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Further comparison of 5-trial adjusting delay and probability loss tasks over a wide range of amounts

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ABSTRACT

Researchers have recently developed brief methods to measure discounting. One brief method uses 5-trial adjusting-delay or -probability tasks. These tasks have provided similar rates of discounting to traditional tasks with monetary gains, but the accuracy with losses have been mixed. Differences in loss discounting across tasks may have been due to the amounts used in previous experiments. Therefore, we had undergraduate students (N = 93) complete two types of discounting tasks across losses ranging from $10 to $10 million. Consistent with previous research using traditional measures, discounting did not differ between tasks or across amounts used. 5-trial discounting tasks of losses provide similar rates of discounting compared to traditional adjusting amount tasks for both probability and delay.

1. Introduction

Humans often choose between outcomes that come at a delay, or with uncertainty. For example, engaging in physical activity may result in immediate physical discomfort, but delayed positive health outcomes. Alternatively, choosing to forego exercise may certainly be more comfortable, but also may increase the probability of long-term negative health outcomes. Given many health-related outcomes occur at a delay or with some probability, researchers have studied precisely how delay and probability influence choice (see McKerchar and Renda, 2012 for review).

Researchers use several methods to study the influence of delay or probability on choice (Madden and Johnson, 2010). One common method is an adjusting amount task. In these tasks, participants make a series of choices between two options. One option results in a smaller-sooner or smaller-certain amount (e.g., $50 right now; $50 for certain). The second option results in a larger-later or larger-uncertain amount (e.g., $100 in 1 month; 50% of getting $100). Following each choice, the amount of the immediate/certain option is adjusted up or down over 5–7 trials. The final adjustment is termed an indifference point and is the amount whereby the person is indifferent between receiving that amount of money right now/for certain, and receiving the larger amount of money at the specified delay/probability. This process is then repeated across 5–7 different delays or probabilities to the larger outcome and a series of indifference points obtained.

The indifference points are used to quantify the rate that delay or probability reduces commodity value. Often, this occurs by fitting a hyperbolic equation (Mazur, 1987) to the indifference points:

$$V = \frac{A}{(1 + \gamma\beta)} \tag{1}$$

In this equation, V is the subjective value of the outcome, A is the undiscounted amount of the outcome, β is the independent variable that leads to discounting (e.g., delay – delay discounting; odds against – probability discounting), and γ is a free parameter that describes how the value of an outcome reduces as a function of the delay or odds against (calculated as $(1\text{-}p)/p$). The robust finding to date is that the value of an outcome will decrease systematically as delay increases (delay discounting) or probability decreases (probability discounting; McKerchar and Renda, 2012).

Many choices in life involve outcomes that vary along multiple dimensions. But adding one additional dimension (e.g., asking about delayed and probabilistic outcomes rather than just delayed outcomes) exponentially increases the trials required to obtain indifference points (Cox and Dallery, 2016). For example, whereas 25 trials would be needed for the standard adjusting amount procedure (5 delays x 5 trials at each delay), 125 trials are needed for examining outcomes that are delayed and probabilistic (5 delays x 5 probabilities x 5 trials at each delay-probability combination; see – Cox and Dallery, (2016,2018) – for other complex choice scenarios that require upwards of 3000 trials). The time needed to complete more complex discounting tasks using adjusting amount procedures may become impractical or lead to decreased response quality from reduced focus or interest. As a result, researchers interested in complex discounting situations have needed new methods to measure discounting in fewer trials.

One example of a more efficient method is 5-trial adjusting-delay or -probability tasks (Cox and Dallery, 2016; Koffarnus and Bickel, 2014). Here, the amount of the immediate/certain alternative is fixed at half

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the delayed/uncertain alternative (e.g., $50 if the delayed/uncertain alternative is $100). Following each choice, the delay/probability to the larger outcome adjusts making it sooner or later (delay discounting), or more or less certain (probability discounting). The delay/probability adjusts for five trials and the final delay/probability provides the rate at which the outcome is discounted by 50% (effective delay of 50% – ED_{50}; effective probability of 50% – EP_{50}).

Adjusting amount and 5-trial adjusting-delay/probability tasks provide similar, but not equivalent, measures of discounting for gains. Although absolute rates of discounting have differed between adjusting amount and 5-trial adjusting delay/probability tasks using the same commodity and amount, estimates of delay and probability discounting gains are moderately-to-strongly correlated between the tasks (Cox and Dallery, 2016; Koffarnus and Bickel, 2014). In addition, discount rates using 5-trial adjusting delay tasks will change in expected directions across manipulations known to influence discounting using adjusting amount tasks (e.g., magnitude effect, domain effect – Koffarnus and Bickel, 2014).

Adjusting amount and 5-trial adjusting delay/probability tasks do not always provide similar discount rates for losses. For example, no trend in discount rates is typically observed across magnitudes using traditional discounting tasks (e.g., magnitudes $20 to $500,000 – Green et al., 2014). Similarly, no trend in probability discounting was observed between $10 and $1000 using 5-trial adjusting-probability tasks (Cox and Dallery, 2016). But, shallower delay discounting of losses was observed at $10 compared to $1000 using 5-trial adjusting-delay tasks (Cox and Dallery, 2016). Differences have been seen when comparing just two loss amounts using traditional discounting tasks (e.g., Fig. 7 – Green et al., 2014; Fig. 1 – Myerson et al., 2017). Thus, it is possible the magnitude effect observed for delayed losses (or the absence of a magnitude effect for probability losses) in previous research was the result of examining only two amounts using the 5-trial adjusting-delay/probability tasks.

The purpose of this experiment was to examine 5-trial adjusting-delay and -probability tasks over a wide range of monetary loss amounts. We hypothesized we would not observe a difference in discount rates across the range of magnitudes assessed. In addition, we hypothesized that rates of discounting would be moderately-to-strongly correlated between, and within, adjusting amount and 5-trial adjusting-delay/probability procedures.

2. Methods

2.1. Participants

93 participants were recruited from an undergraduate Psychology participant pool and randomly assigned to complete delay discounting tasks ($n = 47$) or probability discounting tasks ($n = 46$). Average age was 19; and, 32 and 31 participants in the delay and probability groups self-identified as female, respectively.

2.2. General session information

All experimental tasks were presented in a campus laboratory room on a desktop computer. Tasks were coded using Visual Basic 2015 Community Edition and were completed in a single 30-min session. Participants received one course credit for participation.

2.3. Probability loss

Each participant assigned to the probabilistic loss condition completed two types of discounting tasks. One was a longer adjusting amount task. The second was a 5-trial adjusting-probability task. Across both tasks, participants made choices between losing a small amount of money for sure (100%) and losing a large amount of money with some probability (e.g., 40%).

2.3.1. Adjusting amount task

The adjusting amount task always began by presenting the participant with a choice between (a) 100% chance of losing $500 or (b) a *P*% chance of losing $1000 (e.g., 40% chance of losing $1000). If participants chose the smaller-certain option, the amount of the smaller-certain option increased for the next trial (by $250). If participants chose the larger-uncertain option, the amount of the smaller-certain option decreased for the next trial. The amount of the certain option increased or decreased by $250, $125, $62.50, $31.25, and $15.62 after trials 1–5, respectively. The adjustment following the fifth trial was considered the indifference point for that participant.

Participants completed five blocks of the adjusting amount procedure resulting in five indifference points relative to $1000. Each sequence used a different probability of the larger outcome. Probabilities used were: 1%, 10%, 40%, 70%, and 95%. In addition, each participant completed three adjusting amount tasks. One involved the larger uncertain amount of $1000, as described. The other two tasks involved larger-uncertain amounts of $10, and $10,000,000. Thus, each participant completed 75 choice trials within adjusting-amount procedures. Discounting parameters were estimated using Microsoft Excel Solver.

2.3.2. 5-trial adjusting-probability task

The 5-trial adjusting-probability task always began by presenting the participant with a choice between (a) 100% chance of losing $500 or (b) 50% chance of losing $1000. If participants chose the smaller-certain option, the probability of the larger-uncertain choice decreased. If a participant chose the larger-uncertain option, the probability of the larger-uncertain option increased. The probability of the larger-uncertain option increased or decreased by 25%, 12.5%, 6.75%, 3.37%, and 1.18% on trials 1–5, respectively. The adjustment following the fifth trial was considered the probability at which the value of $1000 reduced by half ($EP_{50}$). The h parameter was estimated by dividing 1 by EP_{50} (Yoon and Higgins, 2008).

Participants in the probability group completed seven, 5-trial adjusting-probability tasks. Each task differed in the amount of the smaller-certain and larger-uncertain amounts. The larger-uncertain amounts used were: $10; $100; $1000; $10,000; $100,000; $1,000,000; and $10,000,000. The smaller-certain amount was always half of the larger-uncertain amount (e.g., $500 vs. $1000). Thus, each participant completed 35 choice trials within the 5-trial adjusting-probability procedures.

2.4. Delayed loss

Each participant assigned to the delayed loss condition also completed three adjusting amount tasks and seven, 5-trial adjusting-delay tasks (110 total choice trials). Across both tasks, participants made choices between losing a small amount of money immediately (0 delay) and losing a large amount of money after some delay (e.g., in 6 months).

2.4.1. Adjusting amount task

The adjusting amount task always began by presenting the participant with a choice between (a) losing $500 immediately or (b) losing $1000 in *Delay* (e.g., losing $1000 in 2 years). If participants chose the smaller-sooner option, the smaller-sooner option increased. If participants chose the larger-later option, the smaller-sooner option would decrease. The amount of the immediate option increased or decreased by $250, $125, $62.50, $31.25, and $15.62 on trials 1–5, respectively. The adjustment following the fifth trial was considered the indifference point.

Participants completed five blocks of the adjusting amount procedure resulting in five indifference points relative to the larger outcome. Each sequence involved a different delay the larger outcome would occur. Delays used were: 1 day, 1 week, 1 month, 1 year, and 5 years across the five blocks. Each participant completed three adjusting

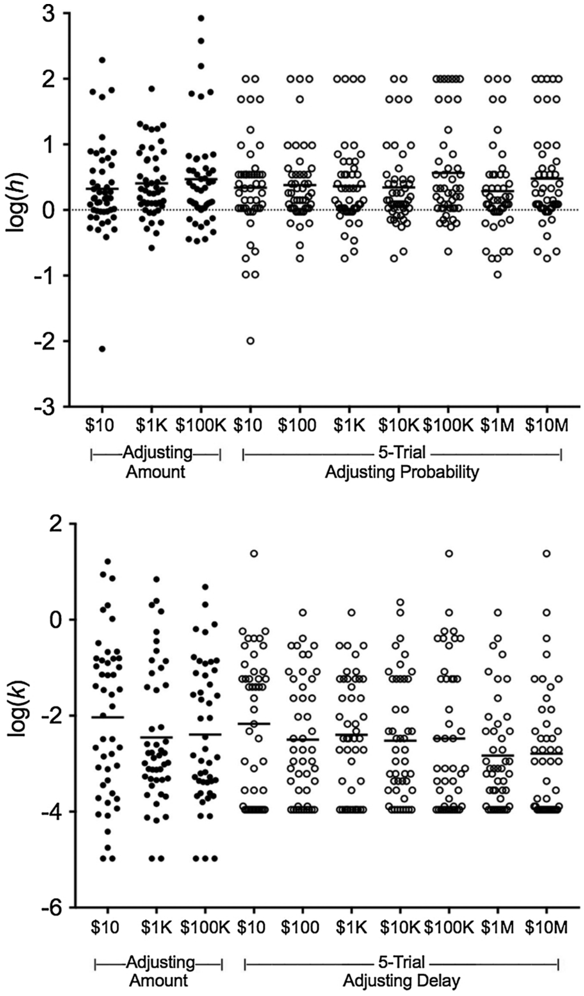

Fig. 1. Individual discounting parameters for participants in the probability group (top) and delay group (bottom). Closed data markers are discounting parameters from the longer adjusting amount tasks. Open data markers are discounting parameters from the 5-trial adjusting-delay/probability tasks. The line of central tendency represents the group average.

amount tasks using larger-later amounts of $10, $1000, and $10,000,000. Rates of delay discounting were calculated in an identical manner to the probability discounting group with the exception of substituting delay to the outcome (*D*) for odds against in Eq. (1).

2.4.2. 5-trial adjusting-delay task

The 5-trial adjusting-delay tasks began by presenting the participant with a choice between (a) losing $500 immediately or (b) losing $1000 in 3 weeks. If participants chose the smaller-sooner option, the delay to the larger-later option decreased (e.g., to "losing $1000 in 1 day"). If a participant chose the larger-later option, the delay to the larger-later option increased (e.g., to "losing $1000 in 2 years") in an identical manner as previous studies using 5-trial adjusting delay tasks and up to a maximum of 25 years (e.g., Cox and Dallery, 2016; Koffarnus and Bickel, 2014). The delay to the larger-later option continued to increase or decrease from the delay on the previous trial for 5 trials. The adjustment following the fifth trial was considered the delay at which the value of $1000 reduced by half ($ED_{50}$). The *k* parameter was estimated by dividing 1 by ED_{50}.

Participants in the delay group completed seven adjusting-delay tasks. Each task differed in the amount of the smaller-sooner and larger-later amounts. The larger-later amounts used were: $10; $100; $1000; $10,000; $100,000; $1,000,000; and $10,000,000.

2.5. Ordering of tasks

The ordering of the adjusting-amount tasks and 5-trial adjusting-delay or -probability tasks were presented randomly to each participant.

2.6. Data analysis

Two-way repeated measures ANOVAs were conducted using IBM SPSS Statistics, version 24.0. Discounting parameters were log-transformed before statistical comparisons to normalize the distribution (Yoon and Higgins, 2008).

2.7. Results and discussion

This experiment explored whether we would observe a trend in loss discounting over a wide range of amounts using 5-trial adjusting-delay and -probability tasks. Participants also completed adjusting amount discounting tasks as a replication check. Each participant completed seven 5-trial adjusting-delay/probability tasks and three adjusting amount tasks.

Fig. 1 shows the individual rates of discounting for the two groups. First, we conducted a two-way repeated measures ANOVA for each group with discounting task and magnitude as the main factors. The probability group did not show different discount rates based on task type ($F(1, 46) = 0.18$; $p = 0.67$; $\eta p^2 = 0.004$); outcome amount ($F(2, 92) = 2.54$; $p = 0.09$; $\eta p^2 = 0.05$); nor interaction between task and amount ($F(2, 92) = 0.34$; $p = 0.72$; $\eta p^2 = 0.01$). Discount rates were moderately correlated between the two tasks at all three equivalent magnitudes ($r = 0.46$, 0.47, 0.53 for $10, $1000, and $100,000; $p < 0.001$ for all).

The delay group did not show different discount rates based on task type ($F(1, 46) = 0.02$; $p = 0.88$; $\eta p^2 = 0.001$); outcome amount ($F(2, 92) = 2.66$; $p = 0.08$; $\eta p^2 = 0.06$); nor interaction between task and amount ($F(2, 92) = 0.17$; $p = 0.86$; $\eta p^2 = 0.003$). Discounting was moderately correlated between the two tasks at all three magnitudes of equivalent value ($r = 0.49$, 0.47, 0.58 for $10, $1000, and $100,000; $p < 0.001$ for all).

These findings are consistent with previous research on discounting of losses using adjusting amount tasks (Green et al., 2014). We did not observe any systematic change in loss discounting based on outcome amount. However, it is possible that a larger sample size would have detected a statistically significant magnitude effect in the delayed loss group. In sum, these data suggest adjusting amount and 5-trial adjusting delay/probability discounting tasks provide similar, but not necessarily equivalent, measures of discounting.

The findings of the current study indicate these procedures can be used in lieu of adjusting amount tasks where needed. This may be important for two reasons. First, rate of discounting has been correlated with several clinically problematic behaviors (e.g., Reynolds and Schiffbauer, 2004; Holt et al., 2003). Second, rate of probability discounting has been shown to predict treatment adherence (Jarmolowicz et al., 2016). Embedding these tasks within a battery of assessments more easily allows clinicians to target individuals for preventive measures and better predict who may need added interventions for treatment adherence.

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