HHS Public Access
Author manuscript
J Exp Anal Behav. Author manuscript; available in PMC 2020 July 21.

Published in final edited form as:
J Exp Anal Behav. 2020 May ; 113(3): 657–679. doi:10.1002/jeab.589.

Delay discounting of different outcomes: Review and theory

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Abstract

Steep delay discounting is characterized by a preference for small immediate outcomes relative to larger delayed outcomes and is predictive of drug abuse, risky sexual behaviors, and other maladaptive behaviors. Nancy M. Petry was a pioneer in delay discounting research who demonstrated that people discount delayed monetary gains less steeply than they discount substances with abuse liability. Subsequent research found steep discounting for not only drugs, but other nonmonetary outcomes such as food, sex, and health. In this systematic review, we evaluate the hypotheses proposed to explain differences in discounting as a function of the type of outcome and explore the trait- and state-like nature of delay discounting. We found overwhelming evidence for the state-like quality of delay discounting: Consistent with Petry and others' work, nonmonetary outcomes are discounted more steeply than monetary outcomes. We propose two hypotheses that together may account for this effect: Decreasing Future Preference and Decreasing Future Worth. We also found clear evidence that delay discounting has trait-like qualities: People who steeply discount monetary outcomes steeply discount nonmonetary outcomes as well. The implication is that changing delay discounting for one outcome could change discounting for other outcomes.

Keywords

delay discounting; temporal discounting; domain; commodity; trait

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Delay discounting, the decline in the present value of a reward with delay to its receipt, is a ubiquitous phenomenon (Odum, 2011a). Steep delay discounting is related to a wide variety of maladaptive behaviors that, although potentially rewarding in the short-term, are detrimental in the long-term (see Amlung et al., 2017; Bickel et al., 2019). Delay discounting is associated with drug abuse (see Mackillop et al., 2011) gambling (e.g., Alessi & Petry, 2003), obesity (see Barlow et al., 2016), risky sexual behaviors (e.g., Johnson, Johnson et al., 2015), preventative health behaviors, and personal safety (e.g., Daugherty & Brase, 2010). If delay discounting plays a causal role in these maladaptive behaviors, understanding the processes that lead to steep delay discounting is paramount.

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The type of outcome being discounted exerts a powerful effect on the degree of delay discounting. For example, Madden et al. (1997) found that people with opioid dependence discounted delayed heroin far more steeply than an equivalent amount of delayed money. Similarly, Bickel et al. (1999) found that current tobacco cigarette smokers discounted delayed cigarettes more steeply than money. What explanation could account for this steeper discounting by delay of drugs of abuse than money? At the time, Bickel et al. reasoned that nicotine and heroin may be steeply discounted because users are trying to escape or avoid withdrawal (a frequent syndrome for both heroin and nicotine). We will term this the *Withdrawal Hypothesis*, which we define as the idea that people discount substances that have a physical withdrawal syndrome more steeply than money because obtaining a relatively small amount of the drug immediately allows them to prevent or escape from withdrawal. This hypothesis is not the same as the empirical question of whether people with drug abuse problems discount more steeply by delay when they are in a state of withdrawal, which we term the effect of withdrawal on delay discounting (see Discussion). The Withdrawal Hypothesis entails that as a category, those substances that are steeply discounted relative to money are those substances that could potentially produce withdrawal if the person did not take the substances.[1]

As the literature developed, however, it became clear that even in cases in which abstinence from the drug would not produce withdrawal, substances that have abuse liability are steeply discounted compared to money. For example, Petry (2001) examined delay discounting for money and alcohol in three groups: people currently experiencing alcohol use problems, people in recovery from alcohol use problems, and people who had never experienced alcohol use problems. If the fact that a substance produces a withdrawal syndrome was the main feature that produces steep delay discounting of that substance compared to money, then alcohol should be discounted more steeply than money only by people with current problematic drinking. Petry found, though, that both people with current alcohol use problems and people in recovery from alcohol abuse more steeply discounted delayed alcohol than delayed money.[2] This finding makes it implausible that the potential to experience withdrawal is the only factor underlying steeper discounting of alcohol than money, as people in recovery were unlikely to experience withdrawal symptoms associated with alcohol abstinence.

The Withdrawal Hypothesis, the idea that drugs of abuse are discounted more steeply than money for the sole reason that they are associated with withdrawal syndromes, cannot be correct, because people who are abstinent from alcohol would not experience withdrawal if they did not drink, yet they still discount alcohol more steeply than they do money (Petry, 2001). Perhaps it is not avoidance of withdrawal that produces steeper discounting of a substance than money. Instead, we could suggest what we term the *Addiction Hypothesis*: People susceptible to abuse of a substance discount that substance steeply relative to money. This hypothesis would explain why people who are in recovery from alcohol abuse discount

[1]This hypothesis does not entail that the drug would be discounted steeply only when the person was experiencing withdrawal, which was known to be false already from the earliest studies, during which the participants were not in active withdrawal (see Bickel et al., 1999; Madden et al., 1997).

[2]People with alcohol abuse also discounted delayed money and alcohol more steeply than did people in recovery from alcohol abuse, as well as more steeply than did control participants.

alcohol more steeply than money. However, Petry (2001) also found that people with no history of alcohol use problems also discounted alcohol more steeply than money. This finding would seem to render even the Addiction Hypothesis unlikely as the sole determinant of steep discounting, because people who have never had problems refraining from alcohol use also discount alcohol more steeply than they do money. That is, alcohol and other drugs of abuse are discounted more steeply than money, but avoidance of withdrawal and being addicted to the substance do not appear to be what is uniquely associated with this relatively steep discounting. This is not to say, of course, that these factors do not contribute to steep delay discounting, only that they cannot be the sole explanation (see Discussion).

Intrigued by the findings of Petry (2001) with money and alcohol, our laboratory began investigation of differential delay discounting of money and consumable outcomes to further evaluate the Withdrawal and Addiction Hypotheses. In our initial study, Odum and Rainaud (2003), we replicated Petry's investigation of money and alcohol, and included another outcome: food. According to both the Addiction and Withdrawal Hypotheses, food should not be discounted more steeply than money, because it is not an abused substance.[3] We were specifically interested in how community members with no known problems with money, alcohol, or food would discount these outcomes, so we screened people for gambling, drinking, and eating disorders. We found that people discounted alcohol more steeply than money, replicating Petry's findings. Additionally, people discounted food more steeply than money, and similarly to alcohol. Together with Petry's results, these findings show that steep delay discounting is not unique to people who potentially experience drug withdrawal. Furthermore, the results of Odum and Rainaud showed that steep discounting by delay is not unique to drugs of abuse. These findings confirmed and extended others in the literature using different methodology (Chapman, 1996; Chapman & Elstein, 1995; Kirby & Guastello, 2001).

Given that the Withdrawal and Addiction hypotheses of steep delay discounting seemed in these cases unlikely explanations of steeper discounting of nonmonetary outcomes than money, Odum and Rainaud (2003) suggested a number of other potentially related hypotheses. One difference between money and the other outcomes studied to that point was that money serves as a generalized conditioned reinforcer, whereas food and drugs of abuse are primary (unconditioned) reinforcers (see also Coffey et al., 2003). Another difference is that money is not perishable, whereas food and, to a lesser extent drugs of abuse, are perishable. Furthermore, money is not generally subject to satiety effects, whereas a person may become sated with food or drugs. Finally, money is not directly consumed, but food and drugs of abuse are. The results of Odum and Rainaud did not eliminate any of these hypotheses, but subsequent studies have appraised these as well as suggested other interesting hypotheses, which we explore in the Discussion.

Another development that led from Petry (2001) was the realization that we had an important source of evidence regarding state as well as trait influences on delay discounting

[3]We recognize that deprivation from food can produce what could be considered withdrawal, and that food could be considered an abused substance. We consider the discussion of this issue beyond the scope of this paper.

(Odum, 2011b). *State influences* on delay discounting are relatively temporary changes in delay discounting as a result of situational variables. These include, for example, the impact of the type of outcome on delay discounting (e.g., Petry, 2001). These effects are measured and quantified by examining the degree of delay discounting across different outcomes. *Trait influences*, in contrast, are relatively stable effects of the individual person on delay discounting. Traits represent persistent patterns of thoughts, feelings, and/or behaviors that a person brings to different situations and contexts (see e.g., Roberts, 2009). Clearly, delay discounting is impacted by both state and trait effects. Furthermore, state and trait effects may interact (e.g., in epigenetic influences, see Meaney, 2010).

There are a number of forms of evidence for trait influences on delay discounting (see Odum, 2011b). These include heritability (see Gray et al., 2019; Mitchell, 2011) and reliability, which we will discuss in turn. Various forms of evidence indicate that delay discounting is heritable. Heritability has different connotations and definitions (see Griffiths et al., 1999; Moore & Shenk, 2017; Tenesa & Haley, 2013); we define it broadly as the extent to which genetic differences can account for differences in a trait.

We discuss heritability because of its centrality to the concept of a trait. One form of evidence of heritability in delay discounting is strain differences in laboratory animals. In this research, the environment is controlled, and the same across strains, so differences in behavior are generally attributable to genetic differences (see Gray et al., 2019; Mitchell, 2011, for caveats). Different strains of rats and mice have characteristic disparate degrees of delay discounting (e.g., Anderson & Woolverton, 2005; Beckwith & Czachowski, 2014; Huskinson et al., 2012; Kirkpatrick et al., 2015; Linsenbardt et al., 2017; Oberlin & Grahame, 2009; Perkel et al., 2015; Pope et al., 2015; Richards et al., 2013; Stein et al., 2012; Wilhelm & Mitchell, 2009). These strain effects show that genetic differences contribute to reliable differences in delay discounting in laboratory rodents.

Another form of evidence for the heritability of delay discounting has been found with humans. Broadly, this evidence takes two forms: heritability estimates from twin studies and molecular genetics studies attempting to find the specific loci associated with delay discounting. For example, Anokhin et al. (2011) examined the relation between delay discounting in monozygotic twins, who share 100% of their genes, and dizygotic twins, who share on average 50% of their genes. The correlation between delay discounting between twins was positive in both cases, but higher in monozygotic twins. This finding indicates a genetic contribution to the degree of delay discounting, because both types of twins have similar environmental influences on delay discounting, yet the correlation was stronger in twin pairs sharing more genes. Subsequent studies have replicated and extended these findings (Anokhin, Grant et al., 2015; Isen et al., 2014; Sparks et al., 2014). Although the studies with twins indicate that delay discounting has a heritable component, the search for the particular loci associated with delay discounting remains ongoing (see MacKillop et al., 2019), and is beyond the scope of this review.

Another type of evidence for delay discounting as a trait comes from studies of its reliability, which fulfills the well-established definition of a trait as a “relatively enduring pattern of … behaviors that reflects the tendency to respond in certain ways under certain circumstances”

(Roberts, 2009). The forms of reliability that we will consider here are same and alternate form test–retest reliability, cross-context reliability, and cross-outcome reliability. We will define and consider the evidence for each of these forms of reliability in turn. These reliabilities of delay discounting all suggest that there is a core process that is time-independent, context-independent, and outcome-independent (i.e., that delay discounting is a trait; see also Mitchell, 2011).

Test–retest reliability is assessed by having a person return to the testing context and take the test more than once. For example, in *same-form* reliability, the degree of delay discounting the first time a person takes a version of the test is strongly related to the degree of delay discounting subsequent times they take the same version of test, whether assessed 1 week apart (r = .91, Simpson & Vuchinich, 2000) or 2 years apart (r = .72, mean across two adolescent cohorts, Anokhin, Golosheykin et al., 2015). This finding of good test–retest reliability in delay discounting is well replicated in people (e.g., Beck & Triplett, 2009; Black & Rosen, 2011; Kirby, 2009; Martínez-Loredo et al., 2017; Matusiewicz et al., 2013; McCarthy et al., 2016; Takahashi et al., 2007; Weafer et al., 2013; Xu et al., 2013), and has also been found in rats (Peterson et al., 2015). Similarly, in *alternate-form* test–retest reliability, the degree of discounting on one type of test of delay discounting is strongly related to the degree of delay discounting found with a different type of test of delay discounting in people (e.g., DeHart et al., 2018; Johnson & Bickel, 2002; Kowal et al., 2007; Robles & Vargas, 2007, 2008; Robles-Sotelo et al., 2009; Rodzon et al., 2011; Smith & Hantula, 2008) and rats (Peterson et al., 2015).

Few studies to date have examined delay discounting in the same participants in more than one context, but we consider the topic here because it can provide strong evidence of both state and trait effects of delay discounting. Dixon et al. (2006) compared delay discounting in people with problem gambling in two contexts: an off-track betting facility and a nongambling context (e.g., coffee shop, restaurant, etc.). The two assessments were conducted in counter-balanced order across participants, approximately one week apart. Dixon et al. found that delay discounting was higher in the gambling context than in the nongambling context, demonstrating that the degree of delay discounting was context-dependent (a state effect). Although the authors did not conduct an analysis of the correlation between discounting across the two contexts, their Table 1 provides the data necessary for the 20 participants. The correlation between the degree of discounting in the gambling and nongambling contexts (r = .876, p = .00000042) was strong and positive, indicating that people who showed relatively steep delay discounting in one context also showed steep discounting in the other context. Notably, the degree of correlation is substantially above .5, which is considered the boundary for a large effect size (Cohen, 1992). More research is needed in the area of the cross-context reliability of delay discounting, but the data from the available study suggest delay discounting is strongly correlated across contexts.[4]

[4]Studies of the effects of different narratives on delay discounting (e.g., Mellis et al., 2018) could also be considered manipulations of context, but we were unable to find research of this nature which was conducted within-subject, which is required for this type of correlational analysis.

Another form of evidence for trait influences on delay discounting, and one that will be a focus in our review, is the relation between how steeply a person discounts one outcome and how steeply they discount another outcome (cross-outcome reliability; Odum, 2011b). If delay discounting is a trait, that is, if it represents how a person discounts across different situations and contexts, then delay discounting for one outcome should be directly related to delay discounting for other outcomes. For example, if a person shows relatively steep discounting for money, and delay discounting is a trait, we would expect that person to also show relatively steep discounting for food. In an initial investigation into this question, we re-analyzed data from a number of studies from our laboratory and found that there was indeed a strong positive correlation between discounting for one outcome type and discounting for another outcome type (Odum, 2011b), replicating and extending the results of prior studies (Charlton & Fantino, 2008; Johnson et al., 2010).

In the following review, we will examine the impact of outcome type on delay discounting in the published literature to date. In the first section, we will examine the effect of outcome type on the relative steepness of discounting for money versus other outcomes (a state effect). In the second section, we will examine the relation between discounting for money and other outcomes (a trait effect). Our goal is to provide for the first time a comprehensive overview of the effects of outcome type on delay discounting. We will examine the extent and reliability of effects as well as evaluate current explanations of these effects.

Method

Identification of Studies

We conducted a literature search in Pubmed to identify studies that assessed delay discounting of multiple outcomes. The initial search included the following search terms: “delay discounting” or “temporal discounting” and “money” and identified 179 articles. A subsequent search was conducted using the terms “delay discounting” or “temporal discounting” and “food”. This search identified an additional 28 articles that were not captured in the initial search, for a total of 207 unique articles. We included four additional articles that were not identified from the literature search, but we deemed relevant to the current review. From these 211 articles, 82 met the following inclusion criteria: The study provided descriptive statistics (e.g., *k* or AUC, see *Measures* below for details) for delay discounting of monetary gains and gains for at least one other outcome, or included a correlation of delay discounting measures (e.g., *k* or AUC) for money and another outcome. Figure 1 is a flow chart describing the study selection methodology and the number of studies included at each stage of inclusion/exclusion. A Microsoft Excel file containing information about each of the studies which met our inclusion criteria is available on the Open Science Framework: osf.io/fbw8h/.

Delay Discounting Assessment Strategies and Measures

There are several common techniques for assessing delay discounting of money. Each of these techniques attempts to quantify the value of a relatively large delayed outcome in terms of a relatively small immediate outcome (i.e., find a point of indifference). Common techniques for assessing delay discounting are Fill-in-the-blank (e.g., Chapman, 1996), the

Kirby monetary choice questionnaire (e.g., Kirby et al., 1999), adjusting amount (e.g., Du et al., 2002), fixed alternative survey (e.g., Rachlin et al., 1991), random order survey (e.g., Mitchell, 1999), experiential discounting task (or other potentially real outcome task; e.g, Reynolds & Schiffbauer, 2004), and visual analogue scale (e.g., Johnson, Herrmann et al., 2015). However, nonmonetary outcomes are more variable in their employed assessments. Details on the employed methodologies used in the studies included in our review of the literature can be found at osf.io/fbw8h/.

Several delay discounting measures were reported across the studies, but the two most commonly reported measures were k from Mazur's (1987) hyperbolic equation (see Eq. 1) and Area Under the Curve (AUC; see Myerson et al., 2001; Eq. 2). In Equation 1, the value of a delayed outcome, V, is a function of A, the objective amount of the reward, k the discount factor that scales the loss of value of the outcome (where a relatively large k indicates a relatively steep decline in value with increases in delay), and D the delay to a reward. The 1 in the denominator prevents V from being undefined when D is zero.

$$V = \frac{A}{1 + kD} \tag{1}$$

AUC is the sum of the trapezoidal area between each set of adjacent indifference points. Equation 2 is the formula for a single trapezoid, where x_1 and x_2 are successive delays and y_1 and y_2 are indifference points associated with those delays. Additionally, the indifference points are standardized by the amount of the delayed outcome and the delays are standardized by the maximum delay such that AUC falls between 0 and 1, with lower values indicating steeper delay discounting.

$$AUC = (x_2 - x_1)\left(\frac{y_1 + y_2}{2}\right) \tag{2}$$

Descriptive Analysis

In general, studies examining delay discounting of multiple outcomes find that nonmonetary outcomes are discounted to a greater degree than monetary outcomes; however, no study has quantitatively demonstrated the robustness of this finding by comparing the degree of discounting for different outcomes across studies. Therefore, we collected descriptive statistics on the degree of discounting for a variety of nonmonetary outcomes to compare them to monetary outcomes. Studies included in the descriptive analysis met the following criteria: 1) reported a measure of central tendency for estimates of k derived from Mazur's (1987) hyperbolic equation (Eq. 1) or AUC (Eq. 2; Myerson et al., 2001) for both a monetary outcome and a nonmonetary outcome; 2) used the same delay ranges in the discounting assessment for both outcomes; and 3) used the same monetary amount (e.g., $10 worth of cigarettes) or the same number of units (e.g., 10 cigarettes) for the monetary and nonmonetary outcomes. Within the studies meeting these criteria, we excluded measures of delay discounting obtained from cross-commodity discounting assessments. Cross-commodity discounting assessments include choices between immediate and delayed outcomes that are qualitatively different (e.g., money now vs. a nonmonetary outcome later). These tasks may not be capturing the effects of delay alone, because the effects of qualitatively different outcomes also affect choice within the same questions. To be conservative, we excluded studies that used cross-commodity assessments. If a measure of central tendency for *k* or AUC was not reported in the study, but was visually available from figures displaying the measure of central tendency, then we used a graphical data extraction tool (Rohatgi, 2018) to obtain an estimate of that central tendency. The obtained measures of central tendency for *k* and AUC were subsequently used to calculate a measure of the relative degree of discounting between monetary and nonmonetary outcomes.

With the collected estimates of *k* and AUC, we calculated a proportional discounting measure to describe the relative degree of delay discounting between monetary and nonmonetary outcomes across a common metric. The proportional discounting measure was the discounting measure (i.e., *k* or AUC) for the nonmonetary outcome divided by the sum of the discounting measures from both the nonmonetary outcome and from the monetary outcome. Proportions less than 0.5 indicate that the nonmonetary outcome was discounted to a lesser degree than the monetary outcome, whereas proportions greater than 0.5 indicate that the nonmonetary outcome was discounted to a greater degree than the monetary outcome. After collecting measures of central tendency for *k* and AUC, we calculated 59 proportions from estimates of *k* obtained from 20 studies and 37 proportions from AUCs obtained from nine studies. One study provided both a measure of central tendency for *k* and AUC; therefore, the final sample included in the descriptive analysis was 28 studies. Calculating proportions allowed us to assess the relative degree of discounting between monetary outcomes and a wide range of nonmonetary outcomes across the studies in the sample on a common scale.

Prior to calculating the proportional discounting measure, we performed two transformations to ensure that our measure characterized the degree of discounting the same way across dependent measures (i.e., higher values indicated steeper discounting). If a study reported log-transformed estimates of *k*, we exponentiated the log-transformed *k*s by the base of the logarithm (e.g., *e* or 10) prior to calculating the proportional discounting measure for *k*. Although higher values of both untransformed and log-transformed estimates of *k* indicate steeper discounting, calculating the proportional discounting measure with log-transformed estimates of *k* would lead to the opposite interpretation of the proportional discounting measure (i.e., proportions less than 0.5 would indicate nonmonetary outcome was discounted to a greater degree than the monetary outcome). We chose to untransform any *k* values to ensure the interpretation of the proportional discounting measure was consistent. The second transformation we conducted was to reverse code AUC by subtracting AUC from 1 (i.e., the area over the curve [AOC]). We calculated area over the curve (AOC) because *k* and area under the curve (AUC) have an inverse relation: Higher estimates of *k* indicate steeper discounting, whereas higher values of area under the curve (AUC) indicate shallower discounting. Therefore, to ensure that proportional discounting rates calculated from estimates of *k* and AUC were consistent in characterizing discounting we calculated AOC. After performing these transformations to ensure a consistent characterization of delay discounting across measures, we calculated proportions for all of the data in our sample.

Collection of Correlation Coefficients

Our second goal was to examine the extent to which degrees of delay discounting for monetary and nonmonetary outcomes are correlated. Thus, we collected 86 correlation coefficients from 38 studies; for 29 studies one or more correlation coefficients were reported in the text and for the remaining nine studies, we contacted the authors, who provided the correlation coefficients upon request (see Fig. 2).

Results

Descriptive Results

We found steeper discounting for nonmonetary outcomes relative to monetary outcomes across most of the studies included in our sample. Figure 2 displays the proportional discounting rates from estimates of *k* across the 22 studies that reported *k*.[5] Ninety-eight percent of the proportions calculated from *k* were greater than 0.5. The mean proportion (M = 0.76, SE = 0.02) was significantly different from 0.5 according to a one-sample *t*-test (t[60] = 13.59, $p < .001$, CI 95: [.72, .79]). One study (Yi & Landes, 2012) was excluded from the *t*-test because *k* was estimated by an exponential power model whereas all other studies estimated *k* with Mazur's (1987) hyperbolic equation. Excluding this study did not affect the results of the *t*-test. Figure 3 displays proportions calculated from AOC across the eight studies that reported AUC. Similar to the proportions calculated from *k*, the majority of the proportions calculated from AOCs (89%) was greater than 0.5, with the average proportion (M = 0.57, SE = 0.01) reliably above 0.5 according to a one-sample *t*-test (t[36] = 7.61, p < .001, CI 95: [.55, .59]). To examine whether sample size affected our estimates of mean *k* and AOC proportions, we calculated weighted averages for both the *k* and AOC proportions; these were within 0.01 of the arithmetic means. Overall, our results provide strong evidence that discounting of nonmonetary outcomes is greater than discounting of monetary outcomes.

Analysis of Correlation Coefficients

Figure 4 shows the 37 correlations between *k* parameters and other metrics of degree of discounting and Figure 5 shows the 49 correlations between AUC values. Eighty-three out of 86 (97%) coefficients are greater than zero, which indicates that people tended to discount relatively similarly across monetary and nonmonetary outcomes. In support of this conclusion, a one-sample *t*-test showed the correlation coefficients (M = .35) were significantly greater than a hypothetical population mean effect size of $r = 0$, (t[85] = 13.64, $p < .001$, CI 95: [.31, .42]).

We also examined whether people discounted all different types of nonmonetary outcomes similarly to money. Thus, we grouped the nonmonetary delayed outcomes based on the label provided in the original studies and conducted several one-sample *t*-tests against a hypothetical population mean effect size of $r = 0$. For all of the grouped outcomes, degree of discounting for money was significantly positively correlated with degree of discounting for

[5]Figures 2 and 3 do not show estimates of error because 1) we calculated a single ratio for each study and 2) estimating error from a single ratio requires the elements of the ratio be normally distributed, which we could not assume.

the alternative delayed outcome: *spirits* (labels: alcohol or beer; $t[8] = 9.10$, $p < .001$, CI 95: [.37, .61]), *non-drug consumables* (labels: candy, food, juice, or soda; $t[21] = 8.65$, $p < .001$, CI 95: [.31, .50]), *drug consumables* (labels: cigarettes, heroin, or marijuana; $t[11] = 7.01$, $p < .001$, CI 95: [.39, .74]), *abstract states* (labels: freedom or health; $t[10] = 3.71$, $p < .01$, CI 95: [.10, .42]), *exchangeables* (labels: voucher or gift card; $t[4] = 4.13$, $p = .01$, CI 95: [.12, .63]), sex (label: sex; $t[15] = 2.95$, $p < .01$, CI 95: [.04, .26]), and *miscellaneous* (labels: activities, entertainment, exercise, material, social, or video games; $t[10] = 7.37$, $p < .001$, CI 95: [.25, .48]). Taken together, the results show that people who relatively steeply discount monetary outcomes tend to also do so for a wide variety of other outcomes as well.

We also wanted to assess whether the result of the all-inclusive *t*-test was affected by unpublished null results. Statistically significant results are more frequently published than nonsignificant results, which can inflate the estimated effect size, a phenomenon referred to as the *file-drawer problem* (Rosenthal, 1979). To assess the extent of a potential file-drawer problem one may calculate a "fail-safe *N*" to estimate the number of null results necessary to reduce the mean effect size to a point where the null hypothesis cannot be rejected (e.g., $p > .05$). We calculated a fail-safe *N* of 16,464 via the method proposed by Rosenberg (2005) with the *fsn* function in the *metafor* package in *R* (Viechtbauer, 2010). This fail-safe *N* means that we would fail to reject the null hypothesis, that the degree of delay discounting between monetary and nonmonetary outcomes is uncorrelated (i.e., $r = 0$) across outcome types, only if at least 16,464 null results have gone unpublished. Thus, we conclude the significant correlation between degree of discounting for monetary and nonmonetary outcomes is unlikely to be due to publication bias.

Additional figures showing the proportional delay discounting of nonmonetary and money as well as correlations grouped by different outcomes can be found at osf.io/fbw8h/.

Discussion

This review has two main findings. First, across the sample of studies, nonmonetary outcomes were more steeply discounted by delay than money (a state effect). There were few exceptions to this general tendency. This review thus shows that steeper discounting of nonmonetary outcomes is a pervasive and reliable finding, occurring with a variety of different outcomes, participant populations, and methodology. Second, across the sample of studies, the degree of delay discounting for nonmonetary outcomes was positively correlated with the degree of delay discounting for money (a trait effect). This result means that people who tend to discount one outcome steeply also discount other outcomes relatively steeply (see Odum, 2011b). This positive correlation was found in the vast majority of studies reviewed, and is highly unlikely to be the result of publication bias, as assessed by the fail-safe *N*.

Steep Discounting of Nonmonetary Outcomes

Why is the value of nonmonetary outcomes degraded more so by delay than is money? There are a number of hypotheses that have been advanced, some of which can be eliminated and some of which cannot. Indeed, the effect may be attributable to more than one factor (see Charlton & Fantino, 2008). First, as described in the Introduction, the idea that nonmonetary outcomes such as drugs of abuse are steeply discounted solely because of associated withdrawal syndromes (the Withdrawal Hypothesis) has been shown to have little coherence, because nonmonetary outcomes that are not drugs of abuse, and so do not have accompanying withdrawal syndromes, are also steeply discounted (Odum & Rainaud, 2003; Petry, 2001). Similarly, the Addiction Hypothesis cannot be the sole explanation of steep discounting, because people who do not have problematic substance use also discount nonmonetary outcomes steeply (Odum & Rainaud, 2003; Petry, 2001).

Withdrawal certainly may have an impact on delay discounting in general. For example, Giordano et al. (2002) reported that opioid deprivation increased delay discounting of hypothetical monetary and heroin rewards. Hughes et al. (2017), however, found that withdrawal from cigarettes decreased delay discounting of hypothetical monetary outcomes. The effects of withdrawal on delay discounting may be heterogenous across studies (see e.g., Field et al., 2006) and/or depend on the type of drug abstinence. A comprehensive review of the literature on the effects of withdrawal on delay discounting is needed and beyond the scope of our goals here.

As for the effects of addiction on differential discounting by delay of nonmonetary outcomes, we found that cigarette smokers discounted hypothetical delayed cigarettes more steeply than they did food (Odum & Baumann, 2007). This finding shows that being addicted to a substance like nicotine may render delay discounting for the specific substance of abuse even steeper than discounting of other nonmonetary outcomes. Jiga-Boy et al. (2013), however, found that cigarette smokers discounted delayed cigarettes to a similar degree as they discounted chocolate. More research and a comprehensive literature review will be necessary to assess the contributions of addiction to steep delay discounting of nonmonetary outcomes.

There are a number of other hypotheses of why nonmonetary outcomes are steeply discounted, to which we now turn. The Primary Reinforcer Hypothesis maintains that nonmonetary outcomes are discounted steeply because they are primary reinforcers/rewards, whereas money is discounted less steeply because it is a conditioned reinforcer (Odum & Rainaud, 2003). Estle et al. (2007), however, showed that probabilistic outcomes that were primary reinforcers (food) were not discounted more than money by uncertainty of receipt. This finding shows that the difference between discounting of nonmonetary outcomes and money must involve in some way the delay of the receipt, and is not due simply to the primary or conditioned reinforcing function. Estle et al. suggested the Inconstancy of Desire Hypothesis: nonmonetary outcomes are discounted steeply by delay because the degree to which they are wanted can fluctuate over time. Money, however, is a generalized conditioned reinforcer, and can be used to purchase whatever is preferred in the future.

The Inconstancy of Desire hypothesis is closely related to what has come to be called the Liquidity Hypothesis (also called the Fungibility Hypothesis; see Holt et al., 2016; Stuppy-Sullivan et al., 2016). According to this hypothesis, outcomes that cannot be exchanged for a variety of things are discounted more steeply than outcomes that can be exchanged. Money retains value when delayed because it can be used to buy something that is preferred in that moment. The results of a number of studies are consistent with the Liquidity Hypothesis (e.g., Charlton & Fantino, 2008; Jimura et al., 2009; Odum et al., 2006; Odum & Rainaud, 2003; Rasmussen et al., 2010; Tsukayama & Duckworth, 2010).

Although closely related and often discussed as one in the literature, these two hypotheses can be distinguished. The Inconstancy of Desire Hypothesis suggests that steep discounting results from the unpredictable appeal of delayed nonmonetary outcomes. The Liquidity Hypothesis suggests that steep discounting arises because nonmonetary outcomes are not exchangeable for multiple things. These two features (inconstant desire and nonliquidity) are naturally confounded and are difficult qualities to separate in most nonmonetary outcomes.

Recently, however, Stuppy-Sullivan et al. (2016) used “self-relevant” outcomes to show that liquidity may not account for the difference between delay discounting for nonmonetary outcomes and money. After completing a delay discounting assessment for money (a modified version of the Monetary Choice Questionnaire; Kirby et al., 1999), participants specified exactly what they would use the smaller immediate and larger delayed amounts of money to purchase for each choice. They then completed a customized delay discounting questionnaire using the outcomes they had specified. For example, a participant could potentially choose between “dinner with your friends (valued at $50) today” and “tuition payment (valued at $350) in 160 days”. These outcomes, which were not liquid, were discounted by delay to a similar degree as money, a finding which stands in contrast to those of most prior studies, in which nonmonetary outcomes were discounted more steeply than monetary ones. These results show that lack of liquidity may not underlie the steep discounting of nonmonetary outcomes.

There are at least two possible reasons why the delayed nonmonetary outcomes were discounted to a similar degree as money in Stuppy-Sullivan et al. (2016). One possible reason, which is not particularly interesting, is that the nonmonetary outcomes were discounted similarly to money simply because the worth of the outcomes was presented in the question itself (see paragraph above). This format is unlike that of other studies of discounting of nonmonetary outcomes, which do not present the dollar amount of the outcome in the question. Instead, prior studies have stated the outcomes in terms of number of servings or number of items (e.g., Charlton & Fantino, 2008; Estle et al., 2007; Odum & Rainaud, 2003).

A second, more interesting, possible explanation for the difference in results is that prior studies have used outcomes which are subject to decreases in preference for those outcomes in the future, when they would actually be received, whereas Stuppy-Sullivan et al. (2016) used self-relevant future outcomes as specified by the participants. They also used delays that were relatively short (maximum of 160 days) compared to typical delay discounting assessments (e.g., maximum of 50 years; Rachlin et al., 1991), which does not allow as much time for decrease in future preference. Prior studies, however, have often used outcomes for which participants would be expected to show decreased preference for over time.

People may have lower preference in the future for consumable outcomes that are highly preferred in the present. For example, in our laboratory, we ask participants their favorite food, then conduct the discounting assessment in terms of servings of that food. The most common favorite food reported in our laboratory for college-age participants is pizza. Because the rate of eating pizza decreases across the lifespan (Rhodes et al., 2014), we would predict future preference for pizza to be lower than current preference. Similarly, steeper discounting of delayed sex than money could be consistent with decreased predicted future preference too, because the rate of sexual activity declines with age (Twenge et al., 2017). This suggestion appears to hold with alcohol and other drugs as well. People will not prefer the drug to the same extent in the future as they do in the present. For example, the rate of drinking alcohol decreases with age (Britton et al., 2015). Older adults are also less likely to smoke tobacco cigarettes than younger adults ("Burden of Tobacco," 2019). Furthermore, 70% of people who smoke cigarettes want to quit, and over half of people who smoke attempt to quit in any given year (Babb, Malarcher, Schauer, Asman, & Jamal, 2017). Thus, preference for commonly studied nonmonetary outcomes decreases with age, and in many cases, people would predict they would have lower preference in the future than they do in the present.

We will call this explanation for steeper delay discounting of nonmonetary outcomes the Decreasing Future Preference Hypothesis. It is a specific restatement of the Inconstancy of Desire Hypothesis, which holds that the appeal of an outcome can fluctuate up or down in the future (see Estle et al., 2007, p. 62). The Decreasing Future Preference Hypothesis maintains that nonmonetary outcomes are discounted more steeply than money because the choice of those outcomes over others will decrease during the delay to the receipt, not because the preference is unpredictable. Money, however, can be used to purchase what is most preferred at the time of receipt, so preference for money does not decrease over the delay period. By using self-relevant choice options, Stuppy-Sullivan et al. (2016) allowed participants to specify outcomes that were not subject to decreasing preference over the relatively short time frame used, and thus these outcomes were discounted to the same degree as money.

What other circumstances could contribute to steep discounting of nonmonetary outcomes? In our review, we found few exceptions to the general rule that delayed nonmonetary outcomes are discounted more steeply than money (see Fig. 3). Although most appear to be simply anomalous, one exception stands out as potentially illuminating. The vast majorities of studies found that food was discounted more steeply than money, but Takahashi et al. (2008) found the opposite. They compared discounting by Thai people of rice (a staple food) and their national currency, the bhat, during a time of economic instability in Thailand. At the smaller value (200 baht and 10 kg of rice), rice and money were discounted to the same degree, which is in itself different from the results of other studies. At the larger value (2,000 baht and 100 kg of rice), rice was discounted less steeply than money, which is opposite to the results of other studies.

This result suggests another source of steeper discounting of delayed nonmonetary outcomes than money: greater relative loss of objective worth with delay (the Decreasing Future Worth Hypothesis). As suggested by Odum and Rainaud (2003), many forms of food are perishable, and thus would have less objective worth after a delay than they do in the present. Recently, Holt and colleagues found that the degree of discounting is directly related to the perishability of the outcome (Holt et al., 2016). In the case of Takahashi et al. (2008), due to the role of rice as a storable staple food and to money losing value rapidly over time due to inflation, rice was less perishable than money. In a related finding, Ostaszewski et al. (1998) found that a newer version of the Polish currency, the złoty, was less steeply discounted than an older version which had a relatively higher inflation rate. In essence, the new złoty was less perishable than the old złoty.

Two other findings of steeper discounting may be related to decreases in worth with delay. The first is the steeper discounting of delayed health outcomes than money (e.g., Baker et al., 2003). People of different ages value the health of older people less than the health of younger people (Busschbach et al., 1993; Petrou et al., 2013). Thus, as delay increases, and a person ages, health is worth less than it is in the present moment. The second finding is that people who are elderly (M = 75 years), and would not be expected to live for an extended period of time, show steeper delay discounting of money than young and middle-aged adults (Read & Read, 2004). Far-off outcomes would have less worth to people who are elderly because they would not expect to receive them.

Thus, we propose that steep delay discounting of nonmonetary outcomes may result from at least two factors: Decreasing Future Preference and Decreasing Future Worth. These two factors often covary, but can be separated. For example, Holt et al. (2016) found that even when future worth was preserved by nonperishable gift cards, people still discounted nonmonetary outcomes like pizza more steeply than they did money. Based on patterns of consumption across the lifespan, people appear to prefer the types of nonmonetary outcomes tested thus far less in the future than they do in the present.

Research on cross-commodity discounting may be interpreted to support our Decreasing Future Preference and Decreasing Future Worth hypotheses. In this type of research, one type of outcome is available immediately, but another type of outcome is available after a delay. For example, Moody et al. (2017) examined delay discounting in people who used alcohol. There were two same-commodity conditions, in which the immediate and delayed outcomes were the same (Money–Money [M–M] and Alcohol–Alcohol [A–A]), and two cross-commodity conditions, in which the immediate and delayed outcomes were different (Money–Alcohol [M–A] and Alcohol–Money [A–M]). The type of alcohol (e.g., beer) was chosen by the individual participants. Moody et al. found that the degree of discounting was lowest when the outcome with the greater predicted Future Preference and Future Worth (M) was delayed and the outcome with the lesser Future Preference and Future Worth (A) was immediate (condition A–M). Delay discounting was highest when the outcome with the greater predicted Future Preference and Future Worth (Money) was immediate and the outcome with the lesser predicted Future Preference and Future Worth (Alcohol) was delayed (M–A). Delay discounting in the two other conditions was intermediate, such that discounting for A–M < M–M < A–A < M–A. Other cross-commodity research shows a similar pattern (e.g., Bickel et al., 2011; Jarmolowicz et al. 2014), and thus appears to support our hypotheses.

The Motivational Hypothesis is another potential explanation of steeper delay discounting of nonmonetary outcomes relative to money (Paglieri et al., 2015). According to this hypothesis, nonmonetary outcomes appear to be more steeply discounted by delay due to a lower motivation to maximize those outcomes. The motivation to maximize an outcome can be assessed by measuring preference for the larger outcome over the smaller outcome when there is no delay to the receipt of either. Outcomes that are maximized are those for which the larger amount is chosen more often over the smaller amount. This baseline level of motivation then determines choice for the larger later outcome independently of delay. Paglieri et al. (2015) found that by this measure, motivation for real food was lower than motivation for money in a delayed outcome choice task, and that motivation and delay had independent effects on value.

In a recent paper, we found mixed evidence for the motivational hypothesis in a delay-discounting task with hypothetical outcomes (Dehart et al., 2018). We found that food was maximized less than money when there was no delay (i.e., the larger amount was chosen over the smaller amount proportionally less for food than for money with no delay), which provides support for the Motivational Hypothesis. However, other aspects of the data do not seem consistent with the Motivational Hypothesis. We found that choice of the larger amount of money at no delay was affected by framing. These data were reported in summary form in DeHart et al. (2018) but not formally analyzed. Here, we report that the proportion of choices for larger clear-framed money (dollars) at no delay was greater than the proportion of choices for larger fuzzy-framed money (handfuls of quarters) at no delay (Number of choices of Small Clear Money = 2, Large Clear Money = 238; Small Fuzzy Money = 24, Large Fuzzy Money = 216; $z = 4.44$, $p < .001$). We found that the value of Fuzzy Money was also discounted more steeply by delay than the value of Clear Money, which is at least superficially consistent with the Motivational Hypothesis, but it is not obvious why the motivation for maximizing money should be influenced by framing. DeHart et al. found in a second experiment that quarters were discounted similarly to dollars, isolating the effect to the fuzzy unit (handfuls) rather than the inconvenience or handling costs of quarters per se. More research is required to evaluate the Motivational Hypothesis as an explanation of steeper discounting of nonmonetary outcomes relative to money.

In summary, this review shows that nonmonetary outcomes are more steeply discounted by delay than money. This state effect on discounting is robust and occurs with a wide variety of outcomes, populations, and procedures. We propose that relatively steep discounting of nonmonetary outcomes may be explained by two factors: Decreasing Future Preference and Decreasing Future Worth. These factors encompass and clarify prior explanations. We hope that these hypotheses will stimulate future research into steep discounting of nonmonetary outcomes, which will in turn lead to improvement of the hypotheses.

Understanding steep discounting of nonmonetary outcomes is important. In attempts to change behavior, such as to help people overcome addiction, many of the rewards for changing behavior are delayed (e.g., better health after quitting smoking) and opposed by immediate punishers (e.g., anxiety, difficulty concentrating, insomnia, irritability; see McLaughlin et al., 2015). Understanding what factors lead to steeper discounting of delayed rewards could lead to improvements in therapies. For example, vouchers for an outcome are discounted less steeply than the outcome (Holt et al., 2016), and thus could promote more powerful behavior change. Understanding why some outcomes are steeply discounted could also potentially lead to insights into why some people steeply discount delayed outcomes.

The Correlation between Discounting for Different Outcomes

The second part of this review focused on a trait influence on delay discounting: the correlation between discounting for a nonmonetary outcome and discounting for money (cross-outcome reliability). We found that these correlations were overwhelmingly positive: steeper discounting for nonmonetary outcomes was associated with steeper discounting for money. Furthermore, the number of null results (no correlation) that would need to be unpublished to negate the published positive correlations was large (16,464).

Given these findings, why have some authors suggested that discounting of one outcome is not related to discounting of other outcomes? For example, Holt et al. (2016) characterize the findings in the literature as "mixed" and state that "discounting of different delayed outcome types [is] largely independent" (p. 51). Similarly, Jimura et al. (2011) state "individuals' discounting of liquid rewards was uncorrelated with their discounting of monetary rewards, providing evidence of domain independence at the individual level" (p. 258). Examination of Figure 5 shows that these two studies had 21 and 20 participants in the calculation of the correlation coefficients, respectively. Cohen (1992) regards the effect size of a correlation coefficient of .10 as small, .30 as medium, and .50 as large. To find a significant small correlation with Power = .80, the necessary N is 783 (Table 2 in Cohen). Even a large effect, defined by Cohen as .5, requires N = 28. These studies were thus underpowered to detect significant differences with the effect sizes they obtained for the correlations between delay discounting of nonmonetary outcomes and money. Although they were not able to detect a significant relation between discounting of liquid and monetary rewards, Jimura et al. were able to detect the very large obtained effect sizes of $r = .92$ for discounting of nonmonetary outcomes at Time 1 and Time 2, and $r = .84$ for discounting of money at Time 1 and Time 2 in Experiment 1. Together, these results highlight the importance of conducting literature reviews and providing a comprehensive overall picture of the state of an area of investigation. Our review clearly indicates that there is a positive relation between the degree of discounting for nonmonetary outcomes of a variety of types and the degree of discounting for money.

The correlation between the degree of delay discounting for one outcome and discounting for another outcome (cross-outcome reliability) is one piece of evidence for trait-level discounting (see Odum & Bauman, 2010). Traits are defined as persistent patterns of thoughts, feelings, and/or behaviors that are common across different situations and contexts (Roberts, 2009). As we have shown in the studies described in the Introduction and our Results, there is increasing evidence for a common core process of delay discounting that persists across outcomes, context, and time. Increasing evidence also shows that delay discounting has another feature of traits, heritability (e.g., Turkheimer, 2000), as described in the Introduction as well. These aspects of delay discounting have led Bickel and colleagues to describe delay discounting as an endophenotype (see e.g., Bickel et al., 2019).

Delay discounting may result from underlying processes. For example, temporal perception appears to be related to delay discounting. Selective overestimation of time (perceiving time as passing more quickly; e.g., Baumann & Odum, 2012), and generally inaccurate temporal perception (e.g., Marshall et al., 2014) are associated with greater delay discounting (see Smith et al., 2019). Differences in temporal perception could underlie delay discounting and thus its trait characteristics. Delay discounting, although correlated with maladaptive behaviors, may not ultimately be the causal factor.

Furthermore, although delay discounting has trait characteristics, it can also be influenced by environmental events over a relatively short time frame, as in the differential discounting of delayed outcomes described in this review, as well as over a longer time frame, as in interventions to reduce delay discounting (see Smith et al., 2019). Because of the detrimental nature of steep delay discounting and its association with addiction, obesity, gambling, and other maladies, there is great recent interest and development in experimental techniques to decrease the degree of delay discounting. Rung and Madden (2018) provide a comprehensive review and meta- analysis that chronicles a variety of ways to produce short term and longer-term reductions in delay discounting. There are a number of different intervention types that appear promising, although much translational work remains to be done.

In summary, delay discounting shows robust state and trait effects, and is also malleable. Nonmonetary outcomes are more steeply discounted by delay than is money, and discounting of one outcome is predictive of discounting for another outcome. Because delay discounting shows trait effects, this latter feature could be useful in the modification of delay discounting to reduce problematic and detrimental behaviors. Delay discounting for some outcomes or in some contexts may be challenging or impractical to attempt to directly change. Changes in delay discounting for more accessible outcomes, like money, could potentially generalize to changes in discounting of other outcomes and/or in other situations.

Acknowledgments

The authors thank the members of the Odum lab for helpful discussion and Amanda C. Anderberg for assistance in data collection for this manuscript. This manuscript is dedicated to Nancy M. Petry, who inspired this line of research. We confirm that no part of this manuscript has been disseminated elsewhere or in any other format.

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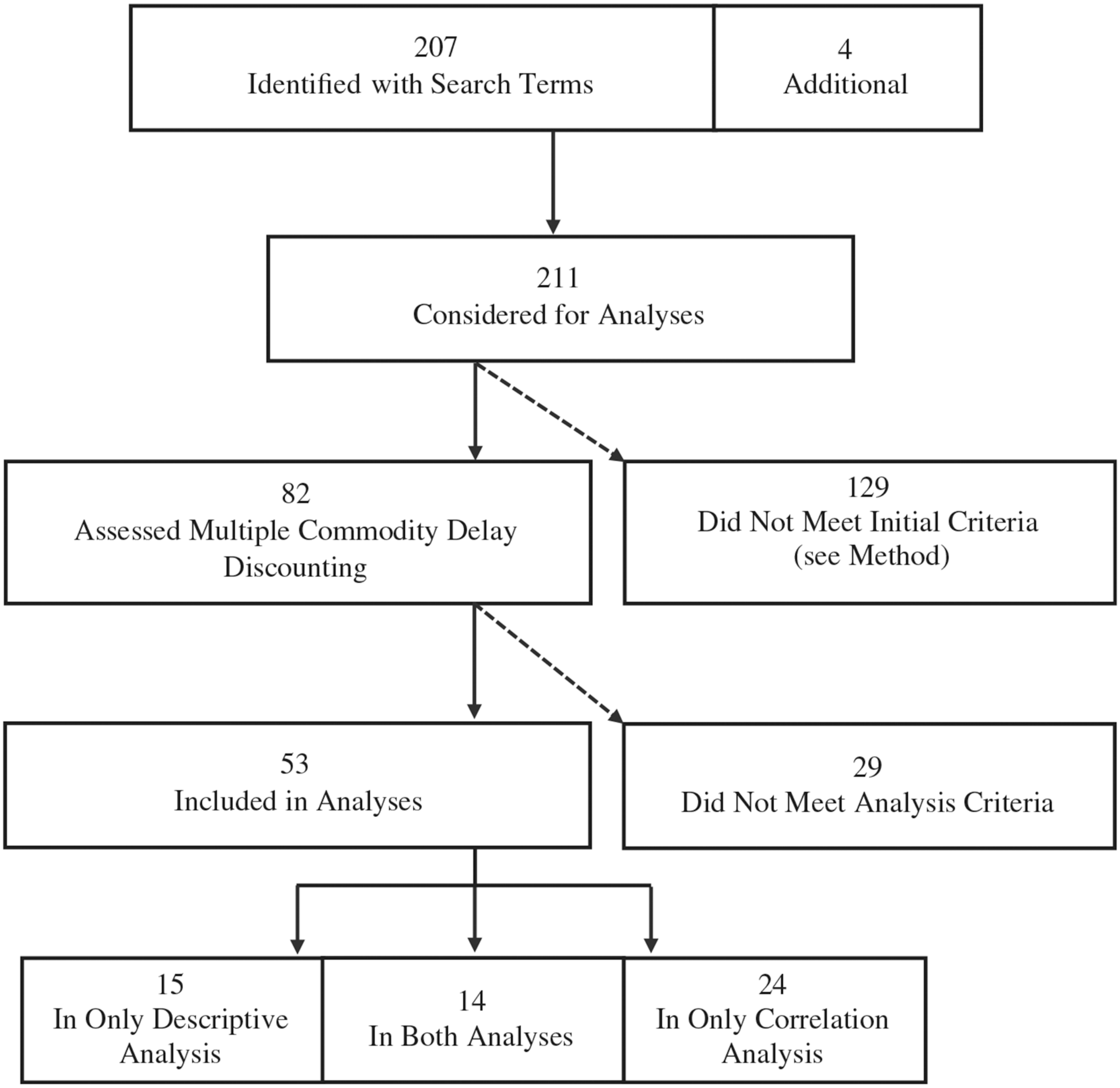


Figure 1. Diagram displaying the process in which articles were retrieved, excluded, and included in the present paper.

Note. Dashed lines indicate points at which articles were excluded. Details on the 82 studies that assessed delay discounting of multiple outcomes can be found here: osf.io/fbw8h/.

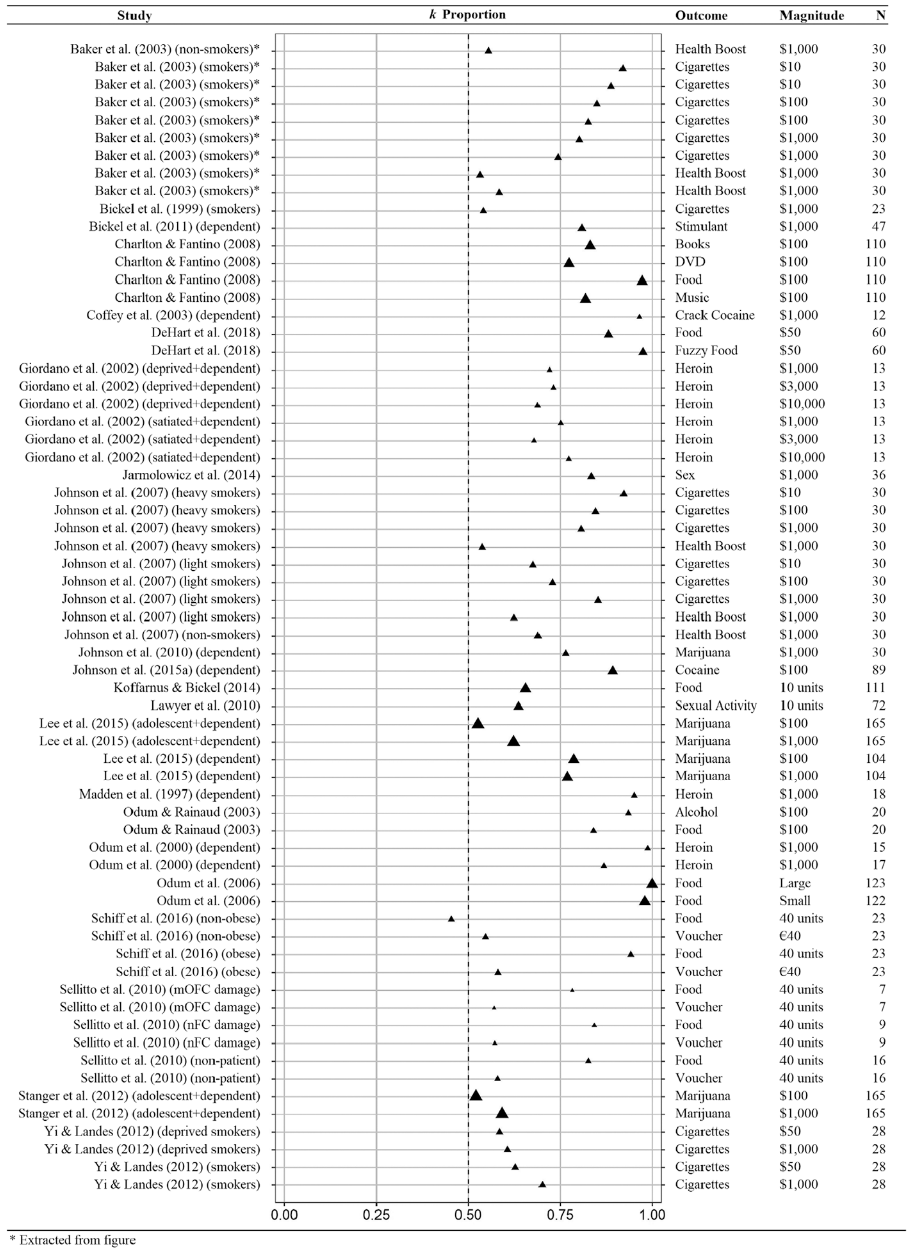


Figure 2. Proportions calculated from measures of central tendency for estimates of k derived from Mazur's (1987) hyperbolic discounting equation.

Note. The left margin lists the study and the right margin lists the nonmonetary outcome, the magnitude of that outcome, the statistic for the measure of central tendency, the sample size of the comparison, and sample characteristics of clinical populations. Size of the data points are scaled according to the sample size for that proportional *k*. Vouchers in Schiff et al. (2016) and Sellitto et al. (2010) were redeemable for a museum tour, gym session, hairdresser/barber session, or book purchase.

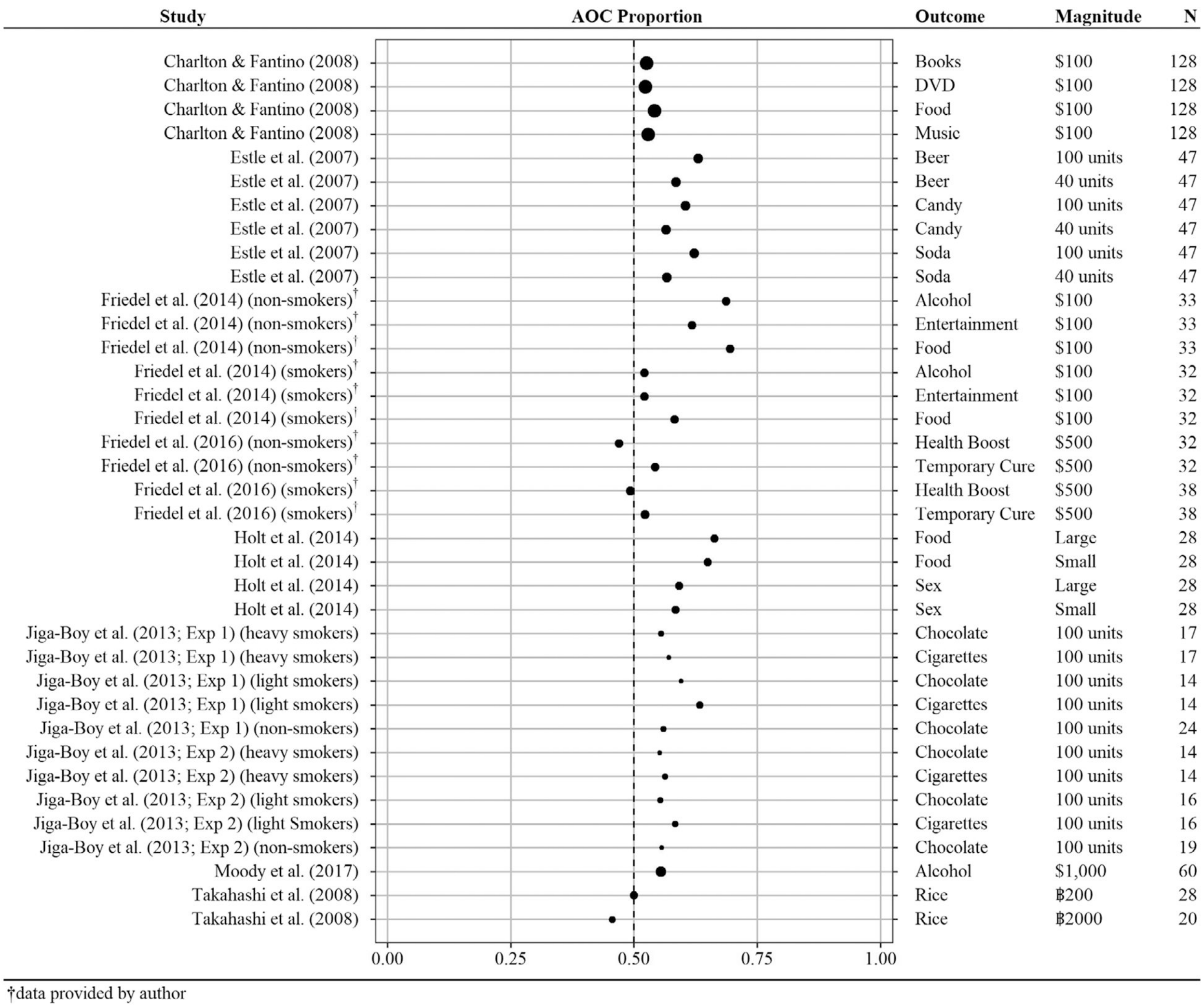
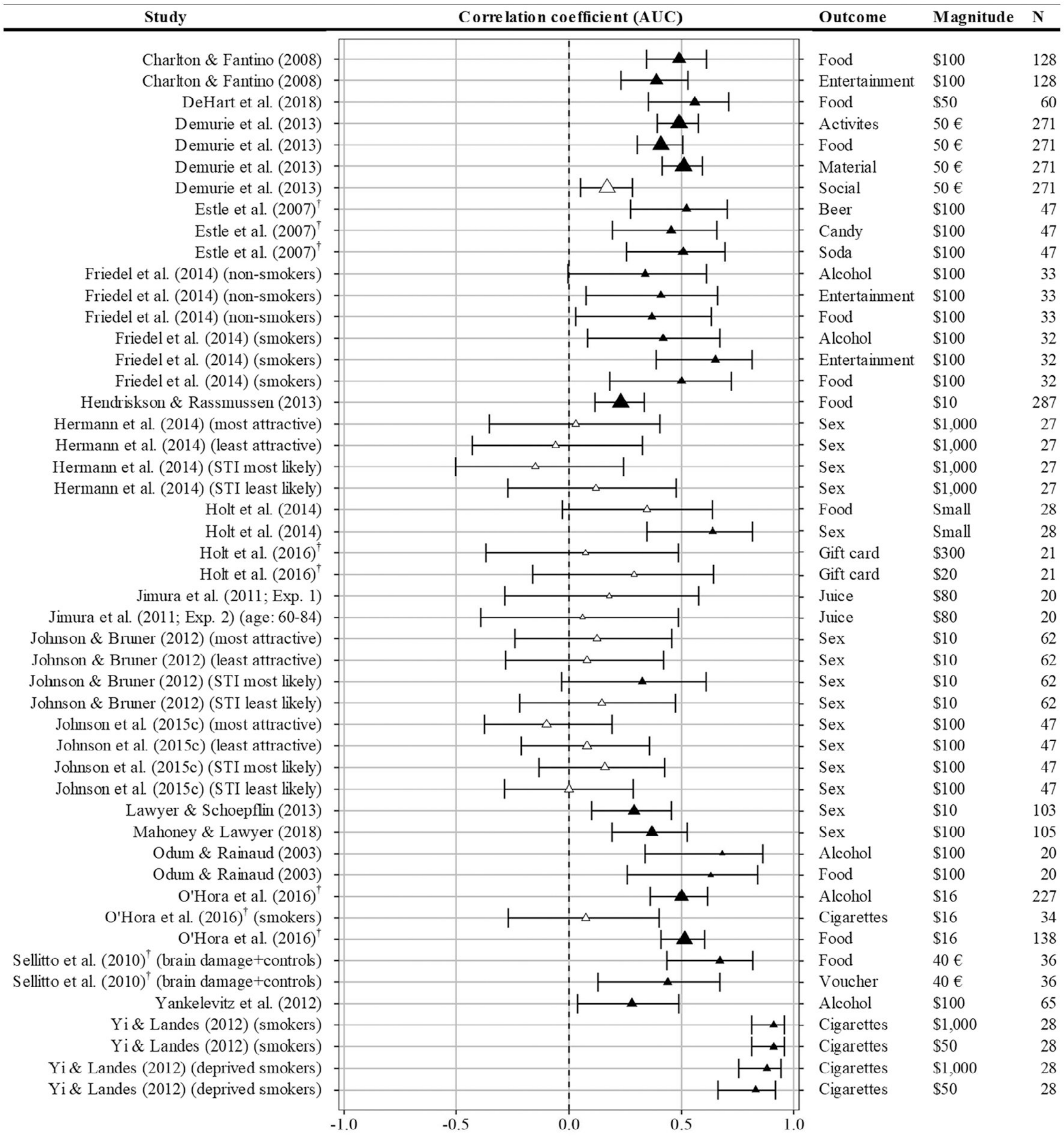


Figure 3. Proportions calculated from area over the curve (AOC).

Note. The left margin lists the study and the right margin lists the nonmonetary outcome, the magnitude of that outcome, the statistic for the measure of central tendency, the sample size of the comparison, and sample characteristics of clinical populations. Size of the data points are scaled according to the sample size for that proportional AOC.



† correlation coefficient provided by author

Figure 4. Correlations between k parameters (circles) and other metrics of degree of discounting (squares) for monetary and nonmonetary outcomes.

Note. Other metrics: impatience coefficients (de Water et al., 2017) and annual discount rates (Chapman, 1996; Chapman & Elstein, 1995). Each data point represents a single coefficient, the size of which is scaled to the sample size (see column N). The value of the correlation is indicated by its position along the abscissa. Filled and unfilled symbols represent statistically significant and nonsignificant correlation coefficients, respectively. Error bars are 95% confidence intervals computed with the *r.con* function in the *psych* package in R, which uses a Fisher z-transformation to compute intervals around the estimate as a function of the sample size (Fisher, 1921; Revelle, 2018).

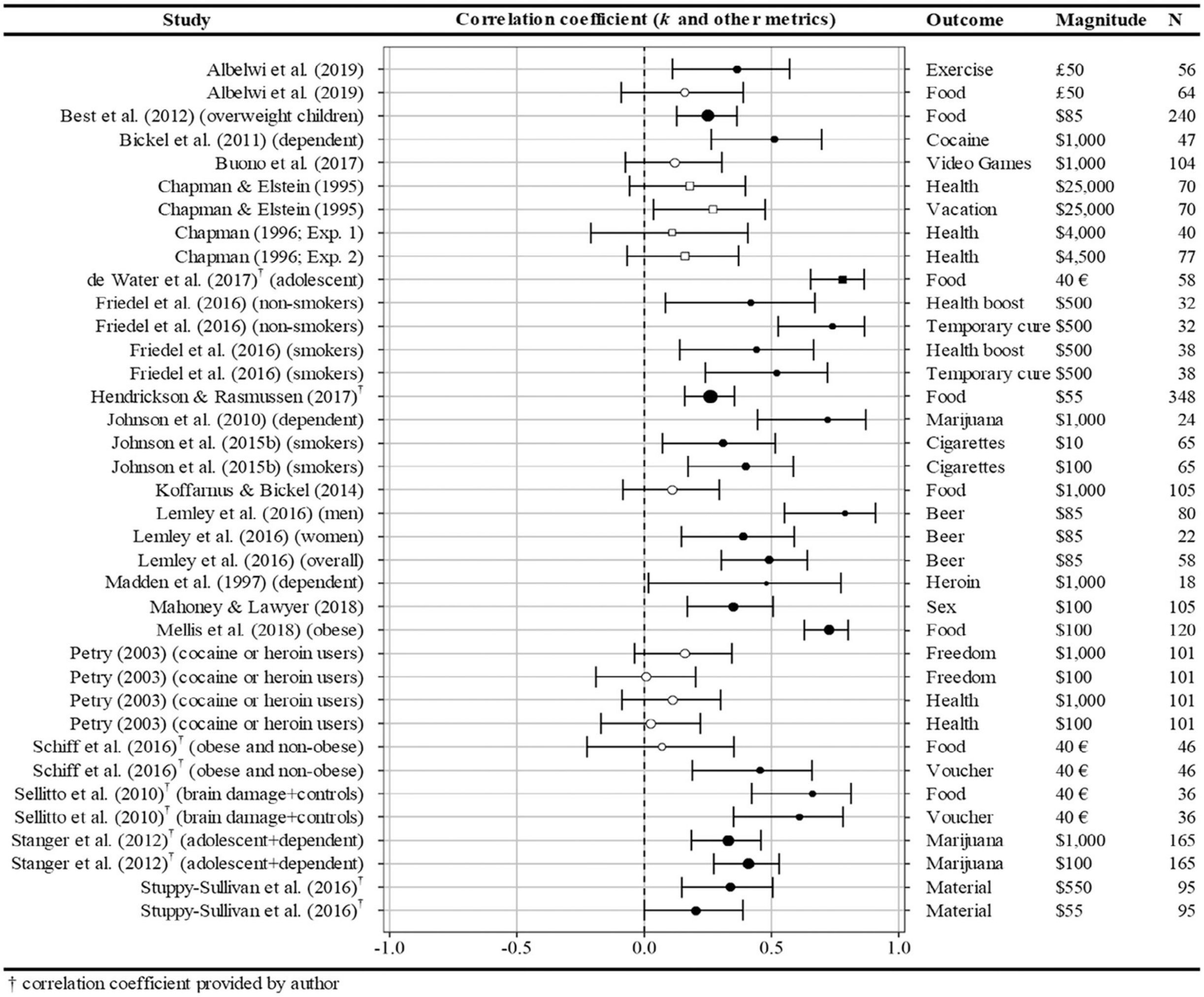


Figure 5. Correlations between AUC for monetary outcomes and nonmonetary outcomes.

Note. Details as in Figure 4.