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Discounting of delayed hypothetical money and food: Effects of amount

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Abstract

Delay discounting research determines how the value of an outcome is affected by delay to its receipt. Research so far shows that consumable outcomes are discounted more steeply by delay than money. Prior studies, however, have used large amounts of the outcomes (e.g. $100 worth) that would not typically be consumed in one bout, unlike the corresponding amount of money (e.g. $100). This experiment examined whether small amounts of food would be discounted more steeply than money, as occurs with larger amounts. One hundred and two adults indicated their preferences in a series of choices for two hypothetical outcome types: immediate versus delayed food and immediate versus delayed money. Participants made choices involving either relatively small maximum amounts of food ($10 worth) and money ($10) or for relatively large maximum amounts of food ($100 worth) and money ($100). In the within-subject comparisons, food was discounted more steeply by delay than money for both groups. In the between-subject comparisons, different amounts of the commodities were affected similarly by delay. Overall, these results suggest that steeper discounting of consumable outcomes than money is a fairly robust phenomenon, occurring with relatively small amounts of outcomes as well as with larger amounts.
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1. Introduction

Delay discounting refers to the tendency for the present value of an outcome to be diminished, or discounted, by a delay to its receipt (e.g. Mazur, 1987; Rachlin et al., 1991; see Critchfield and Kollins, 2001, for review). Delay discounting typically is assessed by having the participants (human or non-human) choose between a relatively small but immediate outcome and a relatively large but delayed outcome. The value of the immediate outcome is typically titrated across choices. The goal is to find the indifference point—the point at which the smaller sooner outcome and larger delayed outcome have equal value. In essence, the technique determines the present value of a delayed outcome. When this procedure is repeated at various delays to the larger later outcome, it generates a series of indifference points that can be plotted to examine the manner in which the value of an outcome decays with delay to its receipt.

The usual finding is that present value declines substantially with shorter delays and then less per unit time with longer delays to receipt of the delayed outcome. This relation is well accounted for across species (e.g. Green and Myerson, 2004) by a variant of a hyperbolic decay model (Mazur, 1987) advocated by Myerson and Green (1995):

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

in which V is the present, discounted value of an outcome, A the amount of that outcome, and D is the delay to receipt of the outcome. The fitted parameter k reflects the impact of delay: If k is large, value is decreased greatly by delay, but if k is small, value is decreased less by delay. The exponent s is thought to reflect the non-linear scaling of amount and/or delay. If $s = 1.0$, Eq. (1) is a simple hyperbola (Mazur, 1987):

$$V = \frac{A}{1 + kD} \quad (2)$$

Delay discounting investigations have become increasingly popular because they are thought to capture important aspects of choice (see Bickel and Marsch, 2001, for review). For example, if delayed consequences like maintaining future health are sufficiently discounted, an injection drug user may share a needle with another person to inject a drug now, thus risking the loss of their health for an immediate high (see Odum et al., 2000).

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In behavioral terms, this is *impulsive* behavior (Ainslie, 1974; Logue, 1988): choosing a smaller more immediate reinforcer (e.g. fleeting drug effects) over a larger more delayed reinforcer (e.g. long-term health). Most studies of delay discounting with human participants use hypothetical outcomes, and research to date indicates that hypothetical outcomes are discounted similarly to actual outcomes (e.g. Johnson and Bickel, 2002; Lagorio and Madden, 2005; Madden et al., 2003, 2004).

Several factors are known to affect the degree of discounting of the value of an outcome. For example, smaller amounts (e.g. $100) tend to be discounted more steeply than larger amounts (e.g. $25,000; Green et al., 1997; see Green and Myerson, 2004, for review). The type of outcome also has an effect. For example, cigarette smokers discount cigarettes more steeply than money (Bickel et al., 1999). Similarly, people with problems with alcohol (Petry, 2001), cocaine (Coffey et al., 2003), and heroin (e.g. Madden et al., 1997) discount their drug of abuse more steeply than money. These findings all suggest that people may be especially likely to behave impulsively with respect to abused drugs, because the drugs have little value if delayed.

Steeper discounting of drugs than money could occur for a variety of reasons. For example, Madden et al. (1997) noted that abstinence from drug use can be accompanied by aversive withdrawal symptoms, and the drug may be taken to relieve these symptoms (i.e. the drug may function as a negative reinforcer). In support of this idea, some limited evidence indicates that negative reinforcers may be discounted more steeply than positive reinforcers (e.g. Navarick, 1982; Solnick et al., 1980). Furthermore, Giordano et al. (2002) showed that relative opioid deprivation increased the degree to which opioid-dependent outpatients discounted delayed money and heroin. In other words, mild opioid withdrawal increased the degree of discounting by delay.

We have been pursuing a different possibility: that drugs are discounted more steeply than money as part of a general process by which directly consumable outcomes are discounted more steeply than outcomes that are not directly consumable. In this view, steeper discounting of drugs than money is not a unique feature related to addiction. What evidence is there for this possibility? Across studies, Navarick (1982) found that discounting rates for consumable reinforcers (e.g. access to a video game) were many times higher than discounting rates for nonconsumable reinforcers (e.g. money). In a direct within-subject comparison, Odum and Rainaud (2003) found that people who were selected because they did not have any self-reported addictive disorders discounted alcohol more steeply than money. Perhaps most important, they also discounted food more steeply than money, and similarly to alcohol. These results showed that normal drinkers, who do not experience withdrawal symptoms, discounted a drug more steeply than money (see also Petry, 2001), and discounted food, another consumable reinforcer, similarly to alcohol. More recently, Estle et al. (in press) showed that college students discounted a variety of consumable outcomes (beer, candy, and soda) more steeply than money.

In the present experiment, we followed up on a potential limitation of earlier studies. Odum and Rainaud (2003) used $100, $100 worth of food, and $100 worth of alcohol in the discounting assessment. This amount was chosen because it was the same or less than the amounts used previously in related experiments (e.g. Bickel et al., 1999; Petry, 2001), but raises questions as to the mechanism of the effects found. For example, one hundred dollars worth of food or alcohol is more than is typically consumed within a single bout for the majority of people, and as such may pose an unrealistic situation for them. Most people have experience with purchasing something that costs atleast $100 though. Estle et al. (in press) used as their smallest amount 40 units of beer, candy, and soda, which is subject to similar concerns.

To assess the generality of the results of previous studies, we examined delay discounting of different amounts of food and money. As in Odum and Rainaud (2003), one group of participants completed the delay discounting assessment with $100 and $100 worth of their favorite food. In addition, another group completed the delay discounting assessment with $10 and $10 worth of their favorite food. The main goal was to determine whether the smaller amount of food (i.e. that could more reasonably be consumed in one bout) was discounted more steeply than the smaller amount of money. We also examined how discounting compared across the different amounts of money and the different amounts of food.

2. Materials and methods

2.1. Participants

One hundred and two participants were recruited for this study from Introductory Psychology classes via announcement. A telephone screen assessed eligibility criteria. Specifically, after answering some demographic questions, participants were asked to answer the five questions from the Eating Disturbance Scale (EDS-5; Rosenvinge et al., 2001). Those with a score of less than 25 were invited to participate. The participants were not informed of the inclusion criteria and those that did not qualify (2) were not told why. During the interview, participants were also asked about their favorite food and its approximate cost. All participants, including the ones that did not meet the criteria to be in the study, earned extra credit for their classes. The Institutional Review Board of Utah State University approved the study.

2.2. Procedure

Participants were tested individually in a small quiet room. They signed an Informed Consent and then provided demographic information. Hypothetical rewards and delays were printed on 3 in. × 5 in. index cards. Participants were seated individually across a table from the research assistant.

2.2.1. Delay assessment

All participants were tested with two outcomes, money and food. The order of assessments for each outcome was counterbalanced among participants using block randomization. Participants were also assigned by block randomization to either the large or the small group. For money, participants of the large

group were asked about $100 and participants of the small group were asked about $10. In the food condition, participants were asked about the equivalent value of their preferred food. For example, if the participant had indicated in the telephone screen that his preferred food was pizza that cost $3.00 a piece, if he were in the small group, he would be asked about 3.33 pieces of pizza ($10 divided by $3). On the other hand, if he were in the large group, he would be asked about 33.33 pieces of pizza ($100 divided by $3).

The index cards describing the delays and the outcomes available were placed in front of the participants. The top row showed the delays. Outcomes on the participant's left were always available "now" and outcomes on the right were available after the specified delay (1 day, 2 days, 1 week, 2 weeks, 1 month, 6 months, or 2 years). The second row of the cards described the amounts of the reward. The values for the immediate outcome changed after each trial. For example, values for the large group began at $100.00, and then decreased to $99.00, $97.50, $95.00, $92.50, $90.00, $85.00, $80.00, $75.00, $65.00, $60.00, $55.00, $50.00, $45.00, $40.00, $35.00, $30.00, $25.00, $20.00, $15.00, $10.00, $7.50, $5.00, $2.50, and $1.00 (or the equivalent amount of their favorite food with any fractions expressed as decimals). For the small group, the amounts were the same as the large amounts but divided by ten. The values for the delayed outcome were always the same: $100.00 (or $100 worth of food) for the large group and $10.00 (or $10 worth of food) for the small group. The bottom row contained a single card describing the type of outcome. In the food trials, the card described the preferred food. For example, if the participant had chosen pizza, the word "pizza" would be written on the card. In the money trials, for all participants the word "money" was written on the card. These delays and amounts are consistent with those used in previous delay discounting studies (e.g. Green et al., 1997; Odum and Rainaud, 2003; Petry, 2001; Reynolds et al., 2004).

For each of the choices for each outcome, participants indicated whether they would choose the immediate or delayed outcome. The research assistant noted each choice. Before starting the assessments, participants were read the following instructions:

> I am going to ask you to make some decisions about which of two rewards you prefer. You will not receive the rewards that you choose, but I want you to make your decisions as though you were really going to receive these rewards you choose. The possible rewards are written on these index cards. The cards on your left display a reward that you can get today. The cards on the right display the reward that you can get after the specified amount of time. So now you are being asked to choose between an immediate amount delivered today versus a delayed amount that you would get after waiting the delay interval. Point to the reward that you would prefer. 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 the other. Just choose the one you really want.

The first choice was always between the highest reward amount delivered immediately ($100 or $10, or equivalent amount of food) and an equal amount delivered after the specified delay. After the participant indicated each choice, the value of the immediate card was decreased. This sequence continued until the minimum amount of the immediate reward was presented. Then the cards were collected and presented again in the reverse order. For each delay, the indifference point was taken as the average between the last immediate amount chosen in the descending order and the first immediate amount chosen in the ascending order. Testing of each participant took approximately 45 min.

2.3. Data analysis

The simpler hyperbolic decay model (Eq. (2); Mazur, 1987) and the more complex hyperboloid decay model (Eq. (1); Myerson and Green, 1995) were fitted to the median indifference points for each outcome using non-linear regression (GraphPad Prism®). Fig. 1 shows the residuals from these fits (the difference between the predicted and obtained present value at each delay) for both equations. The residuals change systematically as a function of delay for both models, but in general appear larger and more systematic for Eq. (2). We also calculated the difference between Akaike's Information Criterion (AIC) for Eqs. (1) and (2) to determine whether the more complex model accounted for enough additional variance to warrant adding a free parameter. The difference in AIC was positive for the large amount of food (5.008), the small amount of money (8.019), and the small amount of food (8.281), but negative for the large amount of money (−6.451). In other words, in the terms associated with the AIC, for all data sets except for the large amount

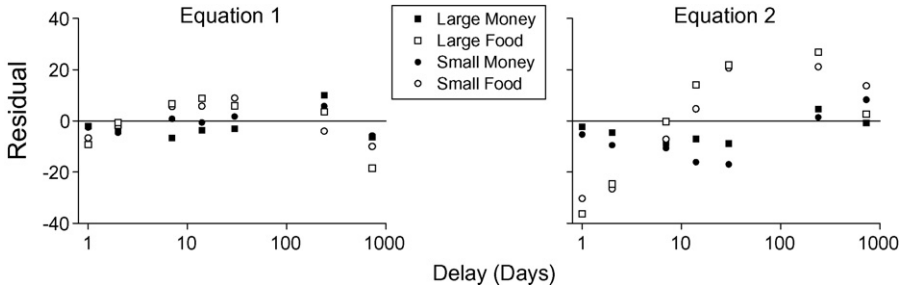

Fig. 1. Residuals (difference between obtained and predicted present value) as a function of delay for Eq. (1) (the more complex hyperboloid decay model; left panel) and Eq. (2) (the simple hyperbolic decay model; right panel). Residuals are shown for each of four outcomes: large amounts of money, large amounts of food, small amounts of money, and small amounts of food. Note that *x*-axes are in logarithmic units for ease of viewing.

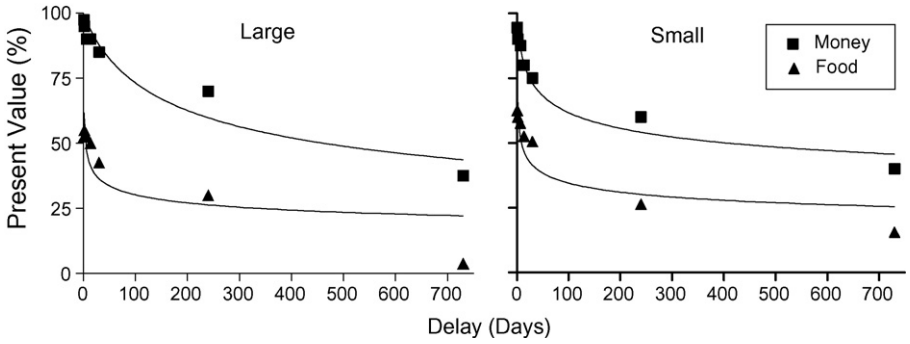

Fig. 2. Temporal discounting functions for large amounts of money and food (left panel) and small amounts of money and food (right panel). Points show median indifference points for the outcomes as a function of delay, expressed as percentage of the delayed amount. Lines show the best-fitting discount functions generated by the hyperboloid model (see text for details).

of money the more complex hyperboloid model is more likely to be correct. For these reasons, we show the fit of Eq. (1) (the more complex hyperboloid decay model) to the data (see Section 3). Because the values for k are not normally distributed, non-parametric analyses are required to evaluate data from individual subjects (see Rachlin et al., 1991). With the present experimental design, however (a within-subjects factor and between-subjects factor), there are no readily available statistical programs that can perform the required analyses, so Eq. (1) was only fit to the median data.

The area under the curve (AUC; Myerson et al., 2001) was calculated for each outcome type for each participant. The AUC is a desirable measure because it is atheoretical and therefore does not impose any particular model or assumptions on the data. Furthermore, it is normally distributed, unlike the derived discounting parameter k from the hyperboloid equation, and can therefore be evaluated with parametric statistics. To calculate the AUC, the delays and indifference points were first normalized. Then the actual area underneath the curve was calculated by summing the results of the following equation for each delay and present value pair: $x_2 - x_1[(y_1 + y_2)/2]$, where x_1 and x_2 are successive delays and y_1 and y_2 are the present values associated with those delays. The AUC can range from 1 (no discounting) to 0 (maximum discounting). To determine the overall effect of outcome type on AUC, an Analysis of Variance (ANOVA) was conducted with two levels of the within-subjects factor of outcome type and two levels of the between-subjects factor of outcome amount. Paired t-tests were used to compare AUCs for money versus food, and independent t-tests were used to compare AUCs for large and small outcomes.

3. Results

Table 1 shows the demographic characteristics of the participants in the large and small groups. On average, 38% of the participants were male, 85% were white and 79% were single. They were on average 22 years old with approximately 14 years of education. They earned on average $601/month and had an average score on the EDS of 15.7 points. A Mann–Whitney test revealed no significant difference in income between the groups. An ANOVA revealed no significant differences for any of the other demographic characteristics.

Table 1
Average demographic and participant characteristics for the large and small groups

Variable	Small group ($N = 51$)	Large group ($N = 51$)
Gender (% male)	34	41.5
Age (years)	21.82 (4.77)	22 (4.91)
Ethnicity (% white)	90	80
Marital status (% single)	78	79
Education (years)	14.04 (1.32)	13.62 (1.23)
Income ($ monthly)	631.72 (869.38)	570.64 (788.22)
EDS-5	16.58 (5.0)	14.71 (5.8)

Fig. 2 shows the median indifference points for the large group (left panel) and small group (right panel) at each of the seven delays. For visual comparison purposes, all values are expressed as the percentage of the delayed (standard) amount. The fitted functions show the estimated value of each outcome as generated by Eq. (1). The present value of delayed outcomes decreased more steeply for food than for money. For example, for the large group, $100 delayed by 1 day was worth $97.5 now, whereas $100 worth of food delayed by 1 day was worth only $55 now. Similarly, for the small group, $10 delayed by 1 day was worth $9.75 now and $10 worth of food delayed by 1 day was worth only $6.25 now. Table 2 shows the k and s parameters and the R^2 (goodness of fit) for the equation fit to the median indifference points for each outcome. The ks for money were substantially smaller than those for food. The exponents (s) were all less than one, as has been previously reported for money (e.g. Myerson and Green, 1995). Overall the fits (R^2) were fairly good, but the equation accounted for more variance

Table 2
The median k and s parameters as well as R^2 for the hyperboloid decay model (Eq. (1)) fit to the median indifference points for large amounts of money, large amounts of food, small amounts of money and small amounts of food (see text for details)

Outcome	k	s	R^2
Large money	0.01608	0.3244	0.91
Large food	21.19	0.1559	0.71
Small money	0.2186	0.1542	0.96
Small food	10.13	0.1537	0.84

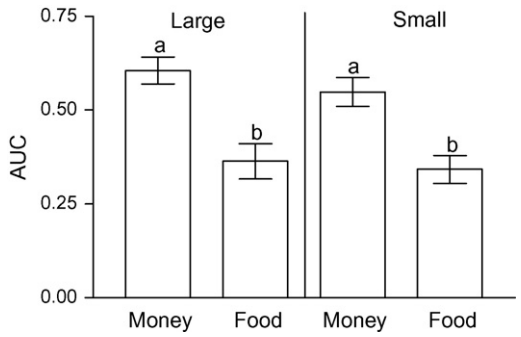

Fig. 3. Mean area under the curve for large amounts of money, large amounts of food, small amounts of money and small amounts of food. Vertical lines indicate one standard error above and below means. The means of outcomes marked with the letter 'a' are significantly different from the means of outcomes marked with the letter 'b'. The means 'a' and 'b' are not significantly different from each other.

in the indifference points for monetary outcomes than for food outcomes.

The mean values for the normally distributed AUC are shown in Fig. 3. The AUCs for monetary outcomes were bigger than the AUCs for food, reflecting steeper discounting of food. The ANOVA revealed a significant overall effect of outcome type, $F(1, 100) = 47.95$, $P < 0.0001$, but no significant effect of outcome amount or significant interaction between outcome amount and type. Follow-up tests showed a significant difference between the AUCs for the large amount of money and the large amount of food, $t(50) = 5.24$, $P < 0.0001$, and the small amount of money and the small amount of food, $t(50) = 4.55$, $P < 0.0001$. Although the mean AUC for \$100 was larger than that for \$10, and for \$100 worth of food was larger than for \$10 worth of food, these differences were not significant.

4. Discussion

This experiment showed that college students discounted food more steeply than money. This result held for small amounts of money (\$10) and food (\$10 worth) as well as for large amounts of money (\$100) and food (\$100 worth). In terms of the discounting of different amounts, however, the results were not as clear. Although larger amounts were discounted less steeply, these differences did not reach conventional levels of significance. Below we discuss each of these findings in turn as well as some of their implications.

First we will consider the effect of the amount of an outcome on the degree of discounting. A well-documented finding is that smaller amounts of money are discounted more steeply than larger amounts of money (e.g. Green et al., 1997; see Green and Myerson, 2004, for review). The results are less clear for directly consumable outcomes, though. For example, Petry (2001) found a non-significant trend ($P = 0.09$) towards smaller amounts of money being discounted more than larger amounts of money. For alcohol, despite the fact that the discounting parameter for smaller amounts of alcohol was larger than the discounting parameter for larger amounts of alcohol, these differences did not reach conventional levels of significance. Similarly, although Estle et al. (in press) found an overall effect of amount on discounting when AUCs for money and the directly consumable outcomes were analyzed together, this effect did not quite reach conventional levels of significance ($P = 0.06$) when only consumable outcomes were analyzed.

These results highlight two aspects of delay discounting. First, although larger amounts of money are typically discounted less steeply than smaller amounts of money, there are cases, as in the present study, where this finding does not seem particularly robust. One difference between the present study and previous ones finding robust amount-dependent discounting with money is that the comparison was between subjects. In the current experiment, our primary focus was to discover whether relatively small amounts of food would be discounted more steeply than relatively small amounts of money, so the comparison between food and money was conducted within subjects. We included the group with larger amounts as a point of reference to our previous study (Odum and Rainaud, 2003), and the comparison between amounts was conducted across subjects. Prior studies have often focused on amount-dependent discounting *per se*, and all of those analyses to our knowledge have been within-subject. Testing different amounts within subjects may facilitate comparisons of the amounts for the participants, creating a contrast effect, and therefore making the difference in the degree to which the different amounts are discounted larger. We are currently investigating this possibility.

Second, the effect of amount on discounting of consumable outcomes may be less robust than the effect of amount on discounting of money. For example, Petry (2001) found no significant difference between discounting of 15 bottles of liquor and 150 bottles of liquor. Estle et al. (in press) found that when data for soda, candy, and beer were analyzed separately from those for money, the effect of amount did not reach conventional levels of significance. In the present study, although large amounts of food were discounted less steeply than small amounts, this difference was not significant. The effects of amount of outcome on the degree of discounting of directly consumable rewards have rarely been investigated and will require more study.

The finding that food was discounted more steeply than money agrees with previous results showing that money is discounted less steeply than directly consumable outcomes. For example, in direct comparisons, Estle et al. (in press) showed that college students discounted candy, beer, and soda more steeply than money. Odum and Rainaud (2003) showed that community volunteers discounted food and alcohol more steeply than money, and Petry (2001) found that alcoholics, currently abstinent alcoholics, and control participants discounted liquor more steeply than money. The results of these prior studies can be questioned, however, on the grounds that the amounts used were so large as to be unrealistic or unable to be consumed in one bout, unlike the corresponding amount of money. Estle et al. (in press) used as their smallest amount 40 units of the different outcomes (i.e. 40 candy bars, 40 beers, 40 sodas, and \$40), Odum and Rainaud (2003) used \$100 worth of food, \$100 worth of alcohol, and \$100, and Petry (2001) used as her smallest amount 15 bottles of liquor and \$100. The present results extend these findings to a relatively small amount of food (\$10 worth) versus money (\$10). This amount was chosen because it is within

the range that college students, as well as the general population, might plausibly consume within a single meal. Therefore, the difference in the degree of discounting between consumable outcomes and money is not restricted to relatively large amounts.

The question that remains is why food is discounted more steeply than money. We originally considered several possibilities (Odum and Rainaud, 2003), some of which may now be ruled out. For example, money is a conditioned reinforcer, whereas food is a primary reinforcer. This difference does not appear to be the important one, because Estle et al. (in press) recently found that money is discounted by probability (rather than delay) to the same extent as food. They argue that if the critical difference between money and food were the conditioned versus primary reinforcing aspect, probability discounting would be expected to yield similar results to delay discounting. The present study with relatively small amounts helps rule out another possibility. People may have discounted food more steeply than money in previous studies because the amounts involved were so large that the food could not be consumed in one bout, unlike the money. Similarly, food may be more steeply discounted than money because it is perishable, and would lose objective value over time. Petry (2001), however, found that bottles of liquor, which are not highly perishable, were also discounted more steeply than money. Odum and Rainaud (2003) also found that a participant's favorite alcoholic beverage was discounted similarly to their favorite food, even though alcoholic beverages are typically less perishable than food.

The current best explanation of those we suggested may be that money is not directly consumed, but is exchangeable for other things, whereas food is directly consumed. Estle et al. (in press) suggest that directly consumable items may be steeply discounted because desire for a particular item may fluctuate over time, but delayed money can always be exchanged for whatever is needed at that point. Regardless of the mechanism, steeper discounting of consumable outcomes appears to have fair generality so far. Direct comparisons have found steeper discounting of a favorite food than money (the present study), of a favorite food and a favorite alcoholic beverage than money (Odum and Rainaud, 2003), of candy, beer, and soda than money (Estle et al., in press), and of liquor than money (Petry, 2001).

These findings may be related to results that are usually interpreted in terms of addiction. People with addiction problems discount their drug of abuse more steeply than money (e.g. Bickel et al., 1999; Coffey et al., 2003; Madden et al., 1997; Petry, 2001). One possibility is that drugs of abuse are discounted steeply because of some feature of addiction (see Madden et al., 1997), perhaps related to relief from withdrawal symptoms (Bickel et al., 1999; Madden et al., 1997; Petry, 2001). Although intuitively appealing, there are a number of factors that appear to pose difficulties for this account. For example, cocaine addicts discount cocaine more steeply than money (Coffey et al., 2003), showing that steeper discounting of drugs than money is not unique to drugs with a pronounced withdrawal syndrome. Furthermore, people without alcohol dependence discount alcohol more steeply than money (Odum and Rainaud, 2003; Petry, 2001), showing that non-drug dependent individuals, who do not experience withdrawal symptoms, discount a drug that others abuse more steeply than money. Finally, people discount another consumable outcome, food, as steeply as forms of alcohol (Estle et al., in press; Odum and Rainaud, 2003). More research will be required to determine whether steep discounting of drugs is related to some aspect of addiction or to the fact that drugs are consumable.

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