Experimental and Clinical Psychopharmacology
2011, Vol. 19, No. 4, 263–274

1064-1297/11/$12.00 DOI: 10.1037/a0024141

Discounting of Hypothetical and Potentially Real Outcomes in Nicotine-Dependent and Nondependent Samples

Steven R. Lawyer, Frederick Schoepflin, Ryan Green, and Charles Jenks
Idaho State University

Discounting is a behavioral phenomenon in which the value of an outcome diminishes as a function of its increased delay or decreased probability and is related to substance abuse research because of its theoretical ties with behavioral models of impulsive choice. Research to date suggests that hypothetical outcomes used in discounting research yield data that are indistinguishable from those using potentially real outcomes. However, the extant literature focuses primarily on delay discounting in non-drug-using humans and has not examined whether hypothetical outcomes yield disproportionate numbers of nonsystematic response patterns. In two experiments, we compared hypothetical and potentially real monetary outcomes in delay and probability discounting tasks in terms of rates of discounting and the frequency of nonsystematic response patterns. In Experiment 1, 61 adults reported no smoking, binge drinking, or illicit drug use in the past year. Experiment 2 included a community sample of nicotine-dependent adults ($N = 36$). In both experiments, discounting for hypothetical and potentially real outcomes yielded similar data, replicating and extending a growing literature pointing to the empirical equivalence of these outcomes. These findings are relevant to research on discounting that is frequently used in the study of substance use and other impulse-control behaviors.

Keywords: delay discounting, probability discounting, nicotine, cigarette

Discounting Overview

Discounting is a behavioral phenomenon in which individuals devalue a reward as a function of its delay or probability. In these terms, rewards that are delayed and/or probabilistic tend to be valued less than those that are immediate and/or certain. Discounting the value of rewards as a function of time and probability corresponds well to behavioral definitions of impulsive choice (e.g., Ainslie, 1975) and can be characterized very well with laboratory procedures in humans.

In the typical delay discounting procedure, an individual makes a series of forced-choice decisions regarding preference for a relatively small outcome available immediately and a larger outcome available after a delay. For example, given a choice between $5 available right now and $100 available 1 day from now, most people choose the delayed outcome. However, as the immediate amount is increased in subsequent questions, most participants eventually "switch" their preference from the larger delayed outcome to the smaller immediate outcome (e.g., at an immediate amount of $90). The point at which the individual switches represents the subjective value of the large reward at that delay. This process is repeated across several delays, which results in a discounting pattern in which the subjective value of the large reward diminishes as the delay increases. Probability discounting procedures are similar except that individuals make decisions regarding smaller immediate outcomes (e.g., $5 for sure) and larger probabilistic outcomes (e.g., $100 with a 25% chance) and subjective values are established across several different probabilities. In probability discounting, the value of a reward tends to diminish as its probability decreases.

Patterns of delay and probability discounting can be described mathematically with a hyperbolic decay function (Equation 1) described by Mazur (1987):

$$Y = A/(1 + bX) \quad (1)$$

In this model, Y represents the subjective value of the delayed or probabilistic outcome, A represents the amount of the large outcome, X represents the delay before (in delay discounting) or odds against receiving the large outcome (in probability discounting; $[1/p] - 1$, where $p =$ the probability of receiving the large outcome), and b represents a free parameter that indexes the rate of discounting. In the delay discounting task, higher b values indicate a preference for smaller–sooner outcomes (i.e., more impulsive decision

This article was published Online First June 27, 2011.

Steven R. Lawyer, Frederick Schoepflin, Ryan Green, and Charles Jenks, Department of Psychology, Idaho State University.

This research was supported by Grant AS09-02 from the Humanities and Social Sciences Research Committee, Idaho State University.

We thank the three anonymous reviewers for their helpful comments on a draft of this article and Taiki Takahashi for his help translating the findings of a article cited herein that was written in Japanese.

Correspondence concerning this article should be addressed to Steven R. Lawyer, Department of Psychology, Stop 8112, Idaho State University, Pocatello, ID 83209. E-mail: lawystev@isu.edu

making). In the probability discounting task, smaller *b* values indicate a preference for probabilistic (i.e., riskier) outcomes.[1]

Recently, Johnson and Bickel (2008) suggested that the frequency of nonsystematic response patterns could serve as a meaningful dependent variable in discounting research. In discounting research, the vast majority of participants generate patterns of discounting that are consistent with a monotonically decreasing change in the value of a reward as a function of increased delay or decreased probability. However, some participants yield data that are inconsistent with the expected pattern. Such patterns may be influenced by a variety of factors, including the parameters of the task, the setting in which the task is completed, and careless or random responding, among others. They propose flexible but replicable algorithms for identifying nonsystematic response patterns in discounting data.

Substance Use and Discounting

There are significant differences in the rate at which some individuals discount the value of delayed and probabilistic outcomes, and a growing literature highlights important connections between discounting patterns and substance use and abuse. Bickel and Johnson (2003) argued persuasively that discounting represents a "fundamental behavioral process" (p. 435) that contributes significantly to the complex processes associated with drug dependence. Indeed, a large literature clearly shows that individuals who are dependent on or abuse heroin (Madden, Petry, Badger, & Bickel, 1997), cocaine (Heil, Johnson, Higgins, & Bickel, 2006), nicotine (Ohmura, Takahashi, & Kitamura, 2005; Reynolds, Richards, Horn, & Karraker, 2004), and alcohol (Field, Christiansen, Cole, & Goudie, 2007; Kollins, 2003; Petry, 2001, 2003; Vuchinich & Simpson, 1998) evidence steeper rates of discounting (i.e., are more impulsive) than do non-drug-using controls.

Research to date regarding differences in rates of probability discounting in drug-using versus control participants is less conclusive. Reynolds et al. (2004) found that smokers discounted the value of probabilistic outcomes more steeply than did nonsmokers, but Mitchell (1999) and Ohmura et al. (2005) found no differences when comparing smokers and nonsmokers on a probability discounting task. In a tightly controlled rat model, Nasrallah, Yang, and Bernstein (2009) found that rats that consumed high levels of alcohol during adolescence showed a bias toward large but probabilistic outcomes over smaller certain outcomes relative to control rats.

Outcome Types in Discounting

Researchers use a variety of outcomes in discounting research, including drugs (e.g., Madden et al., 1997), alcohol (Estle, Green, Myerson, & Holt, 2007; Odum & Rainaud, 2003; Petry, 2001), health outcomes (e.g., Baker, Johnson, & Bickel, 2003; Odum, Madden, & Bickel, 2002), erotica (Lawyer, 2008), sexual activity (Lawyer, Williams, Prihodova, Rollins, & Lester, 2010), and food (e.g., Estle et al., 2007; Odum & Rainaud, 2003; Rasmussen, Lawyer, & Reilly, 2010), among others, but the vast majority of discounting studies have used hypothetical money. Evoking discounting decisions for money is a useful proxy for discounting in general because it is a generalized conditioned reinforcer. Additionally, using hypothetical outcomes circumvents problems with prohibitive costs of delivering some outcomes based on individual choices. Participants may answer several hundred questions in a discounting task, and experimenters may use relatively large outcomes (e.g., $10,000) and delays (e.g., 25 years; Green, Fry, & Myerson, 1994) that would make reward delivery infeasible and/or unethical.

However, one concern associated with the use of hypothetical outcomes in discounting research is that the decisions an individual makes for hypothetical outcomes may not be synonymous with the same decisions for real outcomes. In support of this concern, Kirby (1997) reviewed the literature concerning the discounting of real and hypothetical delayed outcomes and concluded that, although both outcomes are described well by mathematical models of discounting (Mazur, 1987), the value of real rewards tends to be discounted at a steeper rate than the value of hypothetical rewards. However, this review was confounded by magnitude effects due to different methods and outcome amounts used across studies. More recently, researchers have directly compared real and hypothetical outcomes with the discounting paradigm to answer the question of outcome equivalence with internally valid procedures. These comparisons typically are carried out in one of two ways. Some researchers use a lottery-based system for delivering real rewards in which the participant receives one or more randomly selected choices (potentially real outcomes). The assumption in this procedure is that each decision will be for functionally real outcomes, as each choice has an equal chance of being selected at the end of the experiment. In other studies, researchers deliver a reward for each choice that the participant makes (real outcomes).

Research examining the empirical equivalence of potentially real versus hypothetical outcomes in delay discounting has found consistently that the two different outcomes generate similar data. In the first study of this kind, Johnson and Bickel (2002) asked adult participants to complete a computerized discounting task in which individual discounting patterns across several money amounts were established. Some decisions were made in relation to purely hypothetical outcomes, but participants also received several randomly selected real rewards on

[1] Two-parameter hyperboloid models that raise the denominator to the power *s,* which reflects the scaling of time and/or probability (Stevens, 1957) also are used (Myerson & Green, 1995; Rachlin, 2006). These models generally provide a better fit to discounting data (McKerchar et al., 2009) than do other single-parameter models, but the *s* parameter may function contrary to the scaling interpretation (McKerchar, Green, & Myerson, 2010) in probability discounting. In light of this, we retained the more traditional hyperbolic decay model in our analyses.

the basis of their responses to questions in which they actually received the outcome they chose. Because of practical constraints associated with the large payouts that participants received, data for only 6 participants were collected. They found that 5 of the 6 participants made the same patterns of discounting choices when presented with potentially real versus hypothetical outcomes across several different money amounts. Several subsequent studies with larger samples have replicated Johnson and Bickel's findings (Baker et al., 2003; Madden, Begotka, Raiff, & Kastern, 2003; Madden et al., 2004), and Bickel et al. (2009) recently reported data indicating that decision making for potentially real and hypothetical outcomes activate the same brain regions (anterior cingulate, striatum, posterior cingulate, lateral prefrontal cortex). Collectively, these findings suggest that real and potentially real outcomes are functionally equivalent in the delay discounting task. Unfortunately, no research to date has compared potentially real and hypothetical outcomes with the probability discounting task.

A second method used less frequently is to deliver a reward for each choice a participant makes. This method offers a clear comparison of real and hypothetical outcomes but limits the size of the outcomes and delays used for feasibility and ethical reasons. Research directly comparing hypothetical outcomes in delay discounting with real—but small (all large outcomes were for less than $1)—outcomes delivered as a function of each choice has yielded mixed conclusions. Lagorio and Madden (2005) found no difference in discounting patterns when comparing real and hypothetical outcomes in a small sample ($n = 6$) of college students, but Hinvest and Anderson (2010) reported steeper discounting for real outcomes by comparison with hypothetical outcomes. Paloyelis, Asherson, Mehta, Faraone, and Kuntsi (2010) compared delay discounting for hypothetical and real rewards in male adolescents with the combined subtype of attention-deficit/hyperactivity disorder (ADHD-CT) with controls and found that ADHD-CT participants discounted the value of hypothetical outcomes—but not real outcomes—at a steeper rate than did controls. Although this study did not directly compare rates of discounting for hypothetical and real outcomes, the differential response patterns in the clinical and control groups suggests a potentially important interaction between outcome type and ADHD status that merits further attention.

Two studies to date compare real and hypothetical probability discounting outcomes, with differing results. Jikko and Okouchi (2007) reported a series of within-participant experiments comparing real versus hypothetical monetary outcomes in a probability discounting task and concluded that participants discount the value of real probabilistic outcomes at a shallower rate than they do hypothetical outcomes. Hinvest and Anderson (2010), by contrast, found no difference in the rates of probability discounting for real and hypothetical outcomes.

Limitations of the Literature

The findings in the extant literature concerning the comparison of hypothetical monetary outcomes with real and potentially real outcomes suggest that, with a few exceptions, these outcomes yield similar findings, at least in relation to delay discounting. However, several questions remain unanswered. First, the mixed findings of the few studies examining outcomes types in probability discounting offers no clear conclusion about their empirical equivalence. Second, although the majority of discounting research has focused on substance-using and substance-abusing populations, tests of the equivalence of reward types have been evaluated primarily with non-substance-abusing populations. To date, the only study to compare monetary reward types in a substance-abusing population is Baker et al.'s (2003) comparison of hypothetical and potentially real delay discounting outcomes in nicotine-dependent adults. No research to date has compared hypothetical and (potentially) real probability discounting outcomes in a substance-abusing sample.

Finally, no research has examined whether hypothetical outcomes generate a greater frequency of nonsystematic response patterns (Johnson & Bickel, 2008) than do potentially real outcomes. It is reasonable to hypothesize that discounting for hypothetical outcomes (which have no implicit value) may generate more nonsystematic response patterns than potentially real outcomes (which do have implicit value). Research studies comparing hypothetical and potentially real outcomes have either used samples too small to evaluate disproportionate frequencies of nonsystematic response patterns (Johnson & Bickel, 2002) or have aggregated all participants in their analyses (Baker et al., 2003; Bickel et al., 2009; Lagorio & Madden, 2005; Madden et al., 2003; Madden et al., 2004), which may obscure the frequencies of nonsystematic response patterns across outcome types.

The purpose of the present research was to compare patterns of delay and probability discounting in two different samples: (1) a community sample of non-substance-abusing individuals and (2) a community sample of substance-dependent individuals. The procedures used here are similar to those described by Madden et al. (2003). In each experiment, the rates of discounting for delayed and probabilistic outcomes are compared, as are the frequency of nonsystematic response patterns.

Experiment 1

Method

Participants. Sixty-one individuals (40 women, 21 men), with a mean age of 40.2 years ($SD = 16.6$), were recruited using news advertisements and community postings. Individuals interested in participating in the study were screened on the basis of criteria used by Madden et al. (2003) and were excluded if, over the past year, they reported smoking more than 10 cigarettes, having more than 4 drinks in one sitting, or using illicit drugs (e.g., marijuana or cocaine). Participants also were excluded if they were under the age of 18.

Materials. Participants provided basic demographic information (gender, age, annual income, education) in a series of questions posed on a computer. A computer program (Richards, Zhang, Mitchell, & de Wit, 1999) was used to establish discounting choice patterns. In this task, individual indifference point values were established across five different delays (1 day, 1 week, 1 month, 6 months, and 1 year) and five different probabilities (90%, 75%, 50%, 25%, and 10%). The large amount for both tasks was $10, and indifference points were established by adjusting the smaller–sooner and –certain amounts in $0.50 increments using a random-adjusting amount procedure. In this procedure, the variable small amounts used in the questions were determined in a quasi-random fashion by the computer so that answers from previous questions were used to narrow the range of values to be displayed on subsequent questions. The variable amount chosen was based on randomly selected amounts of money that ranged between an upper and lower limit, which changed as a function of the individual's previous choices. This procedure allowed the computer to estimate an indifference point value across delays and probabilities in fewer questions than are typically used in other procedures (Rachlin, Raineri, & Cross, 1991) by progressively narrowing the range of values in discounting questions. As in the original task (see Richards et al., 1999), delay and probability tasks were completed simultaneously, and questions from each tasks were intermixed randomly by the computer program.

Procedure. Procedures were based on those reported by Madden et al. (2003). On arrival to the laboratory, participants provided informed consent for their study participation.

Participants were paid for their time and received $20 for the first hour of participation and $5 for each additional 15-min segment or part thereof (most completed within the first hour). Compensation was paid in a combination of cash and gift cards for local stores. Each participant completed two discounting tasks—one with purely hypothetical outcomes and one with potentially real outcomes. The order of task completion was counterbalanced across participants to control for order effects. Both tasks were completed in one session that lasted approximately 1 hr. Before completing each discounting task, participants were given the following instructions (from Madden et al., 2003):

> I'm going to ask you to make some decision about which of two rewards you would prefer. One of the rewards will either be available right now or for sure, and the other will only be available after you have waited for some period of time or with some probability. For example, I might ask you to choose between $550 delivered right now and $800 delivered in 2 years, or I might ask you to choose between $300 for sure and $600 with a 50% chance. The choices you make are completely up to you.

For the hypothetical task, participants were told:

> You will not receive any of the rewards that you choose, but we want you to make your decisions as though you were really going to get the rewards you choose.

For the potentially real task, participants were told:

> At the end of the session, I will randomly choose three of your preferences from those given in the task. If, in your randomly selected choice, you chose delayed money, a gift card for that amount will be put in an envelope with your name and address on it, and it will be mailed to you after the specified delay. For example, if you choose $10 180 days from now, a gift card for $10 will be mailed to you in 180 days. Alternatively, if your selected answer is from a "chance" question, then you will draw a poker chip from a bag to see if you get the money or not. For example, if your selected answer is that you have a 25% chance of getting $10, then three red poker chips and one blue poker chip will be put in a bag for you to draw from. If you draw the one blue poker chip, you will get the $10, but if you draw one of the three red poker chips, you will not get the money.

In between tasks, a 20-min distracter (a series of addition, subtraction, multiplication, and division of four-digit numbers and prime number identification) was administered to hinder recollection of responses on the initial task that might influence responses on the second task. Participants were asked to complete as many of the math problems as possible but were informed that their performance would not affect their monetary reward.

At the end of the session, three choices posed by the discounting task (taken from all delay and probability discounting questions in the potentially real condition) were selected at random, and participants received the outcomes associated with those choices. For delay discounting questions, small immediate rewards were paid at the end of the session, and delayed rewards (in the form of $10 gift cards) were mailed to participants after the specified delay. For probability discounting questions, rewards were determined by drawing poker chips from a bag based on the randomly selected question. Participants could receive up to $30 based on their responses to the potentially real outcomes, which was paid in addition to their hourly rate for participation.

Statistical methods. Data were analyzed in two stages. First, individual discounting patterns were categorized as systematic and nonsystematic on the basis of Johnson and Bickel's (2008) criteria for identifying atypical response patterns that suggest random or inconsistent patterns of responding. Specifically, individual participants were considered nonsystematic responders if analysis of their delay or probability discounting data revealed that (1) any indifference point (except for the first one) was larger than the previous one by more than $2 and (2) the last indifference point was not less than the first by at least $1. Next, we measured the extent of individual discounting by using area under the curve (AUC; Myerson, Green, & Warusawitharana, 2001) and by estimating the individual discounting rate with the hyperbolic function (Mazur, 1987) using nonlinear regression in SPSS 18.0 (2009). We used these data in conjunction with median indifference values to compare the empirical equivalence of discounting for hypothetical versus potentially real outcomes for both tasks.

Results

There were no significant demographic differences across the counterbalanced conditions, nor were there significant differences in the frequencies of nonsystematic response patterns across the tasks as a function of counterbalance order (see Table 1). There were no effects for counterbal-

Table 1
Demographic Characteristics and Frequency of Nonsystematic Response Patterns Across Counterbalance Conditions in Experiment 1

Demographic variable	Task order		χ^2	*p*
	Hypothetical → real	Real → hypothetical		
n	31	30		
% Male	25.8	43.3	2.08	*ns*
Mean age in years (and *SD*)	42.0 (17.1)	38.5 (16.3)	0.83[a]	*ns*
Median annual income (and interquartile range)	$22,000 ($14,050–$62,500)	$22,000 ($10,434–$39,250)	−0.59[b]	*ns*
% High school educated	41.9	33	0.48	*ns*
Nonsytematic response patterns				
Delay discounting				
Potentially real	5	3	0.50	*ns*
Hypothetical	3	8	2.98	.08
Probability discounting				
Potentially real	2	1	0.32	*ns*
Hypothetical	2	2	0.001	*ns*

[a] Independent-samples *t* test. [b] Mann−Whitney U test.

ance order on the extent of discounting (AUC) for delay discounting, but probability discounting for potentially real outcomes was significantly steeper among participants who completed the hypothetical outcomes task first (see Table 2). Comparison of the frequencies of systematic and nonsystematic response patterns across the tasks with hypothetical and potentially real outcomes (regardless of counterbalance order) using McNemar's χ^2 revealed no significant differences for either delay ($p > .05$) or probability ($p > .05$) discounting, which suggests that using hypothetical monetary outcomes does not generate more nonsystematic response patterns than using potentially real monetary outcomes. There were no significant differences in the fit to the hyperbolic decay model as a function of outcome type for delay or probability discounting (see Table 3).

Figure 1 shows the median indifference point values, mean AUC estimates, and median *b* values calculated with the hyperbolic function for delay discounting for all participants across outcome type. Visual inspection of these median indifference point data suggests that hypothetical outcomes yielded very similar patterns of data by comparison with potentially real outcomes, which was confirmed after we conducted a statistical comparison of mean AUC estimates (see Figure 1, bottom left panel; $t[60] = -1.79$, $p > .05$) using a paired-samples *t* test and median *b* values (see Figure 1, bottom right panel; $Z = -0.93$, $p > .05$) using a Wilcoxon's signed-ranks test. In addition, delay discounting AUC values for potentially real and hypothetical outcomes were significantly correlated ($r = .86$, $N = 61$, $p < .001$). Figure 2 shows probability discounting patterns for all participants for both tasks. Median indifference points overlapped significantly, and there were no significant differences in discounting when AUC estimates ($t[60] = -.33$, $p > .05$) and *b* values ($Z = -0.17$, $p > .05$) were compared. Probability discounting AUC values for potentially real and hypothetical probability discounting outcomes were significantly correlated ($r = .65$, $N = 61$, $p < .001$).

Discussion

Experiment 1 replicated a large research literature (Baker et al., 2003; Bickel et al., 2009; Johnson & Bickel, 2002; Lagorio & Madden, 2005; Madden et al., 2003; Madden et al., 2004) suggesting that delay discounting procedures that use hypothetical monetary outcomes yield rates of discounting that are equivalent to those that use potentially real outcomes. This study suggests further that delay discounting procedures using hypothetical outcomes generated similar rates of nonsystematic response patterns as do those using potentially real outcomes. Findings from Experiment 1 also suggest that the probability discounting procedures that use hypothetical mon-

Table 2
Mean Area Under the Curve Estimates (and Standard Deviations) for All Discounting Tasks as a Function of Counterbalance Order in Experiment 1

Discounting task	Potentially real first ($n = 30$)	Hypothetical first ($n = 31$)	*t*(59)	*p*
Delay discounting				
Hypothetical	0.52 (0.31)	0.54 (0.24)	−0.24	*ns*
Potentially real	0.50 (0.27)	0.50 (0.26)	0.02	*ns*
Probability discounting				
Hypothetical	0.26 (0.14)	0.21 (0.16)	1.24	*ns*
Potentially real	0.27 (0.12)	0.20 (0.11)	2.19	.03

Table 3
Median R^2 Values (and Interquartile Ranges) Produced by the Hyperbolic Function When Fit to Individual Choice Patterns in the Potentially Real and Hypothetical Conditions Across Tasks in Experiment 1 (N = 61)

Task	Outcome type		Z^a
	Hypothetical	Potentially real	
Delay	.71 (.03–.93)	.81 (.11–.93)	−0.80
Probability	.85 (.11–.92)	.82 (.61–.91)	0.43

[a] Based on Wilcoxon signed-ranks test; *p* values were nonsignificant.

etary outcomes generated frequencies of nonsystematic response patterns and rates of discounting that are statistically indistinguishable from those using potentially real outcomes. One potential confound in these findings is the order effect detected in the probability discounting task in which those who completed the hypothetical task first had significantly lower AUC values than those completing the potentially real task first.

The findings from Experiment 1 should increase researcher confidence in the validity of hypothetical monetary outcomes by comparison with potentially real monetary outcomes when using delay and probability discounting procedures. However, the vast majority of research studies comparing real and potentially real outcomes in discounting studies have used non-substance-abusing samples, often excluding individuals who meet even minimal substance use criteria (e.g., Madden et al., 2003). Only one study (Baker et al., 2003) to date compared delay discounting for hypothetical and potentially real outcomes in nicotine-dependent individuals, and none have done so using probability discounting procedures. The purpose of Experiment 2 was to replicate Experiment 1 in a nicotine-dependent sample.

Experiment 2

Method

Thirty-six adults (15 women, 21 men), with a mean age of 35.9 (*SD* = 12.8) years, were recruited through news advertisements and community postings. Interested individ-

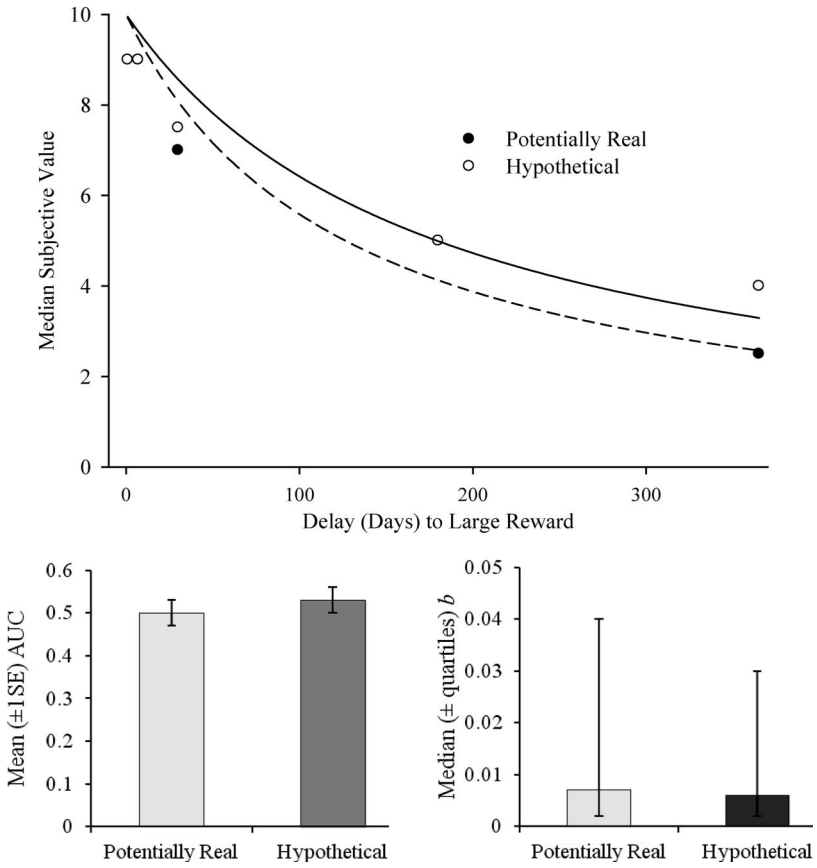

Figure 1. Comparison of delay discounting outcomes among participants (*N* = 61) in Experiment 1. The top panel shows the current subjective value of delayed hypothetical and potentially real monetary rewards; fit lines represent prediction based on the hyperbolic decay function for hypothetical (solid line) and potentially real (dashed line) outcomes. The bottom left panel shows the mean individual area under the curve (AUC) values plus or minus 1 *SE*. The bottom right panel shows the median value of individual discounting rates calculated using the hyperbolic model.

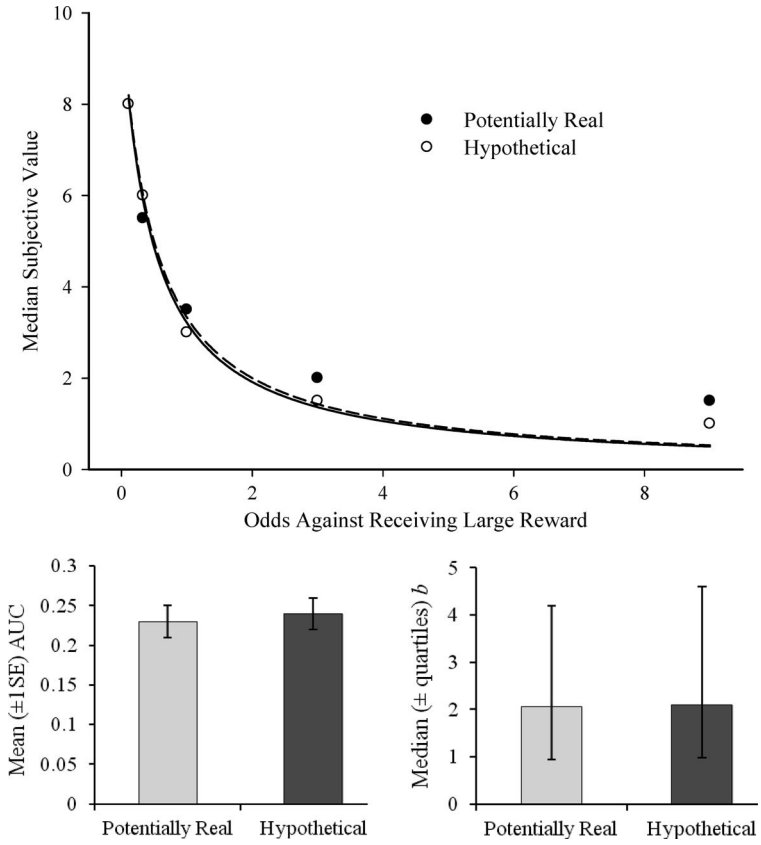

Figure 2. Comparison of probability discounting patterns across outcome types ($N = 61$) in Experiment 1. The top panel shows the current subjective value of probabilistic hypothetical and potentially real monetary rewards; fit lines represent prediction based on the hyperbolic decay function for hypothetical (solid line) and potentially real (dashed line) outcomes. The bottom left panel shows the mean individual area under the curve (AUC) values plus or minus 1 *SE*. The bottom right panel shows the median value of individual discounting rates calculated using the hyperbolic model.

uals were invited to participate in the study if they were at least 18 years of age and had a score of 6 or higher on the Fägerstrom Test for Nicotine Dependence (Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991), which is indicative of severe nicotine dependence. Other than the nicotine-dependent sample recruited for participation, the materials, procedures, and statistical analyses are the same as those described in Experiment 1.

Results

There were no significant differences in the demographic make-up of the samples in each counterbalance condition, nor were there differences in the frequency of nonsystematic response patterns for either delay or probability discounting across counterbalance orders (see Table 4). There were no differences in the extent of delay discounting (AUC) across counterbalance conditions, but participants completing the potentially real outcomes task first had steeper rates of probability discounting for potentially real outcomes, and there was a trend toward a similar effect for hypothetical outcomes (see Table 5). McNemar's χ^2 tests revealed no differences in the frequency on nonsystematic response patterns between outcome type for either delay or probability discounting (both ps $> .05$).

A Wilcoxon's signed-ranks test revealed no difference in model fit as a function of outcome type for delay discounting, but the hyperbolic model did tend to fit data for real outcomes better than it did hypothetical outcomes in the probability discounting task (see Table 6). Figure 3 shows the median indifference point values, mean AUC estimates, and median b values calculated with the hyperbolic function for delay discounting for all participants across outcome type. Median indifference points and fit lines for each outcome overlap significantly, and statistical analyses revealed no differences in mean AUC ($t[35] = -0.44$, $p > .05$) or median b ($Z = -0.049$, $p > .05$) as a function of outcome type. Figure 4 shows similar data for probability discounting. There were no differences in mean AUC ($t[35] = -.042$, $p > .05$) or median b ($Z = -0.131$, $p > .05$) values as a function of outcome type in probability discounting. AUC values for potentially real and hypothetical outcomes were significantly correlated for both delay discounting ($r = .85$, $n = 36$, $p < .001$) and probability discounting ($r = .61$, $n = 36$, $p < .001$) tasks.

Table 4
Demographic Characteristics and Frequency of Nonsystematic Response Patterns Across Counterbalance Conditions in Experiment 2

Demographic variable	Task order		χ^2
	Hypothetical → real	Real → hypothetical	
n	19	17	
% Male	52.6	64.7	2.08
Mean age in years (and *SD*)	35.7 (2.5)	36.1 (3.6)	0.83[a]
Median annual income (and interquartile range)	$14,589 ($2,400–$25,000)	$16,000 ($10,910–$24,500)	−0.59[b]
% High school educated	10.5%	11.8%	0.014
FTND total score	7.63 (1.07)	7.12 (1.17)	−1.38[a]
Nonsytematic response patterns			
Delay discounting			
Potentially real	3	3	0.02
Hypothetical	2	3	0.54
Probability discounting			
Potentially real	1	2	0.50
Hypothetical	4	2	0.56

Note. For chi-square values, *p* values were nonsigificant. FTND = Fagerstrom Test for Nicotine Dependence.
[a] Independent-samples *t* test. [b] Mann-Whitney U test.

Discussion

Experiment 2 findings generally replicated those reported in Experiment 1 and those reported by Baker et al. (2003), suggesting that nicotine-dependent participants discount the value of delayed hypothetical and potentially real rewards similarly. These findings suggest further that nicotine-dependent individuals discount the value of hypothetical outcomes and that of potentially real outcomes similarly in the context of probability discounting, which has not been reported to date. Finally, Experiment 2 findings suggest that hypothetical outcomes do not yield differentially greater frequencies of nonsystematic response patterns than do potentially real outcomes for both delay and probability discounting in nicotine-dependent individuals.

As in Experiment 1, participants completing the potentially real outcomes task first tended to yield steeper discounting rates on the hypothetical outcomes task than those who completed the hypothetical outcomes task first. This finding generally replicates the same one reported in Experiment 1 and suggests that researchers should consider the potential effect of repeated discounting measurements within a session.

General Discussion

The results of the two experiments reported here suggest that hypothetical monetary outcomes yield patterns of discounting that mirror those for potentially real outcomes in both delay and probability discounting. In addition, using hypothetical monetary outcomes did not produce more nonsystematic response patterns than did using potentially real outcomes. Finally, the present study established these findings in both nicotine-dependent and nondependent samples. These findings should increase confidence in the validity of discounting research that uses hypothetical monetary outcomes to examine impulsive decision making in a laboratory context with humans.

Our findings concerning the similarity in delay discounting for potentially real and hypothetical outcomes replicates numerous other studies with similar procedures (Baker et al., 2003; Bickel et al., 2009; Johnson & Bickel, 2002; Lagorio & Madden, 2005; Madden et al., 2003; Madden et al., 2004) that found similar discounting rates across outcome types, but also suggest similarities in the frequency of orderly patterns of responding (Johnson &

Table 5
Mean Area Under the Curve Estimates for All Discounting Tasks as a Function of Counterbalance Order in Experiment 2

Discounting task	Potentially real first (n = 17)	Hypothetical first (n = 19)	$t(34)$	p
Delay discounting				
Hypothetical	0.33 (0.26)	0.22 (0.19)	1.41	*ns*
Potentially real	0.33 (0.24)	0.24 (0.26)	1.16	*ns*
Probability discounting				
Hypothetical	0.29 (0.16)	0.19 (0.13)	1.96	.058
Potentially real	0.29 (0.13)	0.19 (0.10)	2.55	.014

Table 6
Median R^2 Values (and Interquartile Ranges) Produced by the Hyperbolic Function When Fit to Individual Choice Patterns in the Potentially Real and Hypothetical Conditions Across Tasks in Experiment 2 (n = 36)

Task	Outcome type		Z[a]
	Hypothetical	Potentially real	
Delay	0.75 (0.0–0.89)	0.81 (0.0–0.93)	−0.16
Probability	0.83 (0.66–0.91)	0.88 (0.76–0.94)	−2.31*

[a] Based on Wilcoxon signed-ranks test.
* $p < .05$.

Bickel, 2008). Comparing the frequency of nonsystematic response patterns across these tasks provides an additional relevant dependent measure of task equivalence and suggests that participants respond just as carefully on the hypothetical tasks as they do on the potentially real tasks. This is important because it suggests that previous research that used all participants in group-level aggregated findings probably did not obscure nonsystematic response patterns that would be reasonably expected if hypothetical outcomes yielded more careless response patterns because of a devaluing of hypothetical versus potentially real outcomes. Although numerous factors may influence the frequency of nonsystematic response patterns (e.g., instructions to participants, task parameters; see Johnson & Bickel, 2008), using hypothetical outcomes does not appear to influence the probability of nonsystematic response patterns.

This is the first study to compare hypothetical and potentially real monetary outcomes in probability discounting, and our findings indicate empirical equivalence of these outcome types in both a control sample (Experiment 1) and a nicotine-dependent sample (Experiment 2). These findings are encouraging and suggest that hypothetical monetary outcomes yield valid response patterns in probability discounting tasks. Although the majority of research concerning discounting has focused on

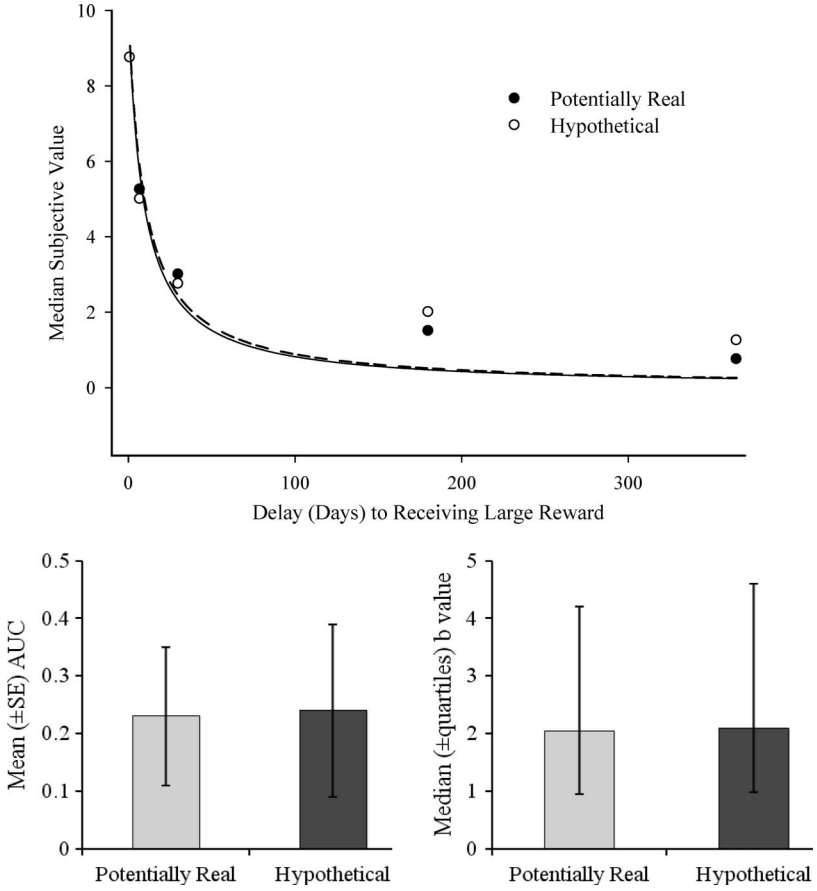

Figure 3. Comparison of delay discounting outcomes among nicotine-dependent participants (n = 36) in Experiment 2. The top panel shows the median subjective value of delayed hypothetical and potentially real monetary rewards; the lines represent best fit of the hyperbolic decay function for hypothetical (solid line) and potentially real (dashed line) outcomes. The bottom left panel shows mean individual area under the curve (AUC) values plus or minus 1 *SE*. The bottom right panel shows the median value of individual discounting rates calculated using the hyperbolic model.

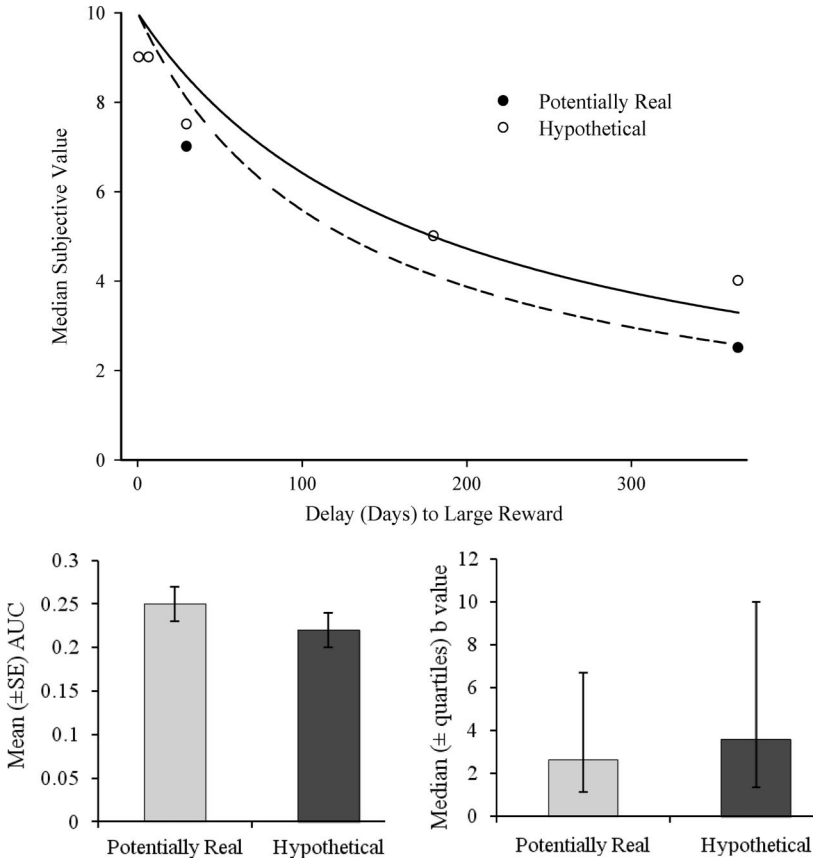

Figure 4. Comparison of probability discounting patterns across outcome types (n = 36) in Experiment 2. The top panel shows the current subjective value of probabilistic hypothetical and potentially real monetary rewards. Fit lines represent prediction based on the hyperbolic function for hypothetical (solid) and potentially real (dashed) outcomes. The bottom left panel shows mean individual area under the curve (AUC) values plus or minus 1 *SE*. The bottom right panel shows the median value of individual discounting rates calculated using the hyperbolic model.

delay discounting, interest in probability discounting is increasing. The present findings are relevant to researchers interested in the validity of probability discounting methods that use hypothetical monetary outcomes.

This is the second study to compare hypothetical and potentially real outcomes in a nicotine-dependent sample and the findings replicate and extend Baker et al.'s (2003) report that delay discounting for hypothetical and potentially real outcomes in a sample of nicotine-dependent individuals yielded similar data. Discounting has been called a "fundamental behavioral process of drug dependence" (Bickel & Johnson, 2003, p. 435), and much of the research concerning discounting focuses on the use and abuse of drugs, so findings that confirm the validity of discounting decisions for hypothetical outcomes in substance-dependent participants are important. Given the relevance of discounting research to the understanding of phenomena that underlie substance use problems, future research should consider replicating these findings in samples of individuals with dependence on or problems stemming from use of other kinds of drugs, such as alcohol, heroin, cocaine, and so forth. Replication of the present findings in other samples is important for establishing the validity of discounting findings using hypothetical outcomes across samples.

It is notable that the present findings are inconsistent with Hinvest and Anderson's (2010) study comparing real and hypothetical outcomes in delay and probability discounting. However, they found only a modest increase in the rate of delay discounting for real outcomes compared with hypothetical outcomes and no such effect for probability discounting. These inconsistent findings could be due to methodological difference across outcome types (real vs. potentially real). No research to date has specifically compared hypothetical, real, and potentially real outcomes in delay or probability discounting, but such a comparison may clarify the equivalence of these tasks.

Although the present findings and those of other studies should encourage researcher confidence in the equiv-

alence of data gathered using these methods, further research in this area is warranted. For example, our finding that counterbalance order influences probability discounting behavior highlights the potential problem with repeated administration of discounting tasks within a session. Research to date on this issue is inconsistent, with some researchers finding a counterbalance order effect (e.g., Hinvest & Anderson, 2010) and others finding no such effect (e.g., Madden et al., 2003). However, discounting researchers might consider using between-groups designs to answer these sorts of questions in the future to avoid such potential confounds. In addition, no research to date has addressed the empirical equivalence of real, potentially real, and hypothetical nonmonetary outcomes, which are receiving increased attention in the discounting literature. Researchers have asked participants to make decisions for hypothetical food (Estle et al., 2007; Odum, Baumann, & Rimington, 2006; Odum & Rainaud, 2003; Rasmussen et al., 2010), alcohol (Estle et al., 2007; Odum & Rainaud, 2003), and sexual outcomes (Lawyer, 2008; Lawyer et al., 2010), among others. Although decisions for these hypothetical outcomes are characterized quite well using discounting procedures and models, no research to date has compared patterns of discounting for hypothetical versus (potentially) real nonmonetary outcomes. A well-conducted series of studies comparing hypothetical and (potentially) real nonmonetary rewards that can be reasonably delivered (e.g., food, cigarettes) would help clarify the role of outcome type in discounting decisions for outcomes more directly related to impulsivity-related human health problems.

References

Ainslie, G. (1975). Specious reward: A behavioral theory of impulsiveness and impulse control. *Psychological Bulletin, 82,* 463–496. doi: 10.1037/h0076860

Baker, F., Johnson, M. W., & Bickel, W. K. (2003). Delay discounting in current and never-before cigarette smokers: Similarities and differences across commodity, sign, and magnitude. *Journal of Abnormal Psychology, 112,* 382–392. doi: 10.1037/0021-843x.112.3.382

Bickel, W. K., & Johnson, M. W. (2003). Delay discounting: A fundamental behavioral process of drug dependence. *Time and decision: Economic and psychological perspectives on intertemporal choice* (pp. 419–440). New York: Sage.

Bickel, W. K., Pitcock, J. A., Yi, R., & Angtuaco, E. J. (2009). Congruence of BOLD response across intertemporal choice conditions: Fictive and real money gains and losses. *Journal of Neuroscience, 29,* 8839–8846. doi: 10.1523/JNEUROSCI.5319–08.2009

Estle, S. J., Green, L., Myerson, J., & Holt, D. D. (2007). Discounting of monetary and directly consumable rewards. *Psychological Science, 18,* 58–63. doi: 10.1111/j.1467–9280.2007.01849.x

Field, M., Christiansen, P., Cole, J., & Goudie, A. (2007). Delay discounting and the alcohol Stroop in heavy drinking adolescents. *Addiction, 102,* 579–586.

Green, L., Fry, A. F., & Myerson, J. (1994). Discounting of delayed rewards: A life-span comparison. *Psychological Science, 5,* 33–36. doi: 10.1111/j.1467–9280.1994.tb00610.x

Heatherton, T. F., Kozlowski, L. T., Frecker, R. C., & Fagerstrom, K. O. (1991). The Fagerstrom Test for Nicotine Dependence: A revision of the Fagerstrom Tolerance Questionnaire. *British Journal of Addiction, 86,* 1119–1127.

Heil, S. H., Johnson, M. W., Higgins, S. T., & Bickel, W. K. (2006). Delay discounting in currently using and currently abstinent cocaine-dependent outpatients and non-drug-using matched controls. *Addictive Behaviors, 31,* 1290–1294.

Hinvest, N. S., & Anderson, I. M. (2010). The effects of real versus hypothetical reward on delay and probability discounting. *Quarterly Journal of Experimental Psychology, 63,* 1072–1084. doi: 10.1080/17470210903276350

Jikko, Y., & Okouchi, H. (2007). Real and hypothetical rewards in probability discounting. *Japanese Journal of Psychology, 78,* 269–276.

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. doi: 10.1901/jeab.2002.77–129

Johnson, M. W., & Bickel, W. K. (2008). An algorithm for identifying nonsystematic delay-discounting data. *Experimental and Clinical Psychopharmacology, 16,* 264–274. doi: 10.1037/1064–1297.16.3.264

Kirby, K. N. (1997). Bidding on the future: Evidence against normative discounting of delayed rewards. *Journal of Experimental Psychology: General, 126,* 54–70. doi: 10.1037/0096–3445.126.1.54

Kollins, S. H. (2003). Delay discounting is associated with substance use in college students. *Addictive Behaviors, 28,* 1167–1173.

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. doi: 10.1016/j.beproc.2005.02.003

Lawyer, S. R. (2008). Probability and delay discounting of erotic stimuli. *Behavioural Processes, 79,* 36–42.

Lawyer, S. R., Williams, S., Prihodova, T., Rollins, J., & Lester, A. (2010). Delay and probability discounting for hypothetical sexual contact. *Behavioural Processes, 84,* 687–692.

Madden, G. J., Begotka, A. M., Raiff, B. R., & Kastern, L. L. (2003). Delay discounting of real and hypothetical rewards. *Experimental and Clinical Psychopharmacology, 11,* 139–145. doi: 10.1037/1064–1297.11.2.139

Madden, G. J., Petry, N. M., Badger, G. J., & Bickel, W. K. (1997). Impulsive and self-control choices in opioid-dependent patients and non-drug-using control patients: Drug and monetary rewards. *Experimental and Clinical Psychopharmacology, 5,* 256–262. doi: 10.1037/1064–1297.5.3.256

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 and Clinical Psychopharmacology, 12,* 251–261. doi: 10.1037/1064–1297.12.4.251

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

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. doi: 10.1016/j.beproc.2010.01.003

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. doi: 10.1016/j.beproc.2008.12.017

Mitchell, S. (1999). Measures of impulsivity in cigarette smokers and non-smokers. *Psychopharmacology, 146,* 455–464.

Myerson, J., & Green, L. (1995). Discounting of delayed rewards: Models of individual choice. *Journal of the Experimental Analysis of Behavior, 64,* 263–276. doi: 10.1901/jeab.1995.64–263

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. doi: 10.1901/jeab.2001.76–235

Nasrallah, N. A., Yang, T. W. H., & Bernstein, I. L. (2009). Long-term risk preference and suboptimal decision making following adolescent alcohol use. *Proceedings of the National Academy of Sciences USA, 106,* 17600–17604. doi: 10.1073/pnas.0906629106

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. doi: 10.1016/j.beproc.2006.06.008

Odum, A. L., Madden, G. J., & Bickel, W. K. (2002). Discounting of delayed health gains and losses by current, never- and ex-smokers of cigarettes. *Nicotine & Tobacco Research, 4,* 295–303. doi: 10.1080/14622200210141257

Odum, A. L., & Rainaud, C. P. (2003). Discounting of delayed hypothetical money, alcohol, and food. *Behavioural Processes, 64,* 305–313. doi: 10.1016/s0376-6357(03)00145–1

Ohmura, Y., Takahashi, T., & Kitamura, N. (2005). Discounting delayed and probabilistic monetary gains and losses by smokers of cigarettes. *Psychopharmacology, 182,* 508.

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. doi: 10.1038/npp.2010.124

Petry, N. M. (2001). Delay discounting of money and alcohol in actively using alcoholics, currently abstinent alcoholics, and controls. *Psychopharmacology, 154,* 243–250. doi: 10.1007/s002130000638

Petry, N. M. (2003). Discounting of money, health, and freedom in substance abusers and controls. *Drug and Alcohol Dependence, 71,* 133.

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,* 233–244. doi: 10.1901/jeab.1991.55–233

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. doi: 10.1016/j.beproc.2009.09.001

Reynolds, B., Richards, J. B., Horn, K., & Karraker, K. (2004). Delay discounting and probability discounting as related to cigarette smoking status in adults. *Behavioural Processes, 65,* 35–42. doi: 10.1016/s0376-6357(03)00109–8

Richards, J. B., Zhang, L., Mitchell, S. H., & de Wit, H. (1999). Delay or probability discounting in a model of impulsive behavior: Effect of alcohol. *Journal of the Experimental Analysis of Behavior, 71,* 121–143. doi: 10.1901/jeab.1999.71–121

Stevens, S. S. (1957). On the psychophysical law. *Psychological Review, 64,* 153–181.

Vuchinich, R. E., & Simpson, C. A. (1998). Hyperbolic temporal discounting in social drinkers and problem drinkers. *Experimental and Clinical Psychopharmacology, 6,* 292–305. doi:10.1037/1064–1297.6.3.292

Received December 3, 2010
Revision received April 16, 2011
Accepted April 25, 2011 ■