Behavioural Processes 149 (2018) 8–15

Contents lists available at ScienceDirect

Behavioural Processes

journal homepage: www.elsevier.com/locate/behavproc

Comparison of potentially real versus hypothetical food outcomes in delay and probability discounting tasks

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ARTICLE INFO

Keywords:
Delay discounting
Food
Food discounting
Impulsivity
Potentially real outcome

ABSTRACT

Much of the research on human delay and probability discounting involves the use of hypothetical outcomes, in which participants indicate preferences for outcomes but do not receive them. Research generally shows that hypothetical and potentially real outcomes are discounted at similar rates. One study, however, shows that potentially real cigarettes are discounted more steeply than hypothetical cigarettes in smokers, calling into question the generality of the finding that potentially real and hypothetical money are discounted at similar rates. Using a within-subject design, we tested the extent to which potentially real and hypothetical monetary (Experiment 1) and food-related (Experiment 2) outcomes were discounted at similar rates. We found mixed results for monetary outcomes, in that potentially real outcomes were discounted more steeply than hypothetical outcomes when all participants were included; however, this effect disappeared when only systematic responders were used. In addition, potentially real and hypothetical monetary outcomes were significantly correlated. For food-related outcomes, we found robust and consistent effects that potentially real and hypothetical food outcomes are discounted similarly and that they correlate strongly. Generally, these findings suggest that using hypothetical outcomes generate similar levels of discounting, in particular for food, which is useful for researchers interested in characterizing food-related impulsivity.

1. Introduction

Delay discounting refers to the tendency for an outcome to lose value as the delay to its receipt increases (Ainslie, 1975; Madden and Johnson, 2010; Rachlin, 1995) and is considered a behavioral process that is a facet of impulsivity (Bickel et al., 1999; Bickel and Marsch, 2001; Green et al., 1994). Relative to controls, higher levels of delay discounting (i.e., impulsivity) have been observed in cigarette smokers (e.g., Bickel et al., 1999), cocaine-dependent (e.g., Heil et al., 2006), heroin-dependent (e.g., Kirby et al., 1999), and obese individuals (e.g., Fields et al., 2011; Hendrickson and Rasmussen, 2013; Jarmolowicz et al., 2014; Rasmussen et al., 2010; Weller et al., 2008). Given that excessive delay discounting is associated with a wide-range of health-related conditions, it is considered a trans-disease process (Bickel and Mueller, 2009; Bickel et al., 2012).

Delay discounting is assessed by presenting choices between a smaller outcome that is immediately available vs. a larger outcome available after a delay (e.g., "Would you prefer $9 now or $10 in a day?" Most choose the large amount to this question). A pattern of preferences for smaller, sooner outcomes are considered impulsive and a pattern of preferences for larger, later outcomes are considered self-controlled (Bickel and Mueller, 2009; Bickel et al., 2012).

Delayed outcomes also inherently include the property of uncertainty. For example, if a person chooses $100 after a year, there is a question of whether the outcome will still be available after this period of time elapses. Therefore, some researchers conceptualize probability discounting as a separate, though related process to delay discounting (Green et al., 1999; Holt et al., 2003; Myerson et al., 2003). Probability discounting, which measures sensitivity to uncertainty, refers to the extent to which an outcome loses its value as the odds against receiving that outcome increase.

In measuring probability discounting, an individual is asked to make choices between smaller, certain outcomes vs. larger, less probabilistic outcomes (e.g., "Would you prefer $3 for sure or $10 with a 50% chance of receiving that outcome"). Individuals who consistently prefer less probabilistic outcomes are characterized as risk averse and those who prefer them are considered risky (Green et al., 1999; Estle et al., 2007; Lawyer et al., 2011; Rasmussen et al., 2010).

Typically in both delay and probability discounting studies using humans, hypothetical outcomes are used for assessing choices; that is, participants do not actually receive the outcome associated with the choice (Madden et al., 1997; Odum et al., 2006; Rasmussen et al.,

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https://doi.org/10.1016/j.beproc.2018.01.014
Received 7 August 2017; Received in revised form 8 November 2017; Accepted 18 January 2018

2010). There are good reasons for this. In studies using money, giving real outcomes to participants is cost-prohibitive and in some cases unrealistic (e.g., thousands of dollars). In addition, when using immediately consumable items like food, each receipt of a food reward may alter the establishing operations (or motivation) for food, thereby potentially confounding the study.

Nonetheless, researchers have considered the possible limitations of the use of hypothetical outcomes with discounting procedures (Baker et al., 2003; Johnson and Bickel, 2002). For instance, individuals may discount hypothetical outcomes differently than real outcomes, which would limit the utility of hypothetical outcomes. To address these concerns, researchers have compared discounting for hypothetical outcomes to those that are *potentially real*. For potentially real outcomes, researchers instruct participants to make each choice as if it were for a real outcome because they will actually receive one of the choices that they make during or after the discounting task. Rates of discounting for hypothetical and potentially real outcomes can then be compared to assess the extent to which discounting processes are similar across outcome type.

Using a within-subjects design, Johnson and Bickel (2002) were the first to compare delay discounting for hypothetical vs. potentially real monetary outcomes. They found that hypothetical and potentially real outcomes were discounted at similar rates with six participants – that is, there were no differences between them. Madden et al. (2003) replicated this study using a larger sample size ($n = 20$) and separated the hypothetical and potentially real tasks by a 20-min interval to reduce carry-over effects. This study also revealed no differences in hypothetical and potentially real monetary outcomes. Matusiewicz et al. (2013) also investigated the extent to which rates of delay and probability discounting for hypothetical vs. potentially real outcomes were similar using equivalence testing and found that, for both delay and probability discounting, hypothetical and potentially real outcomes were discounted at similar rates. Subsequent research comparing rates of discounting for hypothetical vs. potentially real outcomes has been conducted and has resulted in similar conclusions with monetary outcomes in typical populations (Madden et al., 2004), as well as drug-dependent populations (Baker et al., 2003; Lawyer et al., 2011).

To date, only one study (to our knowledge) has investigated hypothetical vs. potentially real outcomes with outcomes other than money. Green and Lawyer (2014) reported on potentially real vs. hypothetical comparisons with cigarettes as the outcome in a sample of smokers. The authors first replicated that discounting rates did not differ between hypothetical vs. potentially real monetary outcomes. However, potentially real cigarettes were discounted at a steeper rate for both delay and probability discounting than hypothetical cigarettes. There are a number of possible reasons for this finding. One, it may be that outcomes that are specifically related to the population of interest (i.e., cigarettes with cigarette smokers) generate these differences. Two, the finding may also have to do with the immediately consumable nature of these outcomes (i.e., cigarettes are more immediately consumable than money).

The current study had two aims. First, to replicate previous work, we tested the extent to which delay and probability discounting for money differed as a function of hypothetical or potentially real outcome type. Second, we tested the extent to which delay discounting for food differed as a function of hypothetical or potentially real outcome type. Importantly, in this study we used three types of statistical information to answer these questions. The first was the extent to which there are significant differences between the two types of outcomes, which can be assessed in within-subjects designs by a dependent samples *t*-test. This type of information is limited, however, in the sense that failing to reject the null hypothesis does not lead to a conclusive statement about whether data from two variables are similar. That is why the second type of statistical information is critically important – equivalence testing, which determines the extent to which two variables are statistically equivalent (Matusiewicz et al., 2013). Finally, correlations describe the extent to which the two types of variables (outcomes, in this case) are related (i.e., as one increases, so does the other), though not necessarily equivalent. We reported all three in this study.

Table 1
Mean and standard deviation for demographic and health variables across entire sample for money discounting.

	Total ($N = 40$) Mean (SD)	Hypothetical	Potentially Real	*p* value
Age	22.85 (8.97)			
% Female	80%			
% Caucasian	77.5%			
% Income < $10,000	10%			
% Smokers	8%			
Time since last meal		9.83 (5.77)	9.76 (5.75)	$p = 0.44$
Time since last snack		7.25 (3.35)	9.76 (5.75)	$p = 0.002$
Subjective Hunger		58.84 (28.33)	56.22 (26.94)	$p = 0.065$
Estimated IQ	103.58 (6.33)			
DAST	1.28 (1.04)			
Audit	1.61 (2.10)			

2. Study 1

The first study is a systematic replication of previous research that examined differences and similarities in hypothetical vs. potentially real outcomes in delay and probability discounting for money using a within-subjects design.

2.1. Method

2.1.1. Participants

Forty college students (80% female) from Idaho State University enrolled in introductory psychology classes were recruited via SONA participant pool database. Participants were an average age of 22.85 ($SD = 8.97$) years old and 77.5% were Caucasian. Researchers instructed participants not to eat for at least four hours prior to the session and not to drink anything for at least two hours prior to the session. Participants were compensated for participation with course credit. Table 1 describes participant demographics.

2.1.2. Delay and probability discounting for money

A computerized program (see Richards et al., 1999 for details) pseudo-randomly presented questions in which the participant chose between smaller, sooner vs. larger, delayed outcomes (delay discounting) or smaller, more certain vs. larger, less certain outcomes (probability discounting). The monetary amount varied between $1–$10 and delays were varied between 1–365 days; the larger, later amount was held constant at $10. For example, the participants were presented with the question, "Would you rather have $9 now or $10 after 1 day?" (most choose the larger, delayed option). The smaller, sooner amount was systematically decreased until the participant reversed his or her preference (e.g. chooses the immediate outcome). From this, an indifference point was generated for that delay that was the median value of the two smaller, sooner options that flanked the indifference point. Indifference points were determined in the same manner for all of the delays (1, 2, 30, 180, and 365 days). The same procedure was used to generate indifference points across 5 different probabilities (10%, 25%, 50%, 75%, and 90%). Probability and delay discounting questions were intermingled in the program. This discounting task has been utilized in other studies (e.g., Rasmussen et al., 2010; Hendrickson et al., 2015).

2.1.3. Self-report measures

Participants were asked to complete a series of pencil-and-paper questionnaires about demographics (e.g. age, gender, ethnicity, religious affiliation, annual income), as well as information regarding health practices (e.g. smoking, alcohol use, drug use, dietary habits, and exercise habits). In addition, participants were asked to complete a Subjective Hunger Questionnaire on which they reported hours since last full meal, hours since last snack, and level of hunger (rated from 0 to 100). Estimated I.Q. was quantified using the Shipley Institute of Living Scale (Zachary, 1986).

2.1.4. Procedure

The procedure was based on those of Johnson and Bickel (2002) and Madden et al. (2003). Using a within-subject design, participants completed both a delay and probability discounting task for hypothetical and potentially real outcomes. The order of outcome type (hypothetical or potentially real) was counterbalanced across subjects. Prior to the delay discounting tasks, each participant completed a Subjective Hunger Questionnaire. Next, the participant read the instructions for the assigned discounting task, for example, the hypothetical outcome condition, which was as follows:

> "In the task that follows you will be asked to make decisions between some amount of money that you receive immediately or after a delay. For instance, you may be asked a question such as, "Would you prefer $3 now or $10 after 1 hour" or "Would you prefer $3 that is certain or $10 with a 50% chance." In this task, you will not receive the reward that you choose, but we want you to make your decisions as if you would actually receive that reward. The choices you make are up to you."

Following the completion of the first discounting task, participants completed three-digit addition and subtraction problems for 20 min. After 20 min elapsed, participants completed a second Subjective Hunger Questionnaire. For the potentially real outcome version of the discounting task, they were presented the following script:

> "In the task that follows you will be asked to make decisions between some amount of food that you receive immediately or after a delay. For instance, you may be asked a question such as, "Would you prefer $3 now or $10 after 1 hour" or "Would you prefer $3 that is certain or $10 with a 50% chance." In this task, you will receive one randomly selected reward that you choose. Thus, each choice has the chance for being selected. At the end of the session, you will draw one number from a bag. Each number represents a given trial. After you pick the number, I will find the choice you made for that trial and you will receive that choice. For the questions that ask about delay, if you chose the immediate outcome, you will receive it at the end of the session. If you chose the delayed outcome, you will be asked to return to the lab to obtain the outcome. For the questions that involve probability, if you select the probabilistic alternative, you will draw a chip from a bag to determine if you receive the reward or not. If the trial you selected was for a certain outcome, you will receive that outcome at the end of the session. Thus, you will have the chance to receive up to one real reward, based on your responses. Remember, the choices you make are up to you."

Participants then completed the Shipley Institute of Living scale (I.Q.) and the demographics questionnaires. Finally, the outcome that the participant received for the potentially real condition was determined. The participants first selected a slip of paper from a bag that indicated if the selected trial would be from the delay or probability discounting questions. The second slip of paper indicated the specific trial associated with the outcome that s/he would receive. If the participant chose the probability discounting alternative, the specific trial from the probability discounting questions was determined by drawing a slip of paper from a second bag. If, for the selected trial, the participant chose a certain outcome, s/he was informed that s/he would receive that outcome. If, on the other hand, the participant chose a probabilistic outcome for that trial, s/he was presented with a bag of poker chips. In this bag, there were two different colors of poker chips and the distribution of each color corresponded with the probability. For instance, if the probability was 50%, the bag contained 5 poker chips that were green and 5 poker chips that were red. Selecting a green poker chip resulted in obtaining the outcome and selecting the red poker chip resulted in receiving no outcome. In reality, the drawings were set up such that each individual only received $1 of an Amazon.com gift card in order to minimize expenses; however, the participants were not aware of this. After receiving the $1 outcome and being compensated with course credit, the participant was dismissed.

2.1.5. Analysis

Indifference points for the delay discounting task were assessed for systematic responding using Johnson and Bickel's (2008) algorithm. The algorithm defines nonsystematic responding by two primary criteria. First, if an indifference point is greater than the indifference point that precedes it by 20% or greater (i.e., $2) it is deemed nonsystematic. Second, if the final indifference point is not less than the first indifference point by at least 10% of the larger, delayed outcome (i.e., $1) it is deemed non-systematic.

Delay discounting was assessed by the hyperbolic discounting function (Mazur, 1987; McKerchar et al., 2009). Indifference points for each delay were plotted against delay for each participant and the equation was fit to the data:

$$V = A/(1 + bD) \quad (1)$$

where V is the indifference point, A is the larger later outcome, D is the delay to the outcome, and b is a free parameter that represents the rate of discounting. In most instances, the value of the delayed outcome plunges hyperbolically as delay to its receipt increases and the free parameter b value indicated the degree of sensitivity to delay (i.e., steeper discounting) and, therefore, levels of impulsivity. Values were log-transformed due to skewed distributions, which is a common finding with calculations of k-values.

Probability discounting was assessed using the hyperbolic probability discounting function (Green et al., 1999) using the same range of monetary values ($1–$10), except instead of delay, the probabilities of receipt of the outcome were used. These included: 10%, 25%, 50%, 75%, and 90% for the larger outcome (the smaller was always 100%). Indifference points were plotted as a function of odds against receiving that outcome and assessed using the hyperbolic discounting function; b represented the rate of probability discounting, or risk aversion (Green et al., 1999). O was calculated with the following formula $[(1/p) - 1]$, where p represents the probability of obtaining the outcome and replaces the delay (D) variable in Eq. (1).

Because traditional null hypothesis statistical testing (e.g., t-tests) assess differences, not similarities, between group means, we investigated the extent to which hypothetical and potentially real b values were equal using equivalence testing (Lakens, 2017; Luzar-Stiffler and Stiffler, 2002). Analyses were performed on untransformed data as recommended by Luzar-Stiffler and Stiffler (2002). Equivalence tests were computed following Matusiewicz et al. (2013). According to this method, a ratio of the $\text{median}_{\text{real}}/\text{median}_{\text{hypothetical}}$ is determined for each measure of discounting. Next, 90% and 95% confidence intervals were computed around each ratio. Statistical equivalence is concluded if the following two criteria are met: (a) the 90% confidence interval must fall within the 0.80–1.25 equivalence region and (b) the 95% confidence interval must include the 1.0 value (Matusiewicz et al., 2013). The criteria that 0.80–1.25 region corresponds to equivalence was adopted from biomedical research as an acceptable level of bioequivalence according to the Food and Drug Administration (Luzar-Stiffler and Stiffler, 2002).

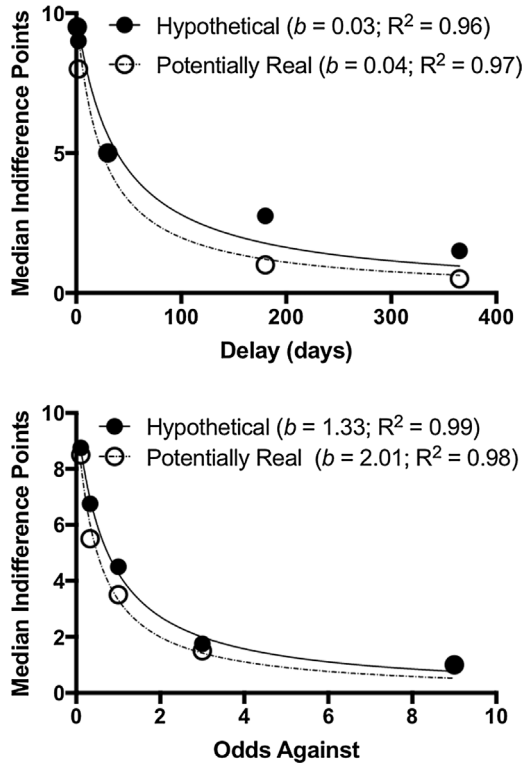

Fig. 1. Rates of delay and probability discounting for money. The top panels show delay discounting and the bottom panel shows probability discounting curves for hypothetical (black circles) and potentially real (white circles) money outcome types.

2.2. Results

2.2.1. Nonsystematic responding

For the hypothetical discounting task, 85% of the participants from the sample demonstrated systematic responding. For the potentially real discounting task, 80% of the sample demonstrated systematic responding. A χ^2 analysis revealed no significant difference between systematic responding as a function of outcome type (χ^2 (1) = 0.11, p = 0.75). For probability discounting, 92.5% of the participants demonstrated systematic responding for the hypothetical task and 87.5% demonstrated systematic responding for the potentially real task; these were not significantly different (t(39) = 0.30, p = 0.77). Data were analyzed using all data, as well as using only systematic responders. For analyses using only systematic responders, participants were classified as systematic responders if systematic responding was observed for both hypothetical and potentially real task types within each delay and probability discounting task.

2.2.2. Delay discounting for hypothetical versus potential real outcomes

The top panel of Fig. 1 shows discounting curves for hypothetical and potentially real outcome types. A dependent t-test was used to assess differences between log transformed b values derived from hypothetical (M = −1.64, SEM = 0.14) and potentially real (M = −1.45, SEM = 0.16) procedures and revealed a difference that approached significance, though did not meet the traditional $p < 0.05$ criterion, t (39) = −1.98, p = 0.06, d = −0.23. There was, however, a statistically significant correlation between hypothetical and potentially real b values, r = 0.79, $p < 0.001$ (when only systematic responders were included $p < 0.001$).

Regarding equivalence testing, Fig. 2 shows confidence intervals for monetary delay discounting. Hypothetical and potentially real outcomes were not significantly equivalent for b values, as the confidence interval of the median ratio fell outside the equivalence region.

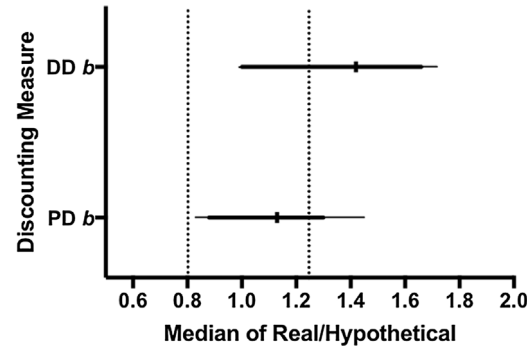

Fig. 2. Equivalence testing for delay and probability discounting for money shows the results from equivalence testing assessing hypothetical vs. potentially real outcomes for delay and probability discounting with money. The 0.80 and 1.25 equivalence bounds are marked by the horizontal dotted lines. Medians are represented by the hash mark. 90% confidence intervals of the median ratios are shown in the thicker lines and 95% confidence intervals of the median ratios are shown in the thinner lines. Statistical significance is reached when the (a) 90% confidence interval falls within the equivalence bounds and (b) if the 95% confidence interval includes 1.0.

2.2.3. Probability discounting hypothetical versus potential real outcomes

The bottom panel of Fig. 1 shows rates of probability discounting for hypothetical and potentially real outcome types. A dependent t-test on b values derived from hypothetical (M = 0.23, SEM = 0.08) and potentially real (M = 0.34, SEM = 0.09) outcomes revealed a difference in discounting values that approached significance, t (39) = −1.96, p = 0.06, d = 0.18. When only systematic responders were included, the p-value changed slightly (t(33) = −1.81, p = 0.08; d = 0.15). There was also a significant correlation between hypothetical and potentially real b values, r = 0.83, $p < 0.001$. For equivalence testing, Fig. 2 also shows that b values did not fall within the upper and lower bounds, and therefore did not meet the criteria for equivalence.

2.3. Discussion

In Study 1 we conducted a systematic replication of previous research (Johnson and Bickel, 2002; Baker et al., 2003; Madden et al., 2003; Madden et al., 2004; Lawyer et al., 2011) by assessing the extent to which delay and probability discounting for monetary outcomes differed as a function of using a hypothetical vs. a potentially real outcome type.

The degree of systematic responding according to Johnson and Bickel's (2008) algorithm was reported and it was found that systematic responding did not differ as a function of outcome type. We found that 80–93% of the sample demonstrated systematic responding, which is similar to ranges reported in the literature for hypothetical monetary and non-monetary outcomes (Berry et al., 2014; Green and Lawyer, 2014; Hendrickson and Rasmussen, 2013; Hendrickson et al., 2015; Johnson et al., 2010; Lawyer et al., 2011, Saville et al., 2010).

2.3.1. Delay discounting

In terms of differences between hypothetical and potentially real outcomes, we found mixed results. When examining the results of the t-tests conducted for discounting values (b), there was a statistical trend in which potentially real values were discounted more steeply than hypothetical values. When data from only systematic responders were included, this trend disappeared. In addition, the effect size associated with the statistical trend in which all participants were included was quite small (d = −0.23). Many of the previous studies that assessed differences in potentially real and hypothetical outcome types were published prior to the development of Johnson and Bickel's (2008) algorithm to identify nonsystematic responding, so it is impossible to compare differences between outcome types when all participants were included vs. only systematic responders. However, the results using all respondents would likely be appropriate comparisons to these other

studies.

Equivalence testing, which was conducted on all responders, revealed that hypothetical and potentially real outcome types were not statistically equivalent for both *b* values. This finding is counter to those of Matusiewicz et al. (2013) who found that hypothetical and potentially real money were equivalently discounted using this statistical test. There were a number of procedural differences that might have contributed to the disparity in the results between the two studies. First, Matusiewicz and colleagues used a different adjusting amount task that used higher larger, later values ($50) than the current study ($10). Second, Matusiewicz and colleagues used different delays to determine indifference for hypothetical (1 day–25 years) and potentially real (1 day–6 months) outcomes, whereas the current study used the same delay range for both outcome types (1 day–1 year). Further research is required to determine the extent to which procedural differences may play a role in real vs. hypothetical outcome differences.

2.3.2. Probability discounting

We found no strong statistically significant differences with *t*-tests between hypothetical and potentially real outcome types for *b* values. For *b* values, there were statistical trends with all participants and with systematic responders. This supports other research that has found no differences in probability discounting according to hypothetical or potentially real outcome type (Green and Lawyer, 2014); however, at least one exception has been noted (Lawyer et al., 2011). The equivalence testing, however, showed that real and hypothetical outcomes were not statistically equivalent. This finding is contrary to those of Matusiewicz et al. (2013), who found that probability discounting values resided completely within the upper and lower bounds of the equivalence interval (therefore, showing statistical similarity). It is noteworthy that Matusiewicz et al., used a different range of probabilities for hypothetical (1%–95%) and potentially real (1%–50%), whereas the current study used the same delay range for both outcome types (10%–90%). It is possible that these procedural differences between the two studies contribute to the disparate findings.

2.3.3. Correlations

Correlations can describe similarity between two variables, but the similarity can only be directional (i.e., as one increases, the other increases). In other words, two variables can be directionally similar without necessarily being equivalent. For delay and probability discounting, outcome types were significantly and strongly correlated. Correlation coefficients for delay discounting ranged from 0.78–0.79; those for probability discounting ranged from 0.71–0.83. These robust findings support previous research (Baker et al., 2003; Johnson and Bickel, 2002; Madden et al., 2003; Madden et al., 2004; Lawyer et al., 2011) that discounting for hypothetical and potentially real outcomes are directionally related; in other words, individuals who are impulsive for real monetary outcomes tend to also be impulsive for hypothetical monetary outcomes. These findings also have implications for the use of hypothetical outcomes as a reasonable proxy for real outcomes in delay discounting research.

2.3.4. General conclusion

Generally, the findings of this study offered mixed results for replicating the finding that hypothetical and potentially real money outcomes are discounted at a similar rate (Johnson and Bickel, 2002; Baker et al., 2003; Madden et al., 2003; Madden et al., 2004; Lawyer et al., 2011). The methods used in the study followed previous research, with the exception that participants were not informed that all potentially real outcome was rigged to always be $1. Because this procedure was held constant across participants and because the participant was informed about the real outcome that s/he received following the collection of discounting data this minor change to the procedure should not have affected discounting rates. As such, these findings highlight the importance of continuing to conduct research that characterizes factors (e.g. demographic, systematic responding) that affect rates of discounting for hypothetical and potentially real outcome types.

Given the recent interest in quantifying delay and probability discounting rates for consumable items (Estle et al., 2007; Friedel et al., 2014; Hendrickson and Rasmussen, 2013; Hendrickson et al., 2015; Rasmussen et al., 2010), we replicated the procedures used in Study 1 and extended them to investigate differences and similarities between rates of delay and probability discounting for hypothetical and potentially real food-related outcomes. Primarily, we were interested in the extent to which hypothetical and potentially real outcomes differed across the entire sample.

3. Study 2

Study 2 investigated differences and similarities hypothetical vs. potentially real outcomes in delay and probability discounting for food using a within-subjects design.

3.1. Methods

3.1.1. Participants

Undergraduate students (n = 119 college students; 59% female) from Idaho State University enrolled in introductory psychology classes were recruited for this study. Participants had a mean age of 22.52 (SD = 6.39) and 76.5% were Caucasian. Researchers instructed participants not to eat for at least four hours prior to the session and not to drink anything for at least two hours prior to the session. Participants were compensated for participation with course credit. Table 2 describes demographic characteristics for this sample.

3.1.2. Discounting tasks

A computerized food delay discounting task (Rasmussen et al., 2010; Hendrickson et al., 2015) was used. The program is identical to the one used in Study 1 (Richards et al., 1999) except that participants made choices between a smaller, sooner or certain vs. a larger, delayed or probabilistic number of bites of food that ranged between 1 and 10 (10 bites was held constant as the larger outcome) and the delays were 1, 2, 5, 10, and 20 h.

3.1.3. Self-report measures

Researchers collected information on demographics and estimated IQ similar to Study 1.

3.1.4. Procedure

The procedure used was generally similar to that of Study 1. Using a within-subject design, participants completed both a delay and

Table 2
Mean and standard deviation for demographic and health variables across entire sample for food discounting.

	Total (N = 119) Mean (SD)	Hypothetical	Potentially Real	p value
Age	22.52 (6.39)			
% Female	59%			
% Caucasian	76.5%			
% Income < $10,000	12.6%			
% Smokers	7.6%			
Time since last meal		9.77 (5.23)	9.76 (5.28)	p = 0.86
Time since last snack		8.12 (4.25)	8.12 (4.31)	p = 0.90
Subjective Hunger		60.55 (23.39)	61.93 (23.28)	p = 0.30
Estimated IQ	101.5 (7.77)			
DAST	1.24 (0.95)			
Audit	2.03 (2.26)			

probability discounting task for hypothetical and potentially real outcomes. The order of outcome type (hypothetical or potentially real) was counterbalanced across subjects. Prior to the discounting task, the participant was provided with five index cards, each one with the name and picture of a specific candy food item (all were calorically similar by weight) — Snickers®, Twix®, Reese's® Peanut Butter Cup, Hershey's® Chocolate Bar, or Baby Ruth®. The participant was instructed to select his/her most preferred food item from that list. Following the completion of the Subjective Hunger Questionnaire, researchers provided participants with 2 cm × 2 cm cube of the actual candy, which was designated as a "standard bite" for answering questions on the food discounting task (Note: for Hershey's® Chocolate Bar, two 2 × 2 cm pieces were used as one standard bite to better approximate caloric density of other candies used). The participants were instructed not to eat this food. Next, the participant read the instructions for the discounting task, for example, if s/he was first assigned to the hypothetical food condition, this script was presented:

> "In the task that follows you will be asked to make decisions between some amount of food that you receive immediately or after a delay. For instance, you may be asked a question such as, "Would you prefer 3 bites of a preferred food now or 10 bites of a preferred food after 1 hour" or "Would you prefer 3 bites of food that is certain or 10 bites of food with a 50% chance." In this task, you will not receive the reward that you choose, but we want you to make your decisions as if you would actually receive that reward. The choices you make are up to you."

After the first discounting task was complete, similar to Study 1, participants completed three-digit addition and subtract problems for 20 min and then a second Subjective Hunger Questionnaire. Then, they were given the script for the second discounting task (in this case, the potentially real condition), which read as follows:

> "In the task that follows you will be asked to make decisions between some amount of food that you receive immediately or after a delay. For instance, you may be asked a question such as, "Would you prefer 3 bites of a preferred food now or 10 bites of a preferred food after 1 hour" or "Would you prefer 3 bites of a preferred food that is certain or 10 bites of a preferred food with a 50% chance." In this task, you will receive one randomly selected reward that you choose. Thus, each choice has the chance for being selected. At the end of the session, you will draw one number from a bag. Each number represents a given trial. After you pick the number, I will find the choice you made for that trial and you will receive that choice. For the questions that ask about delay, if you chose the immediate outcome, you will receive it at the end of the session. If you chose the delayed outcome, you will be asked to return to the lab to obtain the outcome. For the questions that involve probability, if you select the probabilistic alternative, you will draw a chip from a bag to determine if you receive the reward or not. If the trial you selected was for a certain outcome, you will receive that outcome at the end of the session. Thus, you will have the chance to receive up to one real reward, based on your responses. Remember, the choices you make are up to you."

After the second discounting task, participants then completed the Shipley Intelligence Test and the demographics questionnaires. Finally, the outcome that the participant received was determined. The procedure for selecting the outcome was similar to that in Study 1, except that the participant received the amount of food corresponding to the slip of paper drawn. If the participant selected the delay discounting alternative, s/he received the value of an indifference point associated with a given delay that was determined by selecting a slip of paper. The participant was not informed that s/he would receive the indifference point value at the end of the session, rather than actually being asked to return to the laboratory to obtain the outcome. Following the real outcome determination, the participant was compensated with course credit and dismissed.

3.1.5. Analysis

As in study 1, data were first checked for systematic responding following Johnson and Bickel's (2008) algorithm. Next, delay and probability discounting was quantified using the hyperbolic equation (Eq. (1)) to calculate discounting rates. These values were log transformed to correct for skewness. Differences in hypothetical and potentially real outcomes were assessed using a dependent samples *t*-test and similarities were assessed using Pearson's correlation. In addition, equivalence was assessed using the method described for Study 1.

3.2. Results

3.2.1. Nonsystematic responding

For the hypothetical delay discounting task, 70.2% of the participants from the sample demonstrated systematic responding. For the potentially real delay discounting task, 71.0% of the sample demonstrated systematic responding; no differences between outcome type were found (χ^2 (1) = 0.02, p = 0.89). For both hypothetical and potentially real probability discounting tasks, 77.3% of the participants from the sample demonstrated systematic responding; no differences between outcome type were found (χ^2 (1) = 0, p = 0.99). Analyses were performed using all data, as well as data from systematic responders only.

3.2.2. Delay discounting for hypothetical versus potential real outcomes

The top panel of Fig. 3 shows discounting curves for hypothetical and potentially real food outcomes (Hypothetical log*k*: $M = -0.37$, SEM = 0.08; Potentially Real log*k*: $M = -0.33$, SEM = 0.08). There were no differences in hypothetical and potentially real *b* values for delay discounting ($t(118) = -0.54$, $p = 0.59$, $d = -0.04$). There was a statistically significant correlation between *b* values, $r = 0.62$, $p < 0.001$. When only systematic responders were included in the analysis, there was not a difference between discounting rates for

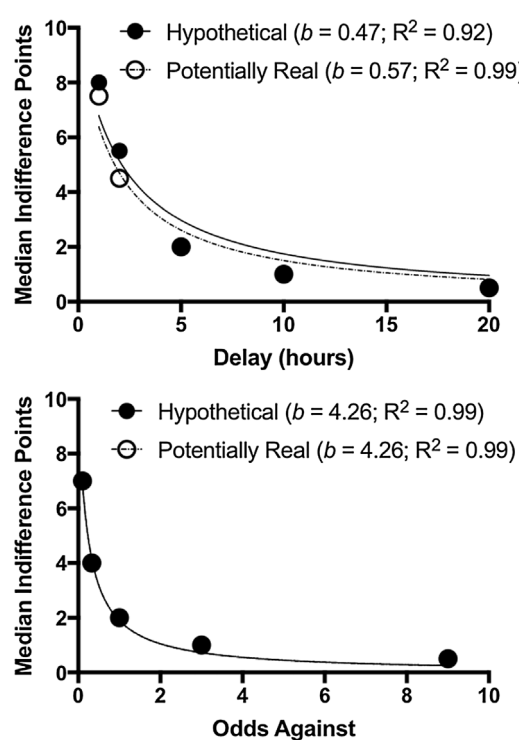

Fig. 3. Rates of delay and probability discounting for food. The top panels show delay discounting and the bottom panel shows probability discounting curves for hypothetical (black circles) and potentially real (white circles) food outcome types.

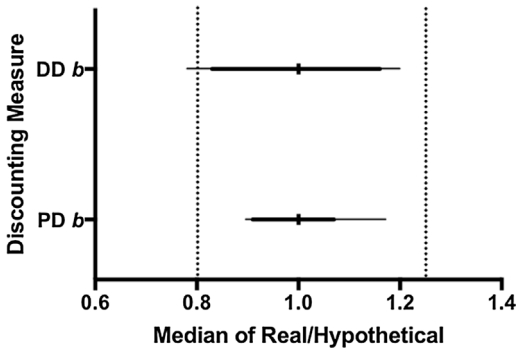

Fig. 4. Equivalence testing for delay and probability discounting for food shows the results from equivalence testing assessing hypothetical vs. potentially real outcomes for delay and probability discounting with food. The 0.80 and 1.25 equivalence bounds are marked by the horizontal dotted lines. Medians are represented by the hash mark. 90% confidence intervals of the median ratios are shown in the thicker lines and 95% confidence intervals of the median ratios are shown in the thinner lines. Statistical significance is reached when the (a) 90% confidence interval falls within the equivalence bounds and (b) if the 95% confidence interval includes 1.0.

hypothetical and potentially real outcomes, ($t(62) = -0.81$, $p = 0.42$, $d = -0.06$); however, the outcome types remained significantly correlated, $r = 0.63$, $p < 0.001$.

Fig. 4 shows confidence intervals used to test equivalence for delay discounting for food. For delay discounting, hypothetical and potentially real outcomes were significantly equivalent according to both equivalence criteria. That is, the 90% confidence intervals fell within the 0.80–1.25 equivalence region and the 95% confidence interval included 1.0.

3.2.3. Probability discounting for hypothetical versus potentially real outcomes

The bottom panel of Fig. 3 shows discounting curves for probability discounting. There were no significant differences between the two outcome types for b values ($t(118) = -0.04$, p = 0.97, $d = 0$). There were significant correlations between hypothetical and potentially real b values, $r = 0.67$, $p < 0.001$. When only systematic responders were included in the analysis, there were no differences in b values ($p > 0.49$; $d = 0.03$); however, outcome types remained correlated for b values ($r = 0.75$, $p < 0.001$). Fig. 4 also shows that confidence intervals for b values resided within the upper and lower bounds, indicating equivalence.

3.3. Discussion

In Study 2, we investigated the extent to which rates of delay and probability discounting for food differ as a function of hypothetical or potentially real outcome type. To our knowledge, this is the first study to examine differences in delay and probability discounting as a function of hypothetical or potentially real food outcomes. For both delay and probability discounting, *t*-tests indicated no differences between potentially real vs. hypothetical outcomes. This was the case when all participants were used or when only systematic responders were used in the analysis. Importantly, equivalence tests indicated that hypothetical and potentially real outcomes were discounted similarly. Finally, discounting rates for outcome type were significantly correlated. As such, the findings in Study 2 indicate that hypothetical and potentially real outcome types do not differ in terms of observed discounting rates.

The majority of the participants in Study 2 demonstrated systematic responding for both delay and probability discounting tasks (ranged from 70.2% to 77.3%). Previous research has reported between 81%–89% of the participants showed systematic responding for food discounting (Hendrickson et al., 2015). As such, patterns of systematic responding were lower, though close to previous research.

4. Conclusions

In this study, we examined the extent to which rates of discounting differed as a function of hypothetical vs. potentially real outcome types. In study 1, we found mixed evidence for differences between hypothetical and potentially real money. When all participants were included in the analysis, potentially real money was discounted more steeply than hypothetical money, and results from an equivalence test indicated that these outcome types were not discounted at equal rates. In addition, when only systematic responders were included, there were no differences between the two types of outcomes. Importantly, though, the outcome types were significantly and positively correlated for all discounting measures for all analyses.

We also found robust and consistent findings that potentially real and hypothetical food outcomes are discounted similarly. This was supported by null hypothesis testing and equivalence testing and whether all responders or only systematic responders were included. Moreover, the two types of outcomes were strongly correlated.

Funding

This work was supported by the INBRE Program [NIH Grant No. P20 GM103408] (National Institute of General Medical Sciences) and the Idaho State University College of Arts and Letters.

Acknowledgements

We thank Andra Cates, Bailey Perschon, Diana Simonson, and Luis Rodriguez for assisting with data collection.

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