DELAYED REWARD AND COST DISCOUNTING

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Participants \((N = 28)\) chose between smaller, immediate and larger, delayed hypothetical monetary amounts in a cost and a reward condition. For both conditions, the choice procedure yielded equivalence points that measure the immediate amount reward or cost that is subjectively equivalent to the larger delayed reward or cost. Equivalence points from each of eight delays were used to estimate a discounting parameter for both hyperbolic and exponential discount functions. Hyperbolic functions accounted for more of the variance in both the reward and the cost condition, and delayed reward and cost discounting was significantly correlated. Participants discounted the value of delayed rewards to a greater degree than delayed costs. Previous research has found that substance abusers discount delayed rewards more than controls. Implications of the present findings for substance abuse and other health behaviors are discussed.

People routinely choose between acts, the consequences of which may be positive and negative and immediate and delayed. For example, one may choose to turn off the alarm in the morning and sleep an extra 30 minutes. This would produce a relatively higher valued immediate outcome, but a relatively lower valued delayed outcome when one is late for work. Or, one could attend college rather than seek employment after high school. This would produce a relatively lower valued, lower income short-term future, but a relatively higher valued, higher income long-term future.

Understanding how we choose between sooner and later rewards and costs has been an important task in psychological and economic research for some time (e.g., Ainslie, 1975; Kagel, Battalio, & Green, 1995; Mischel & Grusec, 1967; Rachlin, 1974). A key issue in understanding these choice situations has been describing the manner in which the value of rewards and costs varies as a function of delay (Kirby, 1997; Kirby & Herrnstein, 1995). Hyperbolic (Equation 1) and exponential...
(Equation 2) temporal discounting equations have been used most often to describe these changes in the value of outcomes.

\[
V = \frac{A}{1 + kD} \quad \text{(Equation 1)}
\]

\[
V = Ae^{-kD} \quad \text{(Equation 2)}
\]

In both equations, \( V, A, D, \) and \( k \) represent the present (discounted) value of the delayed outcome, the amount of the delayed outcome, the delay until the receipt of the outcome, and the discounting parameter, respectively. With hyperbolic discounting, equal increments in delay produce larger decrements in value at short delays than at long delays. Conversely, with exponential discounting, value is discounted at a constant rate at all delays. This difference between the hyperbolic and exponential equations becomes critical in choices between smaller, sooner and larger, later outcomes. As illustrated in Figure 1, when both outcomes are discounted by the same value of \( k \), hyperbolic discounting produces reversals of preference over time, while exponential discounting produces constant preferences over time. The preference reversals predicted by hyperbolic discounting have been demonstrated in laboratory studies (Green, Fry, & Myerson, 1994; Kirby & Herrnstein, 1995) and are integral to behavioral theories of impulsiveness and self-control (e.g., Rachlin, 1997).

Many studies with both human and nonhuman participants have investigated the nature of delayed reward discounting. Virtually all of these studies have found that the hyperbolic discount equation describes reward discounting more accurately than the exponential equation (see reviews by Kirby, 1997; Simpson & Vuchinich, 2000a). The nature of delayed cost discounting is less well understood, because it has received less research attention (Lowenstein, 1988; Shelley, 1993; Yates & Watts, 1975). Some studies with animal participants that manipulated the amount and delay of an aversive event (e.g., electric shock) found that choice between smaller, sooner and larger, later costs may correspond to choice between smaller, sooner and larger, later rewards. That is, the aversiveness of a negative event, such as electric shock, may decrease with increasing delay, and larger, delayed negative events may at times be preferred to smaller, sooner negative events. For instance, Deluty (1978) found that when two electric shocks were of equal duration, rats preferred a later shock to a sooner shock. As the duration of the delayed shock increased, however, rats switched preferences to the sooner shock. Moreover, when a constant delay amount was added to both smaller, sooner and larger, later shocks, rats switched preferences to the smaller immediate shock. Although Deluty noted considerable variability in the rats’ choices, his results suggested that delay may have a similar effect on choice between costs and choice between rewards, and that choices involving delayed costs are consistent with hyperbolic discounting. Deluty, Whitehouse, Mellitz, and Hineline (1983) replicated the above finding,
Figure 1. Figure illustrates exponential and hyperbolic discounting of delayed rewards and costs. The rewards and payments are represented as vertical bars, with amount indicated by their height (positive for rewards, negative for costs) and time of availability indicated by their location on the abscissa. The curves to the left of the rewards and costs are delay discount functions that represent value during the times before they are available; the reward or payment with the highest curve at the time of choice will be preferred. The two left and two right panels show hyperbolic and exponential discount functions, respectively. The two top and two bottom panels represent cost and reward discounting, respectively.

and also found that rats given the opportunity to “commit” to the choice of the smaller, sooner shock would do so (cf. Rachlin & Green, 1972). As predicted by hyperbolic discounting, rats were less likely to commit to the smaller, sooner shock when the time between the commitment option and the shock was decreased.

Studies with human participants have not shown consistent findings regarding the nature of cost discounting. Mischel, Grusec, and Masters (1969) found that college students strongly preferred sooner to later (hypothetical) shocks of equal intensity, but Yates and Watts (1975) argued that because Mischel et al.’s students participated as part of a
course requirement, receipt of the (hypothetical) shock reflected completion of this requirement and was therefore a reinforcing event. Yates and Watts (1975) paid experimental participants $3 at the beginning of the experimental session and then required them to choose between different delays of repaying $2 of the $3. In a control condition, participants received no money initially and chose between monetary rewards equal to the net gain in the experimental condition ($1) and available at the same delays. Although only 8 of the 16 experimental participants consistently preferred the later payment option, 18 of 19 control participants chose to receive their payment at the earlier time, suggesting that “impulsive” choices may be more likely with rewards than with costs.

Studies using hypothetical monetary payment and reward scenarios have also produced inconsistent findings concerning delayed cost discounting. Benzion, Rapoport, and Yagil (1989) asked college students to state the amount of money they would be willing to pay (or receive) after a series of delays (6 months, 1 year, 2 years, and 4 years) instead of paying (or receiving) a set amount immediately ($40, $200, $1,000, and $5,000). Each participant stated one amount at each delay and set payment or receipt amount combination (32 total choices). Discount percentages for payments (16%) were less than for rewards (27%), and individual reward/payment discount percentages were significantly correlated. In a similar procedure, Thaler (1981) found that student participants discounted delayed rewards over five times greater than delayed costs. But Shelley’s (1993) reanalysis of these studies suggested that degree of discounting depended on the interaction of valence (i.e., gain or loss) and frame (i.e., timing) effects. As suggested by Lowenstein (1988), once individuals “adapt” to the arrival of a particular outcome at a specified time, any shift in the time of receipt of the outcome will produce a new outcome, an immediate sense of gain or loss to the status quo resulting from the new delay (i.e., a gain when a cost is delayed and a loss when a reward is delayed), in addition to the original delayed outcome (i.e., reward or cost). For example, an employee who expects a bonus on Friday but learns on Friday that it will not be received until Monday experiences an immediate loss in the expected status quo (on Friday) as well as a delayed gain (on Monday). Compare this to someone who learns on Friday that he or she will receive a bonus on Monday. In this case, the delay occurs before adaptation to the outcome, and thus there is no immediate subjective loss resulting from the wait. An outcome that is postponed is a “delay frame,” as seen in the former case, and induces an immediate subjective gain or loss to the status quo. An outcome without a timing change is a “neutral frame,” as seen in the latter case, and there is no immediate gain or loss to the status quo (Lowenstein, 1988). Shelley (1993) compared discounting of delayed payments and rewards with different frames. Using a scenario similar to Benzion et al. (1989), she found that delayed rewards were discounted more than costs only when the deferred reward resulted in an immediate
subjective loss (i.e., delay frame). In the neutral frame, delayed costs were discounted more than delayed rewards. Across all frames, discounting rates were highest, and most variable, at short delays, which is consistent with hyperbolic discounting.

Existing evidence is ambiguous regarding the relative degrees of temporal discounting of rewards and costs. Moreover, although the evidence is clear that delayed rewards are discounted according to hyperbolic function, there currently is no such clarity regarding discounting of delayed costs. The purpose of the present study was to compare directly the type and degree of temporal discounting of delayed rewards and payments. We used a modified version of the task developed by Rachlin, Raineri, and Cross (1991), which we will call the hypothetical money choice task (HMCT). This procedure yields reliable (Simpson & Vuchinich, 2000b) measures of reward discounting that are consistent in functional form with discounting of real monetary amounts and other tangible outcomes (Kirby, 1997; Kirby & Herrnstein, 1995). Some of the inconsistent results of previous cost discounting studies are possibly caused by inadequate measurement, especially in human studies in which discount rates are inferred from a relatively small number of choices in scenarios that are not consistent across studies. Additionally, given the importance of the subtle framing effects discussed by Shelley (1993), it is possible that the absence of an elaborate verbal scenario surrounding the choices on the HMCT is advantageous.

Method

Participants

Twenty-eight undergraduate college students (14 male and 14 female, \( M_{\text{age}} = 20.07, SD = 1.4 \)) received 1 hour of extra course credit for their participation.

Procedure

Participants came to the laboratory individually for a 40-min session and were told that the purpose of the study was to examine their financial decision making. The HMCT was completed on a personal computer while the experimenter waited in an adjacent room; the order of administration of the reward and cost components of the HMCT was counterbalanced.

Hypothetical Money Choice Task

Reward condition. This procedure yields measures of the amount of immediately available (hypothetical) money that is subjectively equivalent in value to a larger amount of (hypothetical) money that is available after a set of delays. These multiple subjective equivalence points at different delays are then used to estimate the temporal discounting function (Equations 1 & 2).

Participants repeatedly chose between a larger fixed amount of money available after a delay and a smaller amount of money that was
available immediately. There were two series of trials at each of eight delays with a $500 delayed fixed amount reward. On each trial series, the large delayed money amount was held constant across trials, and the smaller immediate amount was changed on each trial. The smaller immediate money amounts consisted of 30 values ranging from 0.1% to 100% of the larger fixed amount (e.g., $.50, $2.50, $5, ..., $490, $495, $500). Each trial series was repeated eight times at different delays of the $500 reward: 1 week, 1 month, 6 months, 1 year, 3 years, 5 years, 10 years, and 25 years. In one trial series the immediate smaller money amounts were presented in ascending order and in one series they were presented in descending order. Participants were read the following instructions prior to beginning the HMCT:

The purpose of this experiment is to see how you make decisions concerning imaginary amounts of money. Two amounts of money will appear on the monitor. A decision takes place when you press the 'A' or 'B' key on the keyboard. Your job is to choose which of the two amounts of hypothetical money is most appealing to you. All choices are unrelated; please do not attempt to plan ahead. Just judge each amount based on what is most appealing to you. You must make your choice within 10 seconds after the choice is presented.

After the instructions, the experimenter showed participants the “A” and “B” keys on the keyboard, and the session began. Two amounts of money were displayed on the monitor on each trial. The amount displayed on the left side of the screen was the delayed fixed amount ($500), under which was displayed the delay of the receipt (e.g., “TO BE RECEIVED IN 6 MONTHS”). The amount displayed on the right side of the screen was the immediate reward (e.g., $450), under which was displayed the message “TO BE RECEIVED IMMEDIATELY.” A message was displayed at the bottom of the screen reading, “Which do you choose (A or B)?” The screen went blank after the participants made a choice by pressing either the “A” or “B” key, and there was a 1.5-sec delay before the next choice was presented.

Cost condition. This procedure was identical to the reward condition except that participants chose between smaller, immediate and larger, delayed payments instead of rewards. Participants repeatedly chose between a larger fixed-amount payment (-$500) to be made after a delay and a smaller, immediate payment amount. On each trial series, the larger delayed payment was held constant across trials, and the smaller, immediate payment was changed on each trial. The smaller immediate payments consisted of 30 values ranging from 0.1% to 100% of the larger fixed amount payment and were identical in absolute value to the above listed reward amounts (e.g., -.50, -$2.50, -$5, ..., -$500). As in the reward condition, each trial series was repeated eight times at different delays of the $500 payment: 1 week, 1 month, 6 months, 1 year, 3 years, 5 years, 10 years, and 25 years.

In both the reward and cost condition, we used Green et al.’s (1994) procedure for determining the subjectively equivalent immediate amount
for each fixed amount at each delay (cf. Vuchinich & Simpson, 1998). In the reward condition, these equivalence points were calculated by averaging two values: (a) the value at which the participant switched preference from the immediate to the delayed reward when the immediate rewards were presented in order of descending value, and (b) the value at which the participant switched preference from the delayed to the immediate reward when the rewards were presented in order of ascending value. Because a deferred payment is generally preferred to an identical immediate payment, the values used to calculate equivalence points in the cost condition were calculated by averaging the following two values: (a) the value at which preference switched from the delayed to the immediate payment when immediate payments were presented in order of descending (absolute) value, and (b) the value at which preference switched from the immediate to the delayed payment when immediate payments were presented in order of ascending (absolute) value. In both conditions participants completed all 30 choices for each trial series, so as to preclude a contingency between preference switches and trial

\[ \text{Figure 2. Figure shows data from 2 participants, for both the reward and cost condition, who had relatively high (P#6) and relatively low (P#7) degrees of temporal discounting. In the two top panels (reward condition), data points represent the amount of immediately available (hypothetical) money that was subjectively equivalent to a larger amount of (hypothetical) money available after a series of delays. In the two bottom panels (cost condition), data points represent the immediate (hypothetical) payment amount that was subjectively equivalent to a larger delayed (hypothetical) payment. The } k \text{ values were estimated with the hyperbolic equation.} \]
completion time. The equivalence points for two individual participants, one each with a relatively high and relatively low degree of cost and reward discounting, are shown in Figure 2.

Results

Comparison of Hyperbolic and Exponential Delay Discount Functions

For both the reward and the cost conditions, nonlinear regression analysis was used to estimate separate \( k \) parameters based on Equations 1 and 2 for each participant. After a \( \log_{10} \) transformation, the goodness of fit parameter (\( R^2 \)) for each estimate was entered into separate 2 x 2 x 2 (Condition Order x Gender x Equation) ANOVAs in the reward and cost conditions.

**Rewards.** This ANOVA revealed significant main effects for type of equation, \( F(1, 24) = 10.99, p = .003 \), with mean \( R^2 \) values being greater for the hyperbolic equation (\( M = .718, SD = .331 \)) than for the exponential equation (\( M = .596, SD = .350 \)), and for Condition Order, \( F(1, 24) = 6.47, p = .018 \), with mean \( R^2 \) values being greater for participants who completed the reward condition first (\( M = .813, SD = .167 \)) than for those who completed the cost condition first (\( M = .478, SD = .398 \)).

**Costs.** This ANOVA revealed a marginally significant main effect for type of equation, \( F(1, 24) = 3.48, p = .075 \), with mean \( R^2 \) values for the hyperbolic equation (\( M = .359, SD = .408 \)) being greater than those for the exponential equation (\( M = .296, SD = .388 \)). The equation x gender interaction approached significance, \( F(1, 24) = 3.16, p = .088 \). The source of this marginal interaction seemed to be a more pronounced gender difference for the hyperbolic equation (women: \( M = .417, SD = .414 \); men: \( M = .299, SD = .409 \)) than for the exponential equation (women: \( M = .319, SD = .404 \); men: \( M = .271, SD = .389 \)).

Adequacy of Hyperbolic \( k \) Parameter Estimates

Because the hyperbolic equation accounted for more variance than the exponential equation in both reward and cost conditions, we used the hyperbolic \( k \) value in all subsequent analyses. We next determined the adequacy of the hyperbolic \( k \) parameters for individual participants. As discussed by Gallant (1987), the adequacy of parameter estimates in nonlinear regression can be evaluated by the ratio of the estimate to its standard error. This ratio is distributed as a t ratio with \( (n - r) \) degrees of freedom, where \( n \) is the number of data points (eight in this case) and \( r \) is the number of parameters in the equation (one in this case). A ratio less than the critical value of \( t \) (for \( p < .05 \)) indicates that the parameter estimate is not an adequate fit for the data. Of the 28 participants, 10 had nonsignificant \( t \) ratios in one or both conditions. There were 9 participants (#4, 5, 10, 13, 16, 18, 23, 24, and 25) and 3 participants (#18, 19, and 24) with nonsignificant \( t \) ratios in the cost and reward conditions, respectively. The data from these 10 participants were therefore excluded from
analyses based on individual participant \( k \) values. The data from all 28 participants are included in the group analysis section.

**Comparison of Cost and Reward Discounting**

Because the distribution of \( k \) values in both the reward and cost condition deviated substantially from normality (i.e., positively skewed, kurtotic), we performed a \( \log_{10} \) transformation on the \( k \) values prior to these analyses. We compared hyperbolic \( k \) parameters from the cost and reward condition in a 2 x 2 x 2 (Condition x Condition Order x Gender) ANOVA. Participants discounted delayed rewards significantly more than delayed costs, \( F(1, 14) = 13.12, p = .003 \) (see Table 1). There was also a significant main effect for condition order, \( F(1, 14) = 8.49, p = .011 \). Mean \( k \) values were greater for participants who completed the reward condition first for both costs (Reward first: \( M = .015, SD = .023 \); Cost first: \( M = .005, SD = .006 \)) and rewards (Reward first: \( M = .141, SD = .19 \); Cost first: \( M = .007, SD = .004 \)). A marginally significant condition x condition order interaction, \( F(1, 14) = 3.59, p = .079 \), suggested that this order effect was more pronounced in the reward condition than in the cost condition, and a marginally significant order x gender interaction, \( F(1, 14) = 4.28, p = .058 \), suggested that the effect of order (i.e., higher \( k \) values when the reward condition is completed first) was stronger for males than it was for females. Figure 3 shows the hyperbolic discount functions for reward and cost discounting using the \( k \) values at the 25\(^{th}\), 50\(^{th}\), and 75\(^{th}\) percentiles of the reward and the cost \( k \) distributions.

To compare the adequacy of the hyperbolic equation in describing reward and cost discounting, we entered the \( R^2 \) values into a 2 x 2 x 2 (Condition x Condition Order x Gender) ANOVA. The hyperbolic equation provided a significantly better description of participant choices in the Table 1:

<table>
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<tr>
<th>Statistic</th>
<th>Cost</th>
<th>Reward</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hyperbolic ( k )</td>
<td>Hyperbolic ( k )</td>
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<tr>
<td>Mean</td>
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<tr>
<td>Standard Deviation</td>
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</tr>
<tr>
<td>25(^{th}) Percentile</td>
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<td>75(^{th}) Percentile</td>
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<td>.009</td>
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<td>( R^2 ) (Mean; ( N = 18 ))</td>
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</tr>
<tr>
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<td>.727</td>
<td>.923</td>
</tr>
<tr>
<td>( R^2 ) (Mean; ( N = 28 ))</td>
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<td>.718</td>
</tr>
<tr>
<td>( R^2 ) (Median; ( N = 28 ))</td>
<td>.173</td>
<td>.815</td>
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</table>

An additional 4 participants (#8, 9, 15, & 28) had \( R^2 \) values of zero in the cost condition. One reviewer suggested these 4 participants also be excluded. The analysis did not substantially change with these participants excluded; the primary difference was that the correlation between the \( R^2 \) values for hyperbolic equation in the cost and reward condition was reduced, but the correlation between the \( k \) values was increased.
Figure 3. Figure shows hyperbolic delay discount functions for costs and rewards for the 25th, 50th, and 75th percentile k distribution of the sample. These k values are shown in Table 1. The top and bottom panel show reward and cost discounting, respectively.

Reward condition ($M = .84$, $SD = .18$) than in cost condition ($M = .55$, $SD = .39$), $F(1, 14) = 10.88$, $p = .003$. Descriptive statistics for $k$ and $R^2$ values in the reward and cost condition are shown in Table 1.

The relationship between delayed reward and cost discounting. Participants’ $k$ values in the reward and cost conditions were significantly correlated, $r(18) = .570$, $p = .014$, as were the goodness of fit parameters ($R^2$), $r(18) = .472$, $p = .043$, indicating that the relative subjective value of delayed costs and rewards tended to be consistent within individuals. Thus, participants tended to be consistent across conditions in terms of both degree of discounting and orderliness of the data. Table 2 shows individual participant $k$ and $R^2$ values in the reward and cost condition.
### Table 2

<table>
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<td>28</td>
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*Participant excluded from analysis of individual participant k values.*

**Group Analyses**

**Comparison of cost and reward discounting.** Rather than analyzing individual participant k values, it is also possible to analyze the data based on median equivalence points of the group of participants (e.g., Myerson & Green, 1995). Thus, we computed the median group equivalence point at each of the eight delays for both costs and rewards (the data from all 28 participants were included in this analysis). As was the case with the aggregated individual participant k values, the hyperbolic equation ($R^2$ cost = .584, $R^2$ rewards = .874) provided a better description of group data than the exponential equations ($R^2$ cost = .402, $R^2$ rewards = .679), and the hyperbolic k value was higher for rewards ($k = .01$) than for costs ($k = .003$). The median and 25th and 75th percentile group equivalence points are shown in Figure 4, as is the hyperbolic discount function based on median equivalence points. As can be seen in the figure, the immediate subjective (absolute) value of rewards is less than that of costs at seven of the eight delays (the subjective value of...
costs and rewards is equal at the 1-week delay). For example, a $500 reward delayed by 3 years is subjectively equivalent to an immediate $343.75 reward (a 31% reduction in value), whereas a $500 payment delayed by 3 years is subjectively equivalent to an immediate $410.63 payment (a 18% reduction in value). Table 3 shows the 25th, 50th, and 75th percentile equivalence points for costs and rewards.

Figure 4. Figure shows the distribution of group equivalence points for costs and rewards. Filled circles and diamonds are the median, 25th and 75th percentiles, respectively. The solid lines are the best fit hyperbolic discount functions for median group equivalence points. The top and bottom panel show reward and cost discounting, respectively.
Correlations between equivalence points in the cost and reward conditions. To determine if participants' relative rate of discounting was similar in the reward and cost conditions, we computed correlation coefficients between the equivalence points for costs and rewards at each of the eight delays (see Table 3). There was an inverse relationship between the length of delay and the strength of the correlation between reward and cost equivalence points. Discounting of delayed rewards and costs was highly correlated at short delays (e.g., \( r = -0.786 \) at 1-month), but only weakly correlated at long delays (e.g., \( r = -0.241 \) at 10 years).

Discussion

To our knowledge, this is the first study to examine discounting of delayed rewards and costs using a procedure that permits quantification of individual participants' discount parameters. There were several key findings: First, the hyperbolic discount equation provided a better description of participant choices than the exponential equation in both the reward and the cost condition. This was true for analyses based on individual participant data and on median group equivalence points and is consistent with previous findings concerning delayed reward discounting (Kirby, 1997; Myerson & Green, 1995, Vuchinich & Simpson, 1998). Although these equations have not previously been used to describe delayed cost discounting, earlier findings had shown that the rate of discounting of delayed costs is greater at short delays than at longer delays (Deluty, 1978; Deluty et al., 1983; Shelley, 1993; Thaler, 1981), which is consistent with hyperbolic and not exponential discounting. Second, participants discounted delayed rewards significantly more than delayed costs (see Figures 3 & 4): The median reward discount parameter \( (k) \) value for individual participants was more than twice as large as the median cost discount parameter. Third, delayed reward and cost discounting were significantly correlated. This was true for hyperbolic \( k \) values used in individual participant analyses and for equivalence points used in group analyses. The group equivalence point
correlations indicated that there was an inverse relationship between the length of the delay and the strength of the association between cost and reward discounting. Fourth, hyperbolic equations accounted for more variance in the reward condition than in the cost condition.

The findings that hyperbolic discount equations accounted for more variance than exponential equations in both the reward and cost condition, and that choices in the reward and cost condition were highly correlated, suggest that there are fundamental similarities in the decision making process concerning immediate versus delayed rewards and costs. This provides support for hyperbolic models of self-control (e.g., Ho, Mobini, Chiang, Bradshaw, & Szabadi, 1999), which assume that a single discount parameter \( k \) quantifies sensitivity to delay in self-control situations involving both positive reinforcers and aversive events. Interestingly, there was a moderate correlation between the goodness of fit parameters \( R^2 \) in the cost and reward condition, suggesting that the degree to which individuals’ choices are consistent with a hyperbolic function may be similar in choice situations involving immediate and delayed costs and rewards.

However, because hyperbolic equations did not accurately describe many participants’ choices in the cost condition, further research is required to determine the extent to which delay similarly influences choice in situations involving rewards and costs. It is unclear if the poor fit for the hyperbolic equations in the cost condition is caused by factors unique to this study (e.g., the use of hypothetical monetary rewards, participant confusion, etc.), or if some individuals do not choose between immediate and delayed aversive events in a manner consistent with hyperbolic discounting. For example, 5 of the 9 participants for which hyperbolic equations did not provide an accurate fit in the cost conditions showed a near exclusive preference for immediate costs, which precludes an accurate fit by any function that relates changes in value to changes in delay. It is possible that this task is not sensitive to extremely low levels of discounting that might be evident on another task. Another possibility is that some participants did not fully understand the cost procedure. For example, for Participant #4 a $500 payment in 1 week was subjectively equivalent to an immediate $468.50 payment (a 6.3% reduction in value), whereas a $500 payment in 1 month was subjectively equivalent to an immediate $498.50 payment (a .3% reduction in value). Such choice patterns are inconsistent with any hypothesized inverse relation between delay and present value. Given that such “inconsistent” choices did not occur in the reward condition, it is possible that some participants did not understand the task. Moreover, the limited income of most college students may have led them to find both payment options equally untenable, resulting in confusion or ambivalence concerning the payment choices. Future studies using smaller payment amounts or nonmonetary outcomes could shed light on this issue. Although hyperbolic discounting of delayed rewards is now a robust finding (Kirby, 1997), this is the first study to evaluate hyperbolic equations with delayed cost discounting.
Hyperbolic discounting implies that preference between a smaller sooner and larger delayed outcome will vary according to the time at which the choice is made (Rachlin et al., 1991). This is consistent with many everyday “self-control” experiences. Consider, for example, a college student who on the night before an 8:00 a.m. class sets her alarm clock for 7:00 a.m., having decided that the distal reward of doing well in class is more valuable than the more proximal reward of sleeping late the next morning. However, when the receipt time for the smaller proximal reward (i.e., sleeping late) is signaled by the buzzing alarm clock, the relative value of sleeping late versus doing well in class may switch, causing her to forgo class and to go back to sleep. Examples of situations that are consistent with hyperbolic discounting of delayed costs are also abundant. One may intend to floss his teeth nightly, so as to avoid the aversive experience of having tarter build-up removed at his next dentist visit. However, when bedtime approaches the immediate aversiveness of 1 minute of flossing may be subjectively greater than the 20 minutes of painful tarter removal during next month’s dentist visit, resulting in a decision not to floss.

A growing amount of research indicates that delay discounting may be related to health behaviors, especially substance abuse (see Simpson & Vuchinich, 2000a). That is, consistently using drugs instead of engaging in activities with greater long-term benefit (e.g., work, relationships, school) may be caused by sharp discounting of these delayed rewards, and preference for the immediate benefits of drug use. In support of this view, studies have found that heavy drinkers (Murphy & Vuchinich, 1999; Vuchinich & Simpson, 1998), heroin users, (Madden, Petry, Badger, & Bickel, 1997), and smokers (Bickel, Odum, & Madden, 1999; Mitchell, 1999; Murphy & Vuchinich, 1999) discount delayed monetary rewards more steeply than controls. Importantly, the finding that discounting of costs and rewards are highly correlated suggests that high degrees of cost discounting may also be related to substance abuse. Just as drug use confers immediate benefits (e.g., euphoria) but often disrupts behavior leading to future rewards, there are also proximal and distal costs associated with decisions concerning substance use. For example, although nicotine withdrawal often results in short-term discomfort, this short-term cost is much less than the future cardiovascular/respiratory consequences associated with smoking. But for individuals who sharply discount delayed costs, the immediate discomfort of quitting smoking may outweigh the future “costs” of poor health. Although the present study did not include substance abusers and thus can not address the discounting substance abuse relationship, these findings, by extending hyperbolic discounting to situations involving costs, provide some support for the generality of hyperbolic discounting, which has been implicated in substance abuse (Bickel et al., 1999; Madden et al., 1997; Vuchinich & Simpson, 1998). A recent study (Odum, Madden, & Bickel, in press) examined discounting of delayed health gains and losses among current, former, and never cigarette smokers. Participants made choices
concerning hypothetical health outcomes; in the “health gains” condition participants repeatedly chose between receiving an immediate but shorter duration cure or a delayed but longer duration cure; in the “health losses” condition the choices were between immediate but shorter duration illness or a delayed but longer duration illness. The results support the relevance of hyperbolic discounting to choices concerning health behavior: Participant choices in both conditions were well described by hyperbolic equations, and current smokers discounted delayed health gains and health losses more steeply than did never smokers.

The present finding that delayed rewards are discounted more sharply than delayed costs is consistent with previous research (e.g., Benzion et al., 1989; Thaler, 1981) and may have important implications for the discounting health-behavior relationship. If the future value of negative health consequences are discounted to a lesser degree than are the “benefits” of future health, then prevention and intervention efforts that focus on the long term “costs” associated with behavior patterns such as alcohol abuse (e.g., liver diseases such as cirrhosis) may be more effective than efforts focused on future rewards (e.g., opportunities for personal relationships, job promotion, etc.) that are foregone as a result of drinking.

Because participants in this study did not experience the actual contingencies of interest, the relevance of the aforementioned implications rests on the assumption that participants’ self-reports are accurate proxies for their behavior in situations involving real rewards or payments. Support for the validity of the hypothetical measure of discounting used in the present study comes from findings that the choice patterns obtained with this procedure are similar in form (i.e., hyperbolic) to choice patterns obtained using real rewards (i.e., Kirby, 1997; Kirby & Herrnstein, 1995) and from findings that performance on this task is correlated with reported substance use (Bickel et al., 1999; Madden et al., 1997; Vuchinich & Simpson, 1998). However, although there is considerable support for the validity of this hypothetical choice task with rewards, its validity with costs has not been evaluated, and it is possible that the finding that hyperbolic equations did not provide a good fit for approximately half of the participants in the cost condition is due to the limited validity of this task. Alternatively, hyperbolic discounting of delayed costs may not be as ubiquitous as hyperbolic reward discounting; some individuals may exhibit a consistent preference for immediate costs or may discount delayed costs according to a nonhyperbolic (or exponential) function. This question could be addressed in future studies.

References


