending on a researcher's proclivities.

Due to the scope and impact of research in the area, the study of delay discounting can be regarded as one of the successes of the field of behavior analysis. Skinner (1938) maintained that the appropriate level of analysis was one that produced orderly and repeatable results (see also Nevin, 1984). Measures of delay discounting such as *k* and AUC fit Skinner's description of appropriate measures, as they have powerful cross-species, cross-population, as well as intraindividual replicability. This generality of measures makes delay discounting well suited for complementary basic laboratory studies with nonhumans and humans, as well as translational, applied and clinical use (see Critchfield & Kollins, 2001).

In the end, whatever it is, delay discounting is related to a host of maladaptive behaviors, including drug abuse, gambling, obesity, as well as poor college performance, personal safety, and self care (e.g., Daugherty & Brase, 2010; Kirby, Winston & Santiesteban, 2005; Odum, 2011; Rasmussen, Lawyer, & Reilly, 2010). Delay discounting is not only correlated with drug abuse, as noted previously, but also may predict the likelihood of initiating drug use and treatment outcomes from drug abuse cessation attempts (e.g., MacKillop & Kahler, 2009). For example, in a prospective longitudinal study, Audrain-McGovern et al. (2009) found the degree of discounting for hypothetical money in adolescents predicted their likelihood of regular cigarette smoking as young adults. Among pregnant women who quit smoking, degree of delay discounting predicted whether they would relapse by 6 months post partum (Yoon et al., 2007).

There may be a genetic basis for the degree of delay discounting (see Odum, 2011, for discussion). For example, different strains of rats and mice show different degrees of discounting (e.g., Anderson & Woolverton, 2005; Madden, Smith, Brewer, Pinkston, & Johnson, 2008; Oberlin & Grahame, 2009; Wilhelm & Mitchell, 2009). In people, the steepness of delay discounting for hypothetical money is associated with particular dopamine polymorphisms (Eisenberg et al., 2007). In a recent longitudinal twin study, the heritability of delay discounting was estimated to be up to 50% (Anokhin, Golosheykin, Grant, & Heath, 2011). Further research is necessary to determine the generality of these effects in humans.

Fortunately, choice of immediate rewards also may be malleable in humans and nonhumans, even if it is in part genetically determined. Pigeons who experience a fading procedure, in which the delay to the smaller more immediate reward is gradually reduced, are less impulsive than pigeons that are faced with the smaller immediate reward choice from the outset (Mazur & Logue, 1978). The fading procedure has been successfully used with a variety of human populations with impulse control problems as well (e.g., Dixon & Holcomb, 2000; Schweitzer & Sulzer-Azaroff, 1988). Recent studies indicate that the degree of delay discounting and recovery from drug addiction may be beneficially impacted by neurocognitive rehabilitation (Bickel, Yi, Landes, Hill, & Baxter, 2011; Black & Rosen, 2011). In these respects, the study of delay discounting may document our foibles, but also hold the key to success over them.

REFERENCES

Ainslie, G. (1974). Impulse control in pigeons. *Journal of the Experimental Analysis of Behavior, 21*, 485–489.

Anderson, K. G., & Woolverton, W. L. (2005). Effects of clomipramine on self-control choice in Lewis and Fischer 344 rats. *Pharmacology, Biochemistry, & Behavior, 80*, 387–393.

Anokhin, A. P., Golosheykin, S., Grant, J. D., & Heath, A. C. (2011). Heritability of delay discounting in adolescence: A longitudinal twin study. *Behavior Genetics, 41*, 175–183.

Audrain-McGovern, J., Rodriguez, D., Epstein, L. H., Cuevas, J., Rodgers, K., & Wileyto, E. P. (2009). Does delay discounting play an etiological role in smoking or is it a consequence of smoking? *Drug and Alcohol Dependence, 103*, 99–106.

Barratt, E. S. (1985). Impulsiveness subtraits: Arousal and information processing. In J. T. Spence, & C. E. Izard (Eds.), *Motivation, emotion, and personality* (pp. 137–146). Amsterdam: Elsevier.

Bickel, W. K., Odum, A. L., & Madden, G. J. (1999). Impulsivity and cigarette smoking: Delay discounting in current, never, and ex-smokers. *Psychopharmacology, 146*, 447–454.

Bickel, W. K., Yi, R., Landes, R. D., Hill, P. F., & Baxter, C. (2011). Remember the future: Working memory training decreases delay discounting among stimulant addicts. *Biological Psychiatry, 69*, 260–265.

Black, A. C., & Rosen, M. I. (2011). A money management-based substance use treatment increases valuation of future rewards. *Addictive Behaviors, 36*, 125–128.

Buss, A. H. (1989). Personality as traits. *American Psychologist, 44*, 1378–1388.

Buss, A. H., & Craik, K. H. (1983). The act frequency approach to personality. *Psychological Review, 90*, 105–126.

Calvert, A. L., Green, L., & Myerson, J. (2010). Delay discounting of qualitatively different reinforcers in rats. *Journal of the Experimental Analysis of Behavior, 93*, 171–184.

Charlton, S. R., & Fantino, E. (2008). Commodity specific rates of temporal discounting: Does metabolic function underlie differences in rates of discounting? *Behavioural Processes*, *77*, 334–342.

Chung, S.-H., & Herrnstein, R. J. (1967). Choice and delay of reinforcement. *Journal of the Experimental Analysis of Behavior*, *10*, 67–74.

Critchfield, T. S., & Kollins, S. H. (2001). Temporal discounting: Basic research and the analysis of socially important behavior. *Journal of Applied Behavior Analysis*, *34*, 101–122.

Daugherty, J. R., & Brase, G. L. (2010). Taking time to be healthy: Predicting health behaviors with delay discounting and time perspective. *Personality and Individual Differences*, *48*, 202–207.

de Wit, H. (2008). Impulsivity as a determinant and consequence of drug use: A review of underlying processes. *Addiction Biology*, *14*, 22–31.

de Wit, H., Flory, J. D., Acheson, A., McCloskey, M., & Manuck, S. B. (2007). IQ and non- planning impulsivity are independently associated with delay discounting in middle-aged adults. *Personality and Individual Differences*, *42*, 111–121.

Dixon, M. R., & Holcomb, S. (2000). Teaching self-control to small groups of dually diagnosed adults. *Journal of Applied Behavior Analysis*, *33*, 611–614.

Du, W., Green, L., & Myerson, J. (2002). Cross-cultural comparison of discounting of delayed and probabilistic rewards. *The Psychological Record*, *52*, 479–492.

Eisenberg, D. T. A., MacKillop, J., Modi, M., Beauchemin, J., Dang, D., Lisman, S. A., & … Wilson, D. S. (2007). Examining impulsivity as an endophenotype using a behavioral approach: A DRD2 Taql A and DRD4 48-bp VNTR association study. *Behavioral and Brain Functions*, *3*, 2.

Eppolito, A. K., France, C. P., & Gerak, L. R. (2011). Effects of acute and chronic flunitrazepam on delay discounting in pigeons. *Journal of the Experimental Analysis of Behavior*, *95*, 163–174.

Estle, S. J., Green, L., Myerson, J., & Holt, D. D. (2007). Discounting of monetary and directly consumable rewards. *Psychological Science*, *18*, 58–63.

Evenden, J. L., & Ryan, C. N. (1996). The pharmacology of impulsive behaviour in rats: The effects of drugs on response choice with varying delays of reinforcement. *Psychopharmacology*, *128*, 161–170.

Ferster, C. B., & Skinner, B. F. (1957). *Schedules of reinforcement*. New York: Appleton-Century-Crofts.

Green, L., Fisher, E. B., Perlow, S., & Sherman, L. (1981). Preference reversal and self control: Choice as a function of reward amount and delay. *Behaviour Analysis Letters*, *1*, 43–51.

Green, L., & Myerson, J. (1995). Discounting of delayed rewards: Models of individual choice. *Journal of the Experimental Analysis of Behavior*, *64*, 263–276.

Green, L., & Myerson, J. (2004). A discounting framework for choice with delayed and probabilistic rewards. *Psychological Bulletin*, *130*, 769–792.

Green, L., Myerson, J., & Calvert, A. L. (2010). Pigeons' discounting of probabilistic and delayed reinforcers. *Journal of the Experimental Analysis of Behavior*, *94*, 113–123.

Green, L., Myerson, J., Shah, A. K., Estle, S. J., & Holt, D. D. (2007). Do adjusting-amount and adjusting-delay procedures produce equivalent estimates of subjective value in pigeons? *Journal of the Experimental Analysis of Behavior*, *87*, 337–347.

Hughes, J. R., & Callas, P. W. (2010). Definition of a quit attempt: A replication test. *Nicotine and Tobacco Research*, *12*, 1176–1179.

Jimura, K., Myerson, J., Hilgard, J., Keighley, J., Braver, T. S., & Green, L. (2011). Domain independence and stability in young and older adults' discounting of delayed rewards. *Behavioural Processes*, *87*, 253–259.

Johnson, M. W., & Bickel, W. K. (2002). Within-subject comparison of real and hypothetical money rewards in delay discounting. *Journal of the Experimental Analysis of Behavior*, *77*, 129–146.

Johnson, M. W., Bickel, W. K., Baker, F., Moore, B. A., Badger, G. J., & Budney, A. J. (2010). Delay discounting in current and former marijuana-dependent individuals. *Experimental and Clinical Psychopharmacology*, *18*, 99–107.

Jones, B. A., & Rachlin, H. (2009). Delay, probability, and social discounting in a public goods game. *Journal of the Experimental Analysis of Behavior*, *91*, 61–73.

Killeen, P. R. (1999). Modeling modeling. *Journal of the Experimental Analysis of Behavior*, *71*, 275–280.

Killeen, P. R. (2009). An additive-utility model of delay discounting. *Psychological Review*, *116*, 602–619.

Kirby, K. N. (2009). One-year temporal stability of delay-discount rates. *Psychonomic Bulletin and Review*, *16*, 457–462.

Kirby, K. N., & Marakovic, N. N. (1996). Delay-discounting probabilistic rewards: Rates decrease as amounts increase. *Psychonomic Bulletin & Review*, *3*, 100–104.

Kirby, K. N., Petry, N. M., & Bickel, W. K. (1999). Heroin addicts have higher discounting rates for delayed rewards than non-drug-using controls. *Journal of Experimental Psychology: General*, *128*, 78–87.

Kirby, K. N., Winston, G. C., & Santiesteban, M. (2005). Impatience and grades: Delay-discount rates correlate negatively with college GPA. *Learning and Individual Differences*, *15*, 213–222.

Lagorio, C. H., & Madden, G. J. (2005). Delay discounting of real and hypothetical rewards III: steady-state assessments, forced-choice trials, and all real rewards. *Behavioural Processes*, *69*, 173–187.

Lattal, K. A. (2010). Delayed reinforcement of operant behavior. *Journal of the Experimental Analysis of Behavior*, *93*, 129–139.

Locey, M. L., & Dallery, J. (2009). Isolating behavioral mechanisms of intertemporal choice: Nicotine effects on delay discounting and amount sensitivity. *Journal of the Experimental Analysis of Behavior*, *10*, 213–223.

MacCorquodale, K., & Meehl, P. E. (1948). On a distinction between hypothetical constructs and intervening variables. *Psychological Review*, *55*, 95–107.

MacKillop, J., & Kahler, C. W. (2009). Delayed reward discounting predicts treatment response for heavy drinkers receiving smoking cessation treatment. *Drug and Alcohol Dependence*, *104*, 197–203.

Madden, G. J., Begotka, A. M., Raiff, B. R., & Kastern, L. L. (2003). Delay discounting of real and hypothetical rewards. *Experimental & Clinical Psychopharmacology*, *11*, 139–145.

Madden, G. J., & Bickel, W. K. (2010). Introduction. In G. J. Madden, & W. K. Bickel (Eds.), *Impulsivity: The behavioral and neurological science of discounting* (pp. 3–8). Washington, DC: American Psychological Association.

Madden, G. J., & Johnson, P. S. (2010). A delay-discounting primer. In G. J. Madden, & W. K. Bickel (Eds.), *Impulsivity: The behavioral and neurological science of discounting* (pp. 11–37). Washington, DC: American Psychological Association.

Madden, G. J., Raiff, B. R., Lagorio, C. H., Begotka, A. M., Mueller, A. M., Hehli, D. J., & Wegener, A. A. (2004). Delay discounting of potentially real and hypothetical rewards: II. between- and within-subject comparisons. *Experimental & Clinical Psychopharmacology, 12*, 251–261.

Madden, G. J., Smith, N. G., Brewer, A. T., Pinkston, J. W., & Johnson, P. S. (2008). Steady-state assessment of impulsive choice in Lewis and Fischer 344 rats: Between-session delay manipulations. *Journal of the Experimental Analysis of Behavior, 90*, 333–344.

Mazur, J. E. (1987). An adjusting procedure for studying delayed reinforcement. In M. L. Commons, J. E. Mazur, J. A. Nevin, & H. Rachlin (Eds.), *Quantitative analysis of behavior: Vol. 5. The effect of delay and of intervening events of reinforcement value* (pp. 55–73). Hillsdale, NJ: Erlbaum.

Mazur, J. E. (2006). Mathematical models and the experimental analysis of behavior. *Journal of the Experimental Analysis of Behavior, 85*, 275–291.

Mazur, J. E., & Biondi, D. R. (2009). Delay-amount tradeoffs in choices by pigeons and rats: Hyperbolic vs. exponential discounting. *Journal of the Experimental Analysis of Behavior, 91*, 197–211.

Mazur, J. E., & Biondi, D. R. (2011). Effects of time between trials on rats' and pigeons' choices with probabilistic delayed reinforcers. *Journal of the Experimental Analysis of Behavior, 95*, 41–56.

Mazur, J. E., & Logue, A. W. (1978). Choice in a ''self-control'' paradigm: Effects of a fading procedure. *Journal of the Experimental Analysis of Behavior, 30*, 11–17.

McCrae, R. R., & Costa, P. T. Jr (1995). Trait explanations in personality psychology. *European Journal of Personality, 9*, 231–252.

McKerchar, T. L., Green, L., Myerson, J., Pickford, T. S., Hill, J. C., & Stout, S. C. (2009). A comparison of four models of delay discounting in humans. *Behavioural Processes, 81*, 256–259.

McKerchar, T. L., Green, L., & Myerson, J. (2010). On the scaling interpretation of exponents in hyperboloid models of delay and probability discounting. *Behavioural Processes, 84*, 440–444.

Myerson, J., Green, L., & Warusawitharana, M. (2001). Area under the curve as a measure of discounting. *Journal of the Experimental Analysis of Behavior, 76*, 235–243.

Nevin, J. A. (1984). Quantitative analysis. *Journal of the Experimental Analysis of Behavior, 42*, 421–434.

Oberlin, B. G., & Grahame, N. J. (2009). High-alcohol preferring mice are more impulsive than low-alcohol preferring mice as measured in the delay discounting task. *Alcoholism, Clinical and Experimental Research, 33*, 1294–1303.

Odum, A. L. (2011). Delay discounting: Trait variable? *Behavioural Processes, 87*, 1–9.

Odum, A. L., & Baumann, A. A. L. (2010). Delay discounting: State and trait variable. In G. J. Madden, W. K. Bickel (Eds.), *Impulsivity: The behavioral and neurological science of discounting* (pp. 39–65). Washington, DC: American Psychological Association.

Odum, A. L., Baumann, A. A. L., & Rimington, D. D. (2006). Discounting of delayed hypothetical money and food: Effects of amount. *Behavioural Processes, 73*, 278–284.

Odum, A. L., & Rainaud, C. P. (2003). Discounting of delayed hypothetical money, alcohol, and food. *Behavioural Processes, 64*, 305–313.

Paloyelis, Y., Asherson, P., Mehta, M. A., Faraone, S. V., & Kuntsi, J. (2010). DAT1 and COMT effects on delay discounting and trait impulsivity in male adolescents with attention deficit/hyperactivity disorder and healthy controls. *Neuropsychopharmacology, 35*, 2414–2426.

Pervin, L. A. (1994). A critical analysis of current trait theory. *Psychological Inquiry, 5*, 103–113.

Rachlin, H. (2006). Notes on discounting. *Journal of the Experimental Analysis of Behavior, 85*, 425–435.

Rachlin, H., Raineri, A., & Cross, D. (1991). Subjective probability and delay. *Journal of the Experimental Analysis of Behavior, 55*, 223–244.

Rasmussen, E. B., Lawyer, S. R., & Reilly, W. (2010). Percent body fat is related to delay and probability discounting for food in humans. *Behavioural Processes, 83*, 23–30.

Reynolds, B. (2006). A review of delay-discounting research with humans: Relations to drug use and gambling. *Behavioural Pharmacology, 17*, 651–667.

Reynolds, B., Ortengren, A., Richards, J. B., & de Wit, H. (2006). Dimensions of impulsive behavior: Personality and behavioral measures. *Personality and Individual Differences, 40*, 305–315.

Reynolds, B., & Schiffbauer, R. (2004). Measuring state changes in human delay discounting: An experiential discounting task. *Behavioural Processes, 67*, 343–356.

Richards, J. B., Mitchell, S. H., de Wit, H., & Seiden, L. S. (1997). Determination of discount functions in rat with an adjusting-amount procedure. *Journal of the Experimental Analysis of Behavior, 67*, 353–366.

Roberts, B. W. (2009). Back to the future: *Personality and Assessment* and personality development. *Journal of Research in Personality, 43*, 137–145.

Rodzon, K., Berry, M. S., & Odum, A. L. (2011). Within-subject comparison of degree of delay discounting using titrating and fixed sequence procedures. *Behavioural Processes, 86*, 164–167.

Samuelson, P. A. (1937). A note on measurement of utility. *The Review of Economic Studies, 4*, 155–161.

Schweitzer, J. B., & Sulzer-Azaroff, B. (1988). Self-control: Teaching tolerance for delay in impulsive children. *Journal of the Experimental Analysis of Behavior, 50*, 173–186.

Shull, R. L. (1991). Mathematical description of operant behavior: An introduction. In I. H. Iversen, & K. A. Lattal (Eds.), *Experimental analysis of behavior: Part 2* (pp. 243–282). Amsterdam: Elsevier.

Simpson, C. A., & Vuchinich, R. E. (2000). Reliability of a measure of temporal discounting. *The Psychological Record, 50*, 3–16.

Skinner, B. F. (1938). *The behavior of organisms*. New York: Appleton-Century-Crofts.

Skinner, B. F. (1950). Are theories of learning necessary? *Psychological Review, 57*, 193–216.

Skinner, B. F. (1953). *Science and human behavior*. Oxford, England: MacMillan.

Skinner, B. F. (1974). *About behaviorism*. Oxford, England: Alfred A. Knopf.

Takahashi, T. (2007). A probabilistic choice model based on Tsallis' statistics. *Physica A, 386*, 335–338.

Tsukayama, E., & Duckworth, A. L. (2010). Domain-specific temporal discounting and temptation. *Judgment and Decision Making, 5*, 72–82.

Valencia Torres, L., da Costa Araújo, S., Olarte Sanchez, C. M., Body, S., Bradshaw, C. M., & Szabadi, E. (2011). Transitional and steady-state choice behavior under an adjusting-delay schedule. *Journal of the Experimental Analysis of Behavior*, *95*, 57–74.

Wilhelm, C. J., & Mitchell, S. H. (2009). Strain differences in delay discounting using inbred rats. *Genes, Brain, and Behavior*, *8*, 426–434.

Yi, R., Mitchell, S. H., & Bickel, W. K. (2010). Delay discounting and substance abuse-dependence. In G. J. Madden, & W. K. Bickel (Eds.), *Impulsivity: The behavioral and neurological science of discounting* (pp. 191–211). Washington, DC: American Psychological Association.

Yoon, J. H., Higgins, S. T., Heil, S. H., Sugarbaker, R. J., Thomas, C. S., & Badger, G. J. (2007). Delay discounting predicts postpartum relapse to cigarette smoking among pregnant women. *Experimental and Clinical Psychopharmacology*, *15*, 176–186.

Zuriff, G. E. (1985). *Behaviorism: A conceptual reconstruction*. New York: Columbia University Press.

Received: June 11, 2011
Final Acceptance: July 29, 2011