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# Delay Discounting of Real and Hypothetical Rewards

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The degree to which real and hypothetical rewards were discounted across delays ranging from 6 hr to 1 year was explored in a within-subjects design. An adjusting-amounts procedure was used to estimate the subjective value of real and hypothetical rewards at each delay. A hyperbolic discounting function provided a significantly better fit to individual participants' preferences than did an exponential function. No significant effect of reward type on degree of hyperbolic discounting or area under the discounting curves was detected. These findings offer some support for the validity of using hypothetical rewards to estimate discounting rates in substance-abusing and other populations, but caution is suggested because this support is gleaned from a failure to detect an effect of reward type.

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A number of researchers have proposed that the degree to which individuals devalue delayed consequences (a phenomenon commonly termed *delay discounting*) is related to impulsive decision-making (e.g., Ainslie & Haendel, 1983; Kagel, Battalio, & Green, 1995; Logue, 1988) and substance abuse (e.g., Bickel & Marsch, 2001; Madden, Petry, Badger, & Bickel, 1997). In delay discounting studies, *impulsivity* is defined as a preference for a smaller–sooner reward while a larger–later one is forgone. The opposite preference has been labeled *self-control* (e.g., Rachlin & Green, 1972).

Attempts to understand delay discounting may be classified into two approaches (Myerson & Green, 1995). One, the normative economic approach (e.g., Lancaster, 1963; Meyer, 1976; Samuelson, 1937), attempts to understand discounting as rational decision-making and uses economic theory and assumptions in its mathematical account of discounting:

$$V = Ae^{-kD}. \tag{1}$$

In this exponential discounting equation, $A$ is the amount of the reward delivered after delay $D$, and the free parameter $k$ is an empirically derived measure of the degree to which the individual discounts the value ($V$) of the delayed reward. According to this equation, the subjective value of a reward decreases exponentially with increasing delays. The second approach, taken by psychologists beginning in the 1960s (e.g., Chung, 1965; Logan, 1965), mathematically describes observed choices between immediate and delayed outcomes. This approach suggests that the form of the delay discounting function is hyperbolic (deVilliers & Herrnstein, 1976). Mazur (1987), using a psychophysical technique to quantify delay discounting in animal subjects, proposed the following hyperbolic discounting equation:

$$V = A/(1 + kD) \tag{2}$$

in which the parameters are identical to Equation 1.

To our knowledge, every study that has compared Equations 1 and 2 favors the hyperbolic function in both animal (e.g., Mazur, 1987; Rodriguez & Logue, 1988) and human (e.g., Kirby, 1997; Myerson & Green, 1995; Rachlin, Raineri, & Cross, 1991) subjects. This concordance between the form of the delay discounting function in human and animal studies provides evidence that the effect of reinforcement delay on decision-making is similar across species.

An appropriate mathematical model of delay discounting (Equation 2) and across-species continuity of this discounting function have provided a foundation for recent attempts to understand components of substance abuse as a product of delay discounting. Several studies have examined the relation between delay discounting and substance abuse status. For example, Madden et al. (1997) reported that heroin-addicted individuals discounted delayed monetary rewards substantially more than matched controls, and this finding has been systematically replicated in problem alcohol drinkers (e.g., Vuchinich & Simpson, 1998), cigarette smokers (Bickel, Odum, & Madden, 1999; Mitchell, 1999), and needle-sharing heroin addicts (Odum, Madden, Badger, & Bickel, 2000).

Results of delay discounting studies like these have led some researchers (e.g., Ainslie, 1992; Bickel & Marsch, 2001; Heather, 1998; Madden, Bickel, & Jacobs, 1999) to speculate that higher rates of delay discounting may play a role in the decision to abuse drugs. Specifically, if drug use is conceptualized as a smaller–sooner reward when com-

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pared with the greater benefits that may be obtained through sustained drug abstinence (i.e., the larger–later reward), and if drug abusers devalue the delayed benefits of abstinence more than non-drug users, then greater delay discounting may predispose an individual to substance abuse because the delayed benefits of abstinence are meaningless (discounted to the point of zero value) when compared with the immediate value of drug use.

More recently, Bickel and Marsch (2001) have suggested that (a) degree of delay discounting may prove a useful predictor of success in drug treatment programs, (b) reducing discounting rates may be an important goal in such treatment, and (c) degree of discounting may prove a useful measure of the success of treatment. Consistent with these hypotheses, Bickel et al. (1999) reported that former cigarette smokers discounted delayed monetary rewards to a degree comparable to that of matched controls and significantly less than that of current smokers.

Given the increased interest in precisely measuring degree of delay discounting either across specific populations (e.g., drug-dependent vs. non-drug-using populations) across time (e.g., longitudinal studies of delay discounting and subsequent development of drug-abuse disorders), or across stages of treatment (as a measure of the efficacy of treatment), evaluating the validity of current procedures for assessing human delay discounting is important.

The most commonly used procedure in studies examining delay discounting in substance abusers was developed by Rachlin et al. (1991), who asked participants to choose between monetary rewards obtained either immediately or following delays ranging from 1 month to 50 years. The amount of the immediate reward is adjusted until the immediate and delayed rewards are of equivalent subjective value. The value of the immediate reward at this indifference point provides a measure of the present subjective value of the delayed reward. This adjusting-amount procedure is the one most widely used in studies examining the relation between degree of delay discounting and substance abuse status (Bickel et al., 1999; Johnson & Bickel, 2002; Madden, et al., 1997, 1999; Mitchell, 1999; Odum et al., 2000; Petry, 2001; Petry & Casarella, 1999; Richards, Zhang, Mitchell, & de Wit, 1999; Vuchinich & Simpson, 1998).

Because of the large number of choices made in each session (typically more than 400) and because of the large delayed-reward magnitudes (typically $1,000), the majority of delay discounting studies using the adjusting-amount procedure have employed hypothetical rewards (Bickel et al., 1999; Johnson & Bickel, 2002; Madden, et al., 1997, 1999; Odum et al., 2000; Petry, 2001; Petry & Casarella, 1999; Vuchinich & Simpson, 1998). Every researcher who has used hypothetical rewards in the substance-abuse literature has questioned the validity of their procedures, noting that choices made between hypothetical outcomes may not accurately reflect choices between real outcomes. Researchers using hypothetical rewards have argued for their validity by noting that Mazur's (1987) hyperbolic discounting model (Equation 2), which provides the best fit of animal delay discounting data, also provides the best fit of human choices when hypothetical outcomes are used (e.g., Madden et al., 1997).

Other substance abuse researchers (Crean, de Wit, & Richards, 2000; Kirby, Petry, & Bickel, 1999; Mitchell, 1999; Richards et al., 1999) have randomly selected one of the participant's choices made during the session and delivered the reward they preferred during the session. Because participants cannot predict which choice will be selected at the end of the session, they should, in theory, behave as though each outcome selected were real.

Although the results of these studies accord well with those of studies using hypothetical outcomes, concerns remain about the use of hypothetical rewards (e.g., Bickel & Marsch, 2001; Critchfield & Kollins, 2001). These concerns appear warranted given studies in the risk-taking literature that show decreased risk taking when real consequences are used (e.g., Feather, 1959; Irwin & McClelland, 1992; Lafferty & Higbee, 1974; Levin, Chapman, & Johnson, 1988; Slovic, 1969) and reports that variables known to affect real risk taking do not affect choices involving hypothetical risks (e.g., Isen & Patrick, 1983). Although some studies have failed to reveal differences between real and hypothetical risks (e.g., Ettenson & Coughlin, 1982), the overwhelming number of studies that have revealed such differences raise concerns about using hypothetical outcomes in the delay discounting literature, especially when the purpose of the research is to precisely quantify degree of discounting or to track changes in discounting produced by therapeutic interventions (Bickel & Marsch, 2001).

Kirby's (1997) review of the discounting literature reduced some of these concerns and simultaneously raised others. Kirby reported that hypothetical and real rewards were both discounted according to Mazur's (1987) hyperbolic discounting equation. However, comparing discounting rates across a number of studies using somewhat different procedures and reward magnitudes, he found that hypothetical rewards were discounted less than real rewards. Johnson and Bickel (2002) provided empirical evidence that this difference in discounting rates across reward type (real or hypothetical) was a function of reward magnitude (small rewards tend to be discounted more than large rewards; Myerson & Green, 1995) rather than reward type.

In addition, Johnson and Bickel (2002) conducted the first study examining the effects of reward type (real and hypothetical rewards) on rate of discounting delayed rewards. In their study, which used an adjusting-amount procedure, discounting rates of 5 of 6 subjects showed no effect of reward type (1 subject discounted hypothetical rewards more than real rewards). Combined with their finding that real and hypothetical rewards were both discounted in accord with the hyperbolic discounting equation (Equation 2), their findings suggested that hypothetical rewards could be validly used in studies of delay discounting.

The present experiment sought to further explore the relation between reward type and rates of delay discounting. Our study was designed to compare discounting rates in a larger group of participants than that used by Johnson and Bickel (2002). Their investigation used large monetary amounts (up to $250), and several real rewards were given to each participant. Thus, practical constraints kept their sample size small ($n = 6$). Using a larger sample size allowed us greater statistical power to detect an effect of reward type (should one exist). Our study also systematically replicates the Johnson and Bickel study because we conducted the experiment with different subjects, in a different location, with somewhat different procedures (smaller reward amounts and only one real reward per subject). Because we found no a priori reason to believe that drug-dependent individuals would be any more or less likely to be affected by real or hypothetical rewards, we conducted our experiments with non-drug-using college students.

## Method

### Participants

Twenty college students (5 men and 15 women) ranging in age from 18 to 21 (average = 19.2) were recruited by means of fliers posted around the campus of the University of Wisconsin—Eau Claire. Applicants were excluded from participating if they reported smoking cigarettes, binge drinking (> 4 drinks in one sitting), or using any illicit drugs within the last year. These exclusion criteria were adopted in the hope of obtaining a homogeneous sample of students that varied little in degree of discounting. Applicants were also excluded if they had taken more than an introductory course in psychology. Participants provided informed consent by signing a form approved by the local institutional review board. Participants were compensated with an amount of money chosen at random at the end of the session (see below).

### Materials

Rewards, and delays to rewards were printed on 4 × 6-in. (10.1 × 15.2-cm) index cards. The monetary reward amounts (in dollars) were 10.00, 9.90, 9.60, 9.20, 8.50, 8.00, 7.50, 7.00, 6.50, 6.00, 5.50, 5.00, 4.50, 4.00, 3.50, 3.00, 2.50, 2.00, 1.50, 1.00, 0.80, 0.60, 0.40, 0.20, 0.10, 0.05, and 0.01. A set of variable delays was printed on another deck of index cards. These delays were 6 hr, 2 days, 1 week, 2 weeks, 1 month, 2 months, 6 months, and 1 year.

### Procedures

Participants were quasirandomly assigned to complete the real-reward condition or the hypothetical-reward condition first (half of the participants completed the real-reward condition first). Demographic characteristics of participants who completed the conditions in the two different orders are given in Table 1. No significant differences in the groups' age, income, or gender composition were detected.

Table 1
*Demographic Characteristics of Participants Completing the Real and Hypothetical Reward Conditions in Different Sequence*

| Demographic | Group: Hypothetical → real | Real → hypothetical |
|---|---|---|
| *n* | 10 | 10 |
| % Male | 30 | 20 |
| Mean age (years) | 19.4 (1.0) | 19.1 (0.9) |
| Median monthly income ($) | 300 (162–650) | 162 (44–350) |

*Note.* Numbers in parentheses are standard deviations (age) or interquartile range (income).

Participants completed one session lasting approximately 60 min. Before the session, subjects were read the following instructions:

> I'm going to ask you to make some decisions about which of two rewards you would prefer. One of the rewards will always be available right now, and the other will only be available in the form of a check after you have waited for some period of time. For example, I might ask you to choose between $550 delivered today and $800 delivered in two years (the actual amounts of the rewards will be much less than this). We will do this with eight sets of rewards and each time the delay to one of the rewards will be different. For example, in the second set I might ask you to choose between some amount of money delivered today and an $800 check mailed to you in 10 years. For each set of rewards I will record the amount of money that the delayed reward seems to be worth to you. The choices you make are completely up to you. Please select the option that you prefer, not what you think I want you to prefer. I do not expect you to choose one particular reward over another. Just choose the reward you really want.

Before the hypothetical-reward condition, participants were read the following additional instructions:

> 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.

Between conditions, participants completed a series of simple single-digit addition and subtraction problems on a computer. Participants were instructed to respond as quickly and accurately as possible. This procedure, which lasted 20 min, was designed to decrease the probability that choices made in the first condition would be recalled and repeated in the second condition.

Prior to the real-reward condition, participants were read the following supplementary instructions:

> For each set of rewards, I will record the amount of money that the delayed reward seems to be worth to you. At the end of the session I will put all of your preferences (that is, how much each of the delayed rewards are worth to you) into a hat and you will pull one out. Whichever reward you select is the one that you will get, so every choice you make is potentially going to determine how much money you will earn. If you happen to select a delayed reward, we will mail you a check so it arrives on the exact day you are supposed to get it. If you happen to select a reward delivered today, we will write you a check as soon as the reward has been selected. Because you don't know which of the eight different rewards you will randomly select, you should make all of your choices as though you were going to get each reward.

The first choice was always between the highest reward amount ($10) delivered immediately and $10 delayed by 6 hr. After the participant pointed to the reward they preferred (the immediate reward in all cases), the immediate reward was decreased to the amount shown on the next card ($9.90). This sequence continued through the entire deck of immediate rewards, regardless of the participant's behavior. When a participant switched from the immediate to the delayed reward, the value of the last immediate reward chosen was recorded. When the end of the deck of immediate rewards was reached, the process was repeated in reverse order, with the experimenter recording the first immediate reward selected. The average of the two recorded values was taken as an indifference point, at which the small–immediate and large–delayed rewards were of equal subjective value to the participant ($V$

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in Equations 1 and 2). These procedures were repeated at each of the eight delays, with delays increasing after each complete progression (forward and backward) through the immediate rewards. With the exception of the reward amounts and delay durations, these procedures are identical to those developed by Rachlin et al. (1991) and used extensively in the delay discounting and substance abuse literature.

At the end of a real-reward session, the participant randomly selected 1 of 16 cards that indicated one of the eight delays and whether the monetary compensation would be obtained immediately or after the indicated delay. If the money was to be delivered immediately, the participant was given a check for the estimated present value of the delayed reward (i.e., the monetary value at the indifference point, *V*). If the money was to be delivered later, the participant was mailed a $10 check after the delay indicated on the card had elapsed (if the delay was less than 1 week, the participant was asked to return to the lab to collect their check).

### *Statistical Methods*

Delta Graph statistical software (SSPS, Chicago, IL) was used to fit individual participants' indifference points across the range of delays by means of the exponential (Equation 1) and hyperbolic (Equation 2) discounting functions. Delays to each reward were expressed as days in estimating degree of discounting ($k$). The percentages of variance accounted for ($R^2$) by the exponential and hyperbolic functions were compared by calculating difference scores for each subject (hyperbolic $R^2$ minus exponential $R^2$). Wilcoxon's matched-pairs signed rank test was used to assess the significance of this difference and to evaluate the significance of the difference in discounting rates ($k$) derived in the hypothetical- and real-reward conditions. The Mann–Whitney $U$ test was used to examine differences in discounting between subject groups who completed the conditions in a different sequence. Nonparametric tests were used because the distributions of parameters estimates and $R^2$ values were non-normal and influenced by outliers. Area under the discounting curve was calculated for individual participants (see Myerson, Green, & Warusawitharana, 2001). These values provide a more accurate measure of discounting rate than values derived using either the hyperbolic or exponential equation (the latter often provide inadequate fits to individual participants' data, thereby introducing a degree of measurement error). Because area-under-the-curve values were normally distributed, a $t$ test was used to compare the difference between discounting rates across conditions.

## Results

The upper panels of Figure 1 show exponential (Equation 1) and hyperbolic (Equation 2) discounting functions fit to the median indifference points for the hypothetical- and real-reward conditions. Data shown in the figure represent median subjective values of immediate rewards when participants equally preferred the immediate and fixed-amount delayed rewards. For the purpose of graphical representation, values are expressed as a percentage of the delayed rewards; this transformation has no effect on the estimated degree of discounting. The hyperbolic functions provided a better fit of the median hypothetical (hyperbolic $k$ = .0042, $R^2$ = .65; exponential $k$ = .0025, $R^2$ = .54) and real (hyperbolic $k$ = .0044, $R^2$ = .85; exponential $k$ = .0027, $R^2$ = .73) reward data.

The hyperbolic and exponential equations provided adequate fits to individual participants' choices in both the hypothetical- and real-reward conditions. Table 2 provides median $R^2$ values and interquartile ranges from each condition. The lower panel of Figure 1 shows the relative ability of the exponential and hyperbolic functions to fit individual subjects' indifference points. This graph shows the mean difference between $R^2$ values produced by the exponential and hyperbolic discounting equations (hyperbolic minus exponential, thus positive values reflect better fits provided by the hyperbolic function). The fits provided by the hyperbolic function yielded significantly higher $R^2$ values than the exponential functions in both the real- ($T$ = 37, $p < .01$) and hypothetical- ($T$ = 12, $p < .001$) reward conditions.

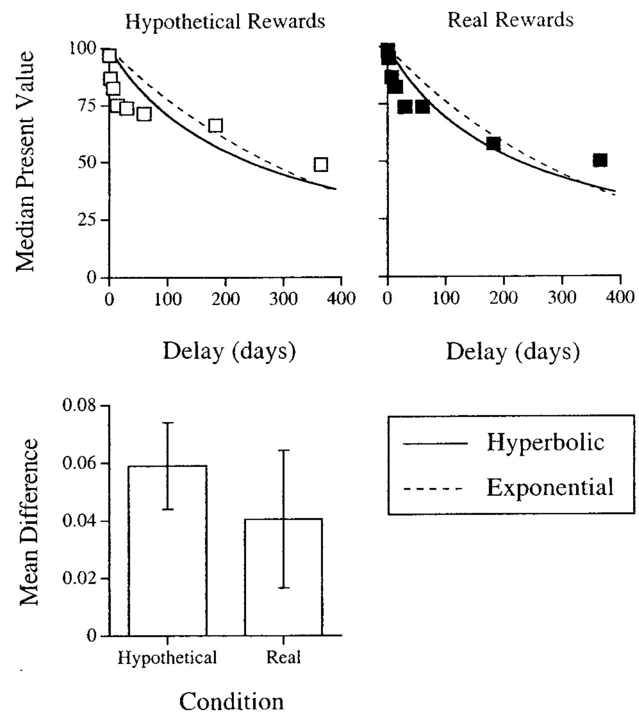


*Figure 1.* The top two panels show the median value of the immediate reward at the indifference point for each of the eight delayed rewards (i.e., the present value of the delayed rewards). These values provide an estimate of the value of the delayed reward in terms of money available now. Amounts are provided as a percentage of the value of the delayed hypothetical (left panel) and real (right panel) $10 rewards. The lower panel shows the mean difference between $R^2$ values derived from the fits provided by the hyperbolic (solid function) and exponential (dashed function) discounting functions in the upper panels (error bars correspond to *SEM*).

The top panel of Figure 2 shows median indifference points and hyperbolic discounting functions fit to these points from the real- and hypothetical-reward conditions. The middle panel shows median $k$ values derived from individual participants' indifference points by using the hyperbolic discounting function (error bars correspond to the interquartile range). Only the $k$ values derived with the hyperbolic discounting function were used because it provided a better fit to both the real- and hypothetical-reward data than the exponential function. No significant difference

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Table 2
*Median $R^2$ Values (and Interquartile Ranges) Produced by the Hyperbolic and Exponential Functions When Fit to Individual Participants' Choices in the Real- and Hypothetical-Reward Conditions*

| Condition | Hyperbolic | Exponential |
|---|---|---|
| Hypothetical | 0.81 (0.48–0.88) | 0.67 (0.43–0.78) |
| Real | 0.70 (0.58–0.92) | 0.63 (0.42–0.80) |

in degree of delay discounting was detected across conditions ($T = 99$, $p > .05$). Likewise, no significant difference was detected in those participants who completed the real-reward condition first ($T = 17$, $p > .05$) or completed the hypothetical-reward condition first ($T = 11$, $p > .05$).

The bottom panel of Figure 2 shows the average area under individual participants' discounting curves from both conditions. Consistent with the discounting parameters derived from individual participants' indifference points, area-under-the-curve values were not significantly different across the real- and hypothetical-reward conditions, $t(39) = 0.26$, $p = .80$.

Figure 3 shows the relation between discounting rates in the real- and hypothetical-reward conditions. Discounting rates ($k$) in the figure were logarithmically transformed because the distribution of values was non-normal, with most participants demonstrating very low rates of discounting (positively skewed). The strong positive correlation ($r = .92$) shown in Figure 3 demonstrates, beyond the statistical tests provided above, that individual participants' discounting rates were similar across the real- and hypothetical-reward conditions.

The lack of a significant difference in discounting rates across the real and hypothetical conditions may have occurred because participants recalled their responses in the first condition and reproduced them in the second. To assess this possibility, we compared discounting rates of the 10 participants that completed the real-reward condition first with the other 10 participants who first chose between hypothetical rewards. This comparison did not yield a statistically significant difference ($p = .29$).

## Discussion

This experiment was designed to determine whether delayed real rewards are discounted at a different rate than delayed hypothetical rewards and whether the hyperbolic discounting equation provides a better fit to these data than the exponential equation. A within-groups comparison design was used to provide adequate statistical power to detect effects of reward type. Consistent with findings reported by Johnson and Bickel (2002), the hyperbolic discounting function (Equation 2) provided a better fit to both grouped and individual participants' choices in both the hypothetical- and real-reward conditions. Also consistent with Johnson and Bickel is our failure to provide evidence for a difference in discounting rates across the real- and hypothetical-reward conditions.

Our findings may be added to those reporting that the hyperbolic discounting function proposed by Mazur (1987) provides a better fit of delay discounting data in humans. Prior studies have demonstrated that Equation 2 provides a better fit than Equation 1 regardless of whether animals (e.g., Mazur, 1987; Rodriguez & Logue, 1988), non-substance-abusing humans (e.g., Kirby, 1997; Myerson & Green, 1995; Rachlin et al., 1991), or substance-abusing humans (Madden et al., 1999) serve as subjects. Johnson and Bickel (2002) demonstrated better fits provided by the hyperbolic function in both real- and hypothetical-reward conditions in 6 participants, and our findings obtained with a larger sample size accord well with their findings.

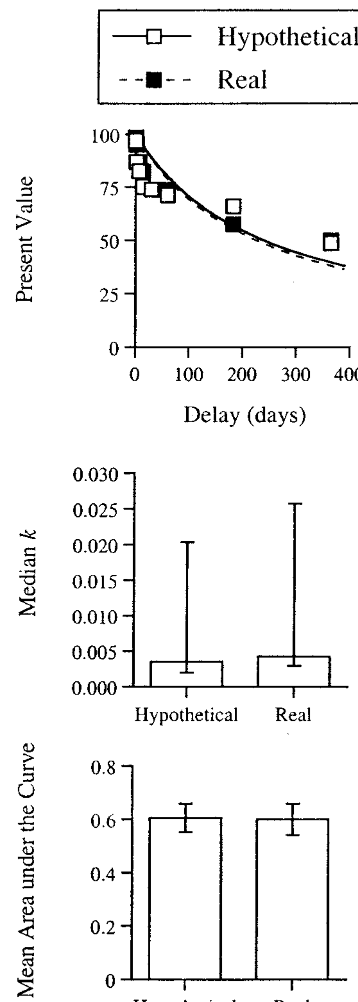


*Figure 2.* The top panel shows the present value of the eight different delayed hypothetical and real rewards (amounts are provided as a percentage of the value of the delayed $10 rewards). Discounting functions drawn through these data were fit by using Mazur's (1987) hyperbolic discounting function. The center panel shows the median value of individual participants' discounting rate ($k$) derived from Mazur's hyperbolic discounting function (error bars correspond to interquartile ranges). The bottom graph shows the median area under individual participants' discounting curves (error bars correspond to *SE*). These values were derived by using the method outlined by Myerson et al. (2001).

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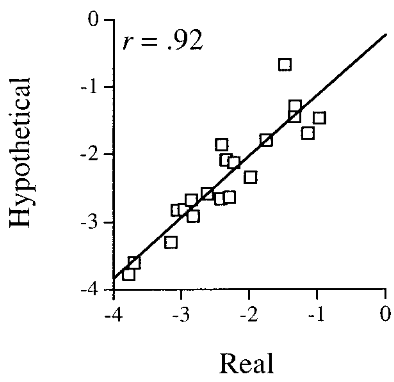


*Figure 3.* Correlation between individual participants' discounting rates ($k$) in the real- and hypothetical-reward conditions. Discounting rates were derived by using Mazur's (1987) hyperbolic discounting function and were logarithmically transformed because the distribution was positively skewed.

Some readers may object that, even with a sample size of 20 participants and the use of within-subjects comparisons, we lacked sufficient statistical power to detect an effect of reward type. Certainly if we had used 40 or 60 participants, we would have increased our ability to detect smaller or less consistent effects, but we selected a sample size of 20 because this is approximately the number of participants used in most human delay discounting studies. If the current sample size was inadequate to detect a statistically significant effect of reward type, then that effect must be very small and of little practical importance in the delay discounting literature. We believe that our findings should be viewed skeptically (see below), but we recommend the reader not confuse statistical significance with practical or clinical significance.

One may be tempted to suggest that when our findings are combined with those reported by Johnson and Bickel (2002), there is ample evidence that participants can accurately report their rates of delay discounting when the consequences are exclusively hypothetical. This conclusion must be approached cautiously, however, because it is based on extant failures to demonstrate an effect of reward type. There are at least two reasons to suspect that reward type may yet affect delay discounting. We briefly explore both of these and suggest that additional studies are required.

First, choices made in the real-reward condition were composed of 216 separate choices, for only 1 of which was the reward actually delivered. Thus, 215 of 216 choices (99.54%) were hypothetical. Given this distribution, it is entirely possible that participants made approximately the same choices in both conditions because the real rewards functioned as hypothetical rewards. Left unanswered by this experiment, therefore, is whether hypothetical and real rewards would be equivalently discounted if the consequence of every choice involving a real reward were actually delivered. To date, no such experiment has been conducted.

The second reason for approaching the conclusion that real and hypothetical rewards are equivalently discounted is that within-subject comparisons like those conducted here and by Johnson and Bickel (2002) cannot rule out the possibility that participants recalled the responses provided in the first condition and reproduced them in the second. This possibility appears tenable because participants in both experiments were instructed to behave as though the hypothetical rewards were real. Participants may have been disposed to comply with this instruction because they were monetarily compensated for their participation in both studies. A between-subjects comparison of discounting rates produced by those 10 of our participants who completed the hypothetical rewards condition first and the other 10 who completed the conditions in reverse order did not yield a statistically significant effect of reward type ($p = .29$), but with only 10 participants in each group, this failure may reflect a lack of statistical power. Further research should explore the effects of reward type using a between-groups comparison design.

Bickel and Marsch (2001) argued that rates of delay discounting may prove a useful predictor of success in a substance-abuse treatment program and that reduced impulsive decision making should be targeted as a treatment goal because increased preference for larger, more delayed reinforcers may render the individual less susceptible to continued drug use or drug relapse. A number of studies in animal (Logue & Mazur, 1981; Mazur & Logue, 1978) and human (Binder, Dixon, & Ghezzi, 2000; Schweitzer & Sulzer-Azaroff, 1988) subjects have demonstrated that impulsive decision-making can be modified when participants experience the consequences of their choices. Whether similar procedures would modify choices made with hypothetical outcomes and, more important, whether these modified choices would translate to an increased probability of making self-control choices involving real outcomes (e.g., preference for the delayed benefits of drug abstinence over the smaller, more immediate consequences of drug use) remain unanswered.

In summary, our findings support the hyperbolic form of the delay discounting equation and suggest that participants are capable of reporting the extent to which they discount delayed rewards when those rewards are hypothetical. Because the latter conclusion is based on a failure to demonstrate an effect of reward type and may be confounded with a carry-over effect, we recommend this conclusion be approached cautiously and that further research is required.

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