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Nonmonotonicity in Absolute and Relative Preferences for Real and Imagined Rewards

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NONMONOTONICITY IN ABSOLUTE AND RELATIVE PREFERENCES FOR REAL AND IMAGINED REWARDS

By

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Abstract

A key assumption in many studies examining valuation of reward is that participants' preferences for various rewards are meaningfully, monotonically ordered with respect to other possible rewards. However, this assumption has not been systematically tested. Two studies consisting of 74 undergraduates from the University of Nevada, Las Vegas and 122 community members demonstrated nonmonotonic reward preferences when provided with parametrically varied reward magnitudes. Although deficits in reward processing are believed to be a key feature of depression, depressed participants were more willing to work hard for rewards and exhibited more monotonic reward preferences than non-depressed participants. Relative to imaginary rewards, participants were more willing to work for real money and spent more time making decisions when there was a possibility of earning real money.

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Chapter 1: Literature Review

The degree to which people are willing to work harder for larger rewards is an important measure to consider when studying individual differences in "wanting". It is typically believed that individuals display greater wanting and are willing to work harder for larger, more meaningful rewards. As a result, a key assumption in many studies examining valuation of reward is that participants' preferences for various rewards are meaningfully, monotonically ordered with respect to other possible rewards (Treadway, Bossaller, Shelton, & Zald, 2012; Treadway, Buckholtz, Schwartzman, Lambert, & Zald, 2009; Franzen & Brinkmann, 2015). However, this assumption has not been systematically tested. If this assumption is not correct, it limits the certainty of the conclusions that one can make in regards to studies operating under the assumption. The current study attempts to standardize previous studies examining reward processing by providing parametrically varied reward magnitudes. Additionally, previous studies have not examined how absolute and relative reward differences affect choice behavior or decision response times. The new information provided by the current study aims to identify differences between normative and depressed reward processing to help better understand the features of depression and guide future studies.

The current studies examine calculated reward preferences amongst pairs of monetary rewards that differ in magnitude and required effort. These preferences are examined in undergraduate students, community members with depression, and community members without depression. As previously noted, there is a disparity of research in regards to the general population's reward preferences. Additionally, previous research on reward preferences of individuals with depression have focused on their non-calculated, "gut", reactions to rewards rather than their ability to reason amongst different possible rewards (Treadway et al., 2009).

Cognitive Biases, Reward Types, and Reward Valuation

Reward valuation does not exist in a vacuum independent of factors outside the reward itself. Several factors influence and may distort the valuation of a reward's magnitude relative to other available rewards. For instance, numerical biases can interfere with an individual's ability to accurately assign value to a monetary reward when given a choice of multiple monetary rewards. One of these biases is the *whole number bias.* The whole number bias refers to comparing the whole number components of fractions rather than the entire fractions themselves, therefore making an individual more likely to believe 1/8 is larger than 1/2 because 8 is larger than 2 or that 7/10 is larger than 4/5 because 7 is larger than 4. Though this phenomenon was originally studied in children, adults have been shown to exhibit this bias as well (DeWolf & Vosniadou, 2015). The whole number bias is so influential that even expert mathematicians, defined as individuals with a Master's level math degree or higher, exhibit the bias when the fractions being compared share either a common numerator or common denominator (Obersteiner, Van Dooren, Van Hoof, & Verschaffel, 2013).

Another bias that interferes with accurate monetary valuation is *the distance effect*. The distance effect refers to the tendency for more errors in quantity judgment to occur as the similarity in magnitude increases amongst the numbers being compared. For example, people are less likely to recognize that the number 44 is smaller than the number 51 than that the number 44 is smaller than the number 67. In addition to the distance effect, the whole number bias becomes most prominent when the fractions being compared are very close in magnitude (DeWolf & Vosniadou, 2015). For example, people are less likely to recognize that 5/8 is less than 6/7. An exception to the distance effect is when decimal quantities are being compared; an increase in quantity judgment errors occurs as the orthographic similarity of decimals become more alike,

rather than their magnitude (Cohen, 2010). For example, a quantity judgment error is more likely to occur when comparing the values .325 and .352 than when comparing the values .325 and .348.

Individuals' overall math abilities impact their ability to precisely value monetary rewards. Jones, Price, and Randall (2011) found that college students commonly make errors in basic mathematics; such errors include fraction to percentage conversion, solving for missing values, basic arithmetic, and appropriate use of order of operations. Some of the difficulties involving basic mathematics may abate over time, as repeated exposure to the same math equations leads to a lesser error rate and a faster reaction time (Charness & Campbell, 1988). Therefore, valuation accuracy may be affected if the same reward choices are presented several times.

The nature of the potential reward affects one's valuation of the reward. Imaginary rewards are often used in studies examining wanting due to resource constraints. Miyapuram, Tobler, Gregorios-Pippas, and Schultz (2012) demonstrated that participants rate imagined rewards and real rewards as equally pleasant. These findings suggest that both real and imaginary rewards share the same valuation systems. Additionally, both types of rewards display similar patterns of delay discounting. Therefore minimal difference should be observed between reward types even when the reward is not immediately administered (Johnson & Bickel, 2002). Nevertheless, caution is required when using imaginary rewards, as individual differences in delayed reward discounting may be dependent on one's ability to imagine the reward accurately. Those who are able to represent the reward with greater vividness display less discounting over time (Hakimi & Hare, 2015).

Cognition and Reward Valuation

Reappraisal of a reward, a form of cognitive affect regulation, is associated with decreased pleasant anticipation, decreased reward seeking behavior, and decreased reward encoding (Staudinger, Erk, & Walter, 2011). When individuals generate value predictions associated with gains, the predictions are subsequently compared with actual outcomes to reveal potential prediction errors; observed prediction errors often result in an adjustment of valuation (Yacubian, Gläscher, Schroeder, Sommer, Braus, & Büchel, 2006).

Valuation is also affected by other current and past rewards. Although people may be presented with the same choice, different neural processes handle the method in which they process the choice. This is observed in the orbitofrontal cortex (OFC), a region of the brain associated with reward valuation; OFC neurons show increased activation for relative rewards, but not absolute rewards (Elliott, Agnew, & Deakin, 2008). When making a decision relative to other choices, individuals tend to accurately adjust their choice preference when information changes. By contrast, individuals who make decisions based on absolute values tend to not adjust their preferences when new information is provided (Teodorescu, Moran, & Usher, 2015). Although money is a secondary reward, a "common reward circuit" in the brain is activated by both primary and secondary rewards (Sescousse, Caldú, & Segura, 2013).

The Role of Effort in Reward Discounting and Overvaluation

Another influence on reward valuation is reward discounting. Reward discounting refers to the tendency for individuals to attribute less value to a reward if it is not made immediately available. One situation in which discounting occurs is when a delay is present before receiving a reward. Humans tend to discount future rewards as a hyperbolic function: There is a steep discount when the delay is short, but as the length of time increases, the value decreases at a much slower rate (Johnson, Herrmann, & Johnson, 2015; Scheres, de Water, & Miles, 2013; Zarr

& Brown, 2014). Another factor is knowing the probability of obtaining a reward. As the probability of obtaining a reward decreases, the reward is discounted hyperbolically (Greenhow, Hunt, Macaskill, & Harper, 2015). Required physical effort also induces discounting. Humans tend to discount effort-based rewards parabolically: There is a small discount when minimal effort is required, but as the effort required increases, the value decreases at a much faster rate (Hartmann, Hager, Tobler, & Kaiser, 2013).

Not all monetary rewards are discounted by effort at the same rate. Larger monetary amounts are discounted at a lesser rate than smaller amounts (Ostaszewski, Bąbel, & Swebodziński, 2013). When a reward is subjected to both a temporal delay and lesser probability, the discounting effects of both are multiplicative rather than additive (Vanderveldt, Green, & Myerson, 2015). However, when increased effort is required to obtain a reward, individuals attribute greater value to the reward (Ma, Meng, Wang, & Shen, 2014). Although individuals attribute greater value to rewards obtained through increased effort, they prefer easier tasks to obtain the same reward despite attributing less value to it (Alessandri, Darcheville, Delevoye-Turrell, & Zentall, 2008; Nishiyama, 2014). The increased valuation of rewards obtained after greater effort has been exerted is often explained as *cognitive dissonance*, or *the justification effect*; this phenomenon has been observed in human and nonhuman animals alike and is used to personally justify why a person has put forth increased effort (Klein, Bhatt, & Zentall, 2005).

Effort's effects on decision-making are also observable through individuals' preferences. Individuals devalue effort-based rewards in a manner similar to delayed rewards (Prévost, Pessiglione, Météreau, Cléry-Melin, & Dreher, 2010). As a result, it is likely that individuals will stop valuing effort-based rewards much sooner than they would non-effort-based rewards.

Kurniawan, Guitart-Masip, Dayan, and Dolan (2013) used fMRI to demonstrate that individuals are sensitive to effort even when initially valuing rewards. Neural representations of anticipated actions respond to anticipated demands, but they are insensitive to anticipated values of rewards. Greater levels of effort results in a discount of outcome valuation, which aids in estimating a net value that considers both cost and benefit.

Depression and Reward Processing

Depression is a clinical state that entails substantial deficits in wanting and reward processing. Specifically, those diagnosed with major depressive disorder demonstrate less motivation to obtain possible rewards (Ubl, Kuehner, Kirsch, Ruttorf, Diener, & Flor, 2015; Whitton, Treadway, & Pizzagalli, 2015). Additionally, those diagnosed with depression demonstrate a lower heart rate in response to potential rewards and also report having less motivation to obtain rewards than healthy controls (Franzen & Brinkmann, 2015).

Effort expenditure for rewards task. The Effort Expenditure for Rewards Task (EEfRT) is a measure of effort-based decision-making and reward valuation, allowing researchers to examine wanting in normal and clinical populations (Treadway et al., 2009). The task consists of multiple trials in which participants choose either an easy task for one dollar, or a hard task for amounts varying from 1.24 to 4.30 dollars. These widely varying amounts were chosen so that participants would not be likely to formally compute expected values for each choice during a trial. The easy task requires participants to press a button with the index finger of their dominant hand 30 times in 7 seconds; the hard task requires participants to press a button with the little finger of their non-dominant hand 100 times in 21 seconds. Participants are not guaranteed to win money on each trial, instead they are informed of the probability of winning the differing monetary amounts for each successful trial: 88%, 50%, or 12%. Once the monetary

values and probability are presented, participants are given 5 seconds to choose either the easy or the hard task. If a participant does not specify a choice, they are randomly assigned to one of the tasks. When each task begins, a bar fills with each button press to represent the participants' progress towards reaching the required number of presses. After each trial, the participant is informed whether the trial was a success or failure. After the participant has engaged in the task for 20 minutes, two trials' winnings are chosen based on the displayed probabilities, and participants are rewarded that amount.

The EEfRT was initially used to examine differences in wanting among individuals with anhedonia, but it has more recently been expanded to look at individuals with Major Depressive Disorder (MDD; Treadway, Bossaller, Shelton, & Zald, 2012). The authors found that individuals with MDD chose the high effort, high reward tasks less often than individuals in the control group. Additionally, the MDD group showed less sensitivity to information regarding the magnitude of the rewards and the probabilities of receiving the rewards than the control group. Thus, in addition to having findings that are in agreement with the results of a memory task used by Franzen and Brinkmann (2015) that individuals with MDD demonstrate motivational deficits, Treadway et al. (2012) found that individuals with MDD also demonstrate decision-making deficits.

Decision Making and Depressive Realism

Treadway et al.'s (2009) EEfRT was designed to explicitly emphasize gut-level decision making over calculated decision making by presenting non-parametric monetary pairs. Although the EEfRT gives a glimpse into potential differences in affective wanting, it does not allow for the examination of potential differences in planned decision-making.

Depressive realism is a term that describes the tendency for individuals with Major Depressive Disorder to make more accurate inferences than individuals without Major Depressive Disorder (Moore & Fresco, 2012). Not all studies support depressive realism, Allan, Siegel, and Hannah (2007) explain the phenomenon as non-depressed individuals being overly optimistic when given information, whereas depressed individuals are more pessimistic and require more evidence before they believe something will occur. In regards to perceptual accuracy Moore and Fresco's (2012) meta-analysis found a small effect of depressive realism across 75 studies.

Depressive realism also has an effect on non-clinical populations in regards to time estimation. Those with higher scores on the Beck Depression Inventory (BDI), higher scores indicating higher levels of depressive symptomatology, demonstrated more accuracy when asked to estimate the amount of time passed from an initial point. Participants in this study consisted of non-clinically depressed college students. Previous studies have not found an effect of depressive realism on time estimation in clinical populations (Kornbrot & Grimwood, 2013).

Non-depressed and depressed individuals demonstrate differences in decision-making when making decisions regarding money, health, and interpersonal relationships for themselves versus others. (Garcia-Retamero, Okan, & Maldonado, 2015). Non-depressed individuals demonstrate a bias of making riskier decisions for themselves than they do for others. They also show a bias by predicting that others would make riskier decisions than they would make for themselves. Depressed individuals demonstrated a bias towards making less risky decisions for others than they would for themselves, but they did not demonstrate a bias when predicting others' decisions (Garcia-Retamero, Okan, & Maldonado, 2015). The differences demonstrated between non-depressed and depressed individuals in regards to predicting others' decisions

provide support for depressive realism in regards to money, health, and interpersonal relationships.

Chapter 2: Current Studies

Study 1

The first study examined the assumption in previous studies that reward preferences are meaningfully and monotonically ordered using a modified EEfRT that is described below. I analyzed reward choices and reaction times of the choices of undergraduates who completed the task for imaginary monetary rewards. This pilot study was designed to better understand differences in absolute and relative reward valuation across time.

Hypotheses

Although there is some evidence, such as the above mentioned biases, that suggests the contrary, I predicted that participants' choices would be monotonically and meaningfully ordered; participants would be more willing to exert greater effort as the discrepancy between monetary reward values increases. Additionally, participants would make faster decisions in regards to reward preference as they progress through the experiment due to their increased familiarity with the available choices.

Study 2

The second study built on the first, using real monetary rewards to identify potential deficits in reward preferences of individuals with depression relative to healthy controls. Additionally, the second study allows for a comparison of reward preferences between imaginary and real monetary rewards when analyzed in regards to the first study. Specifically, I analyzed reward choices and reaction times of choices of community members who engaged in the same modified EEfRT.

Hypotheses

Once again although some phenomena, such as depressive realism, suggest the contrary, I predicted similar results to Treadway et al. (2009), such that depressed participants would make fewer accurate decisions in regards to reward magnitude than individuals with the control group; that is, unlike the control group, individuals in the depression group would not make monotonically ordered choices. Based on previous work, I also expected depressed participants to choose the hard task less frequently than control participants. Additionally, participants in both groups would make faster decisions in regards to reward preference as they progress through the experiment due to becoming aware of the available choices.

Chapter 3: Method

Study 1

Participants

Participants consisted of 74 (67% female) undergraduate students from the University of Nevada, Las Vegas via the Sona system. The mean participant age was 21.2 years. In total, 50.7% of participants were White, 16% were African American, 10.6% were Asian, 11.9% were Pacific Islander, and 5.3% identified as some other racial group; 29.3% of participants identified as Hispanic.

Participants were excluded if they did not complete at least 50% of the trials (n = 1) or had a trial success rate below 60% across the entire experiment (n = 8) due to the task being designed to have a success rate of approximately 90%. Individual trials were excluded (n = 11) if the choice reaction time for the trial was 2.5 standard deviations larger from a given participant's mean reaction time. This left a total of 65 participants and 3,860 trials.

Modified EEfRT

Before each trial, participants were given the option to engage in an easy trial for less money or a hard trial for more money. The fiscal pairs were as follows: $1.00 vs. $0.50, $1.50 vs. $0.50, $2.00 vs. $0.50, $4.00 vs. $0.50, $1.50 vs. $1.00, $2.00 vs. $1.00, $4.00 vs. $1.00, $2.00 vs. $1.50, $4.00 vs. $1.50, and $4.00 vs. $2.00. Participants encountered each choice six times throughout the experiment, for a total of 60 choice trials in the experiment. The order of the pairs that participants encountered were determined by a fixed run order that was dependent on their assigned participant number. There were also 30 "forced" trials interspersed throughout the experiment in which participants were presented with an easy or hard trial without being given a choice of which one they would like to engage in. The forced trials were

included to collect psychophysiological data in regards to specific levels of reward. Data from these trials were not analyzed here, as there was no choice that the participant made.

Easy trials were completed by pressing either the number line 1 (for left-handed participants) or the number pad 5 (for right-handed participants) key 18 times in four seconds while using the index finger of their dominant hand. The hard trials were completed by pressing the opposite key 58 times in twelve seconds while using the little finger of their non-dominant hand. When each task began, an on-screen timer appeared and a bar would fill with each button press to represent the participants' progress towards reaching the required number of presses. If the bar was completely filled before the timer reached zero, then the trial was considered successful.

Besides using pairs of five fixed amounts that varied for both easy and hard tasks to examine choice strategies, we modified the orthodox EEfRT in three additional ways. We shortened the durations of both the easy and hard tasks to lessen the potential for fatigue. Our task lasted 30 minutes instead of 20 minutes to allow for collection of psychophysiological as well as behavioral data. Finally, we removed the probability manipulation to make the task easier for participants in anticipation of using it in less numerically adept community samples.

Procedures

Participants read and signed a consent form before being allowed to participate in the study. They were then informed that the money they could earn during the experiment was conceptual, and that they would receive no financial reward regardless of choices. Participants were provided with a computer keyboard and sat 100 cm away from a 19" LED monitor that displayed instructions and information regarding the task. They completed the EEfRT for 30

minutes as part of a larger battery of tasks that took approximately two hours in total. After all tasks were completed, participants received course credits for their participation.

Study 2

Participants

Participants consisted of 122 (55% female) community members recruited from an ad on Craigslist; the ad specified that after an initial over-the-phone interview, those who qualified would be invited to the lab for a 4 hour study and be compensated $100 with the opportunity to win as much as an additional $12 for completing a series of tasks. The sample included 90 individuals currently experiencing a major depressive episode and 32 healthy controls. Individuals diagnosed with a psychotic disorder or who have ever had a manic episode were excluded due to differences in reward referencing not caused by a depressive episode. The mean participant age was 33.7 years. In total, 55.0% of participants were white, 22.5% were African American, 15.8% were Asian, 2.5% were Pacific Islander, 0.8% were Native American or Native Alaskan, and 3.7% identified as some other racial group; 12.4% of participants identified as Hispanic.

Participants were excluded if they did not complete at least 50% of the trials (n = 2 in the depressed group, n = 1 in the control group) or had a trial success rate below 60% across the entire experiment (n = 5 in the depressed group, n = 1 in the control group) due to the task being designed to have a success rate of approximately 90%. Individual trials were excluded (n = 159) if the choice reaction time for the trial was 2.5 standard deviations larger from a given participant's mean reaction time. This left a total of 83 participants in the depression group, 30 participants in the control group, and 6,531 trials.

Measures

Inventory of Depressive Symptomatology (Clinician-Rated; IDS-C). The IDS-C is a 30 item, clinician administered assessment. It assesses the severity of depression symptoms and addresses all criterion of a major depressive episode specified by the Diagnostic and Statistical Manual of Mental Disorders - 4th edition (DSM-IV). All questions pertain to the seven days prior the assessment, with the exception of weight loss and gain questions, which pertain to the prior 14 days. Rush, Gullion, Basco, Jarrett, and Trivedi (1996) demonstrated good internal consistency for a sample of healthy controls and adult outpatients with Major Depressive Disorder with a Cronbach's alpha of .94; our sample's IDS-C total scores also had a Cronbach's alpha of .94. The maximum score possible on the IDS is 84. Individuals who scored between 0 and 7 were placed into the control group; for comparison, scores at or between 0 and 11 represent a level of symptomatology consistent with no depression (Rush et al., 1996). Individuals who scored at 24 or greater were placed into the depression group. For comparison, scores between 24 and 36 indicate moderate levels of depressive severity, scores between 37 and 46 represent severe depression, and scores 47 or above index very severe (Rush et al., 1996). Those who scored at or between 8 and 23 did not qualify to participate in the study.

Structured Clinical Interview I for DSM-IV-Text Revision: Mood Episodes. The Structured Clinical Interview I for DSM-IV-Text Revision (SCID-I; First, Spitzer, Gibbon, & Williams, 2002) is a semi-structured clinical interview designed to assess the diagnostic criteria for disorders listed in the DSM-IV-TR. In this study, we used the Mood Episodes module to screen out individuals who met criteria for any current or past manic episodes.

Procedures

The procedure of study 2 was almost identical to those of study 1 with a few exceptions. First, participants were grouped according to their depression scores, but they were not informed

of their group membership. Second, participants were able to win real money. Before beginning the task, participants were informed that three trials would be chosen at random, regardless of whether they are successes or failures, and they received the winnings for only those three trials. There was no significant difference between the amounts won by individuals in the depressed group (M = \$5.36, SD = \$2.82) and individuals in the control group (M = \$4.37, SD = \$2.67); $t(118) = 1.70$, $p = .091$.

Chapter 4: Data Analysis

Study 1

In four separate Generalized Estimating Equations (GEEs), I examined the dependent variables of a) the proportion of hard choices made and b) participants' reaction time to make each choice. For each dependent variable, data across fiscal pairs were analyzed by both the a) absolute Difference (i.e., hard – easy reward value) and b) relative Ratio (i.e., hard/easy reward value) between reward options as within-subjects factors. Examining pairs by their absolute difference assumes that individuals are making valuations between monetary amounts via subtraction. Examining pairs by their relative ratio assumes that individuals are making valuations between monetary amounts via division. Each GEE also included whether trials were in the first or second Half of the experiment to examine how participants may have changed their behavior across the experiment. Because not every pair had identical numbers of trials within it, we elected to aggregate data over halves of the experiment instead of analyzing data trial by trial.

Each GEE used a factorial model and an unstructured covariance matrix to analyze the data. I used a binomial distribution with a logit link function for GEEs analyzing the proportion of hard choices. For GEEs analyzing reaction times, we used a normal distribution with a logarithmic link for reaction times to correct for the significant skewness of 2.96 before transformation of absolute differences and 2.87 before transformation of relative ratios of these data. Participant number was the subject factor.

Significant results were followed up by sequential Sidak comparisons for each individual monetary pair to control Type I error. Half x Difference and Half X Ratio interactions were only compared by different monetary pairs within a specific half of the experiment and the same pair across halves of the experiment. A target α level of .05 was used for all analyses.

Preliminary Analyses

To ensure that no single value was associated with excessively high or low choices of the easy or hard task, I examined the Easy x Hard value interaction in a Generalized Estimating Equation (GEE) with the proportion of hard choices made as the dependent variable. As displayed in Table 1, there was a significant interaction effect of easy choice value and hard choice value, Wald $\chi^2(3) = 13.4$, $p = .004$. This substantially qualified the main effects of easy choice value, Wald $\chi^2(3) = 45.3$, $p < .001$ and hard choice value, Wald $\chi^2(3) = 49.0$, $p < .001$. The observed pattern of results suggests that that no one monetary value is driving participants' choices.

Absolute Difference

Choices. There was a significant Difference x Half interaction, Wald $\chi^2(6) = 32.3$, $p > .001$. This substantially qualified the main effects of absolute differences, Wald $\chi^2(6) = 64.6$, $p < .001$, and half of the experiment, Wald $\chi^2(1) = 36.8$, $p < .001$. The relevant pairwise comparisons with a sequential Sidak adjustment are represented in Figure 1; significant differences among means are detailed below.

In the first half of the experiment, the hard task was chosen less often with pairs differing by \$0.50 than pairs differing by \$1.50, and \$2.50, and more, Wald $\chi^2(1)$s > 16.6, *p*s < .005. The hard task was chosen less often during pairs differing by \$1.00 than pairs differing by \$1.50, and \$2.50 and more, Wald $\chi^2(1)$s > 13.9, *p*s < .010. Unexpectedly, the hard task was chosen more often during pairs differing by \$1.50 than those differing by \$2.00, Wald $\chi^2(1) = 11.1$, $p = .03$. The hard task was chosen less often during pairs that differed by \$2.00 than pairs that differed by \$3.00 and more, Wald $\chi^2(1)$s > 13.7, *p*s < .019.

In the second half of the experiment, the hard task was chosen less frequently in pairs that differed by \$0.50 and \$1.00 than in pairs that differed by \$3.50, Wald $\chi^2(1)$s > 11.6, *ps* < .046. When comparing the same absolute differences across halves of the experiment, the hard task was chosen more frequently in pairs that differed by \$1.50, first half of the experiment compared to the second half of the experiment, Wald $\chi^2(1)$s = 33.8 *p*s < .001.

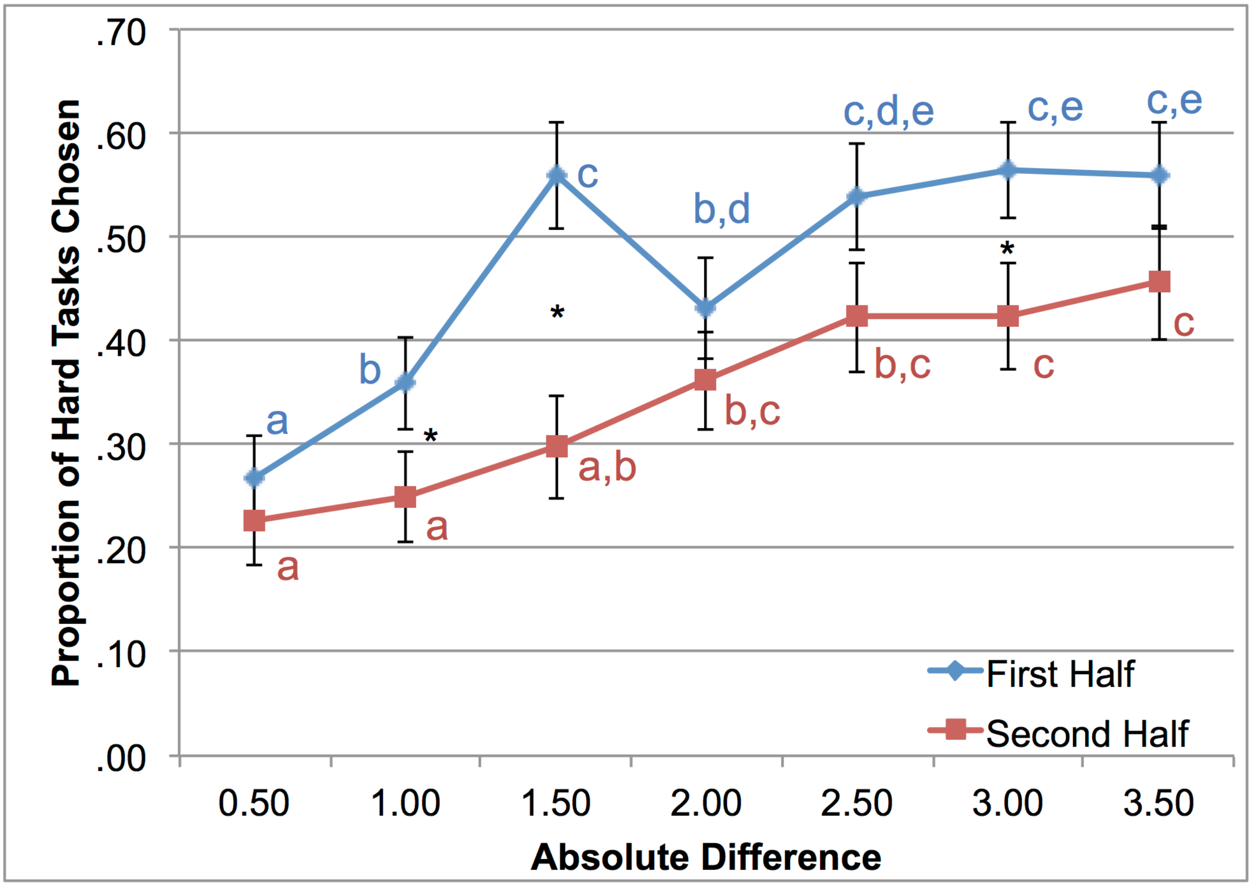

Figure 1. Choices of undergraduates by absolute differences. Absolute differences not sharing a common letter within a half represents a significant difference of choices. Asterisks denote significant differences between halves at a specific absolute difference.

Reaction time. There were significant main effects of Difference, Wald $\chi^2(6) = 26.7$, $p < .001$, and Half, Wald $\chi^2(1) = 45.0$, $p < .001$, on choice reaction time. However, there was no

Difference x Half interaction, Wald $\chi^2(6) = 7.00$, $p = .321$. The pairwise comparisons with a sequential Sidak adjustment of these results are displayed in Figure 2 and summarized below.

Throughout the entire experiment, reaction times of choosing either the easy or hard task were faster for pairs that differed by \$3.00 than pairs that differed by \$0.50 and \$1.00, Wald $\chi^2(1)$s > 9.5, ps $< .04$. Additionally, pairs in the second half of the experiment were chosen faster than pairs in the first of the experiment, Wald $\chi^2(1)$s > 54.3, $p < .001$.

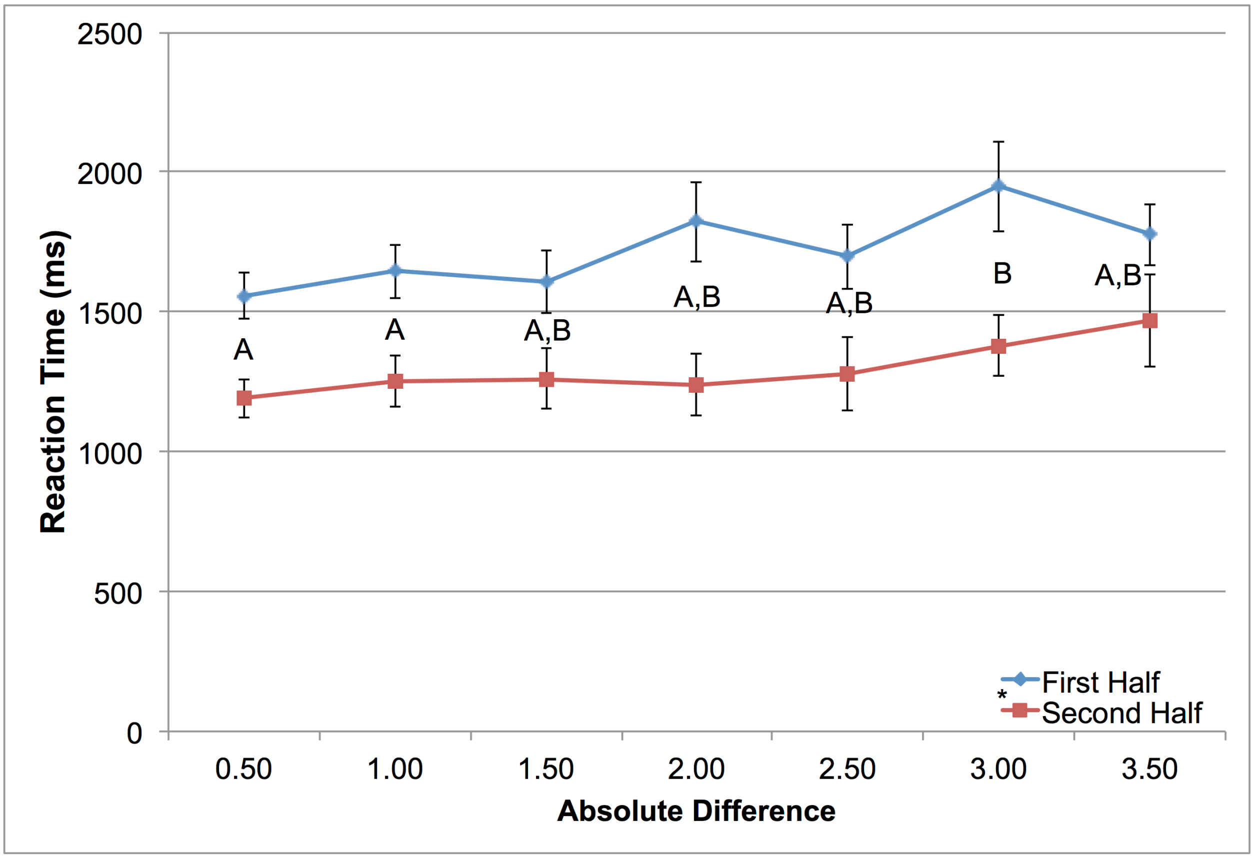

Figure 2. Reaction times of undergraduates by absolute differences. Absolute differences not sharing a common letter represent a significant difference of choices. The asterisk denotes a significant difference between halves.

Choices. There was a significant Ratio x Half interaction, Wald $\chi^2(6) = 29.7$, $p < .001$, which substantially qualified the main effects of relative Ratio, Wald $\chi^2(6) = 66.9$, $p < .001$, and

Half of the experiment, Wald $\chi^2(1) = 38.7$, $p = .001$. The relevant pairwise comparisons with a sequential Sidak adjustment are represented in Figure 3 and summarized below.

In the first half of the experiment, the hard task was chosen less often with pairs that had ratios of 1.33 than pairs that had ratios of 2.67 and more, Wald $\chi^2(1)$s > 12.8, *p*s < .02. The hard task was chosen less often with pairs that had ratios of 1.50 than pairs that had ratios of 2.00 and more, Wald $\chi^2(1)$s > 11.9, *p*s < .02. The hard task was chosen less often with pairs that had a ratio of 2.00 than pairs that had ratios of 2.67, 4.00, and 8.00, Wald $\chi^2(1)$s > 25.0, *p*s < .001. The hard task was chosen less often with pairs that had ratios of 3.00 than pairs that had ratios of 4.00 Wald $\chi^2(1)$s > 15.1, $p = .004$.

In the second half of the experiment, the hard task was chosen less often with pairs that had ratios of 1.33, 1.50, and 2.00 than pairs that had ratios of 2.67 and 8.00, Wald $\chi^2(1)$s > 18.4, *p*s < .001. Although unexpected, the hard task was chosen more often with pairs that had ratios of 2.67 than pairs that had ratios of 3.00 and 4 Wald $\chi^2(1)$s > 11.8, *p*s < .031.The hard task was chosen less often with pairs that had ratios of 3.00 than pairs that had ratios of 8.00, Wald $\chi^2(1)$s = 11.5, $p = .024$.

Across halves of the experiment, the hard task was chosen more often with pairs that had ratios of 2.00, 3.00, and 4.00 in their first-half appearances compared to their second-half appearances, Wald $\chi^2(1)$s > 12.1, *p*s < .024.

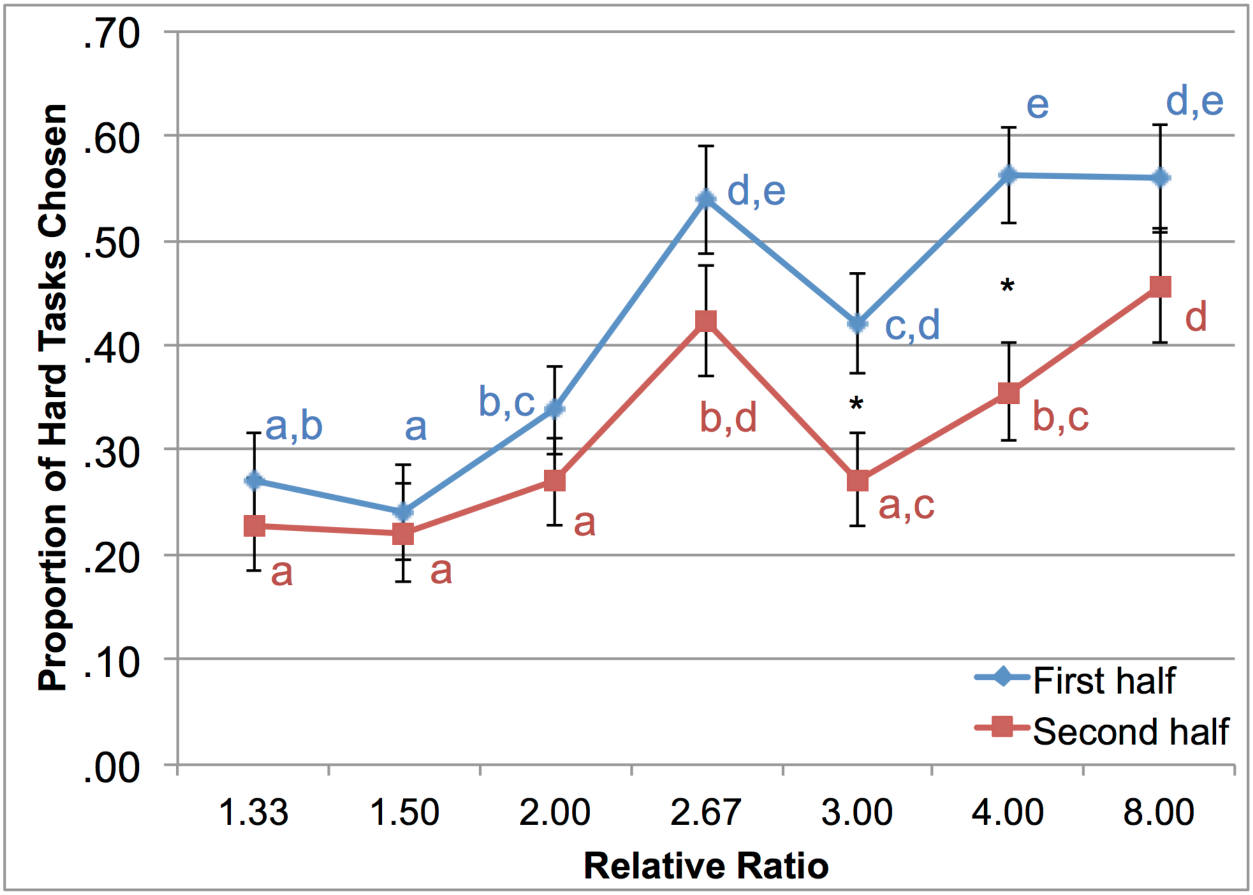

Figure 3. Choices of undergraduates by relative ratio. Relative ratios not sharing a common letter within a half represents a significant difference of choices. Asterisks denote significant differences between halves at a specific relative ratio.

Reaction time. There was a significant Ratio x Half interaction, Wald $\chi^2(6) = 12.8$, $p = .046$, which substantially qualified the main effects of relative Ratio, Wald $\chi^2(6) = 36.3$, $p < .001$, and Half of the experiment, Wald $\chi^2(1) = 52.6$, $p < .001$. The relevant pairwise comparisons with a sequential Sidak adjustment are represented in Figure 4 and summarized below.

In the first half of the experiment, pairs with ratios of 1.33 were chosen faster than pairs with ratios of 3.00 and 4.00, Wald $\chi^2(1)$s > 19.6, *p*s < .002. There were no significant differences among ratios in the second half of the experiment, Wald $\chi^2(1)$s < 6.06, *p*s > .002. Across halves of the experiment, reaction times for choosing either the easy or hard task were faster for pairs

with ratios of 2.00, 2.67, 3.00, and 4.00 in the second half of the experiment than the first half, Wald $\chi^2(1)$s > 20.3, *ps* < .002.

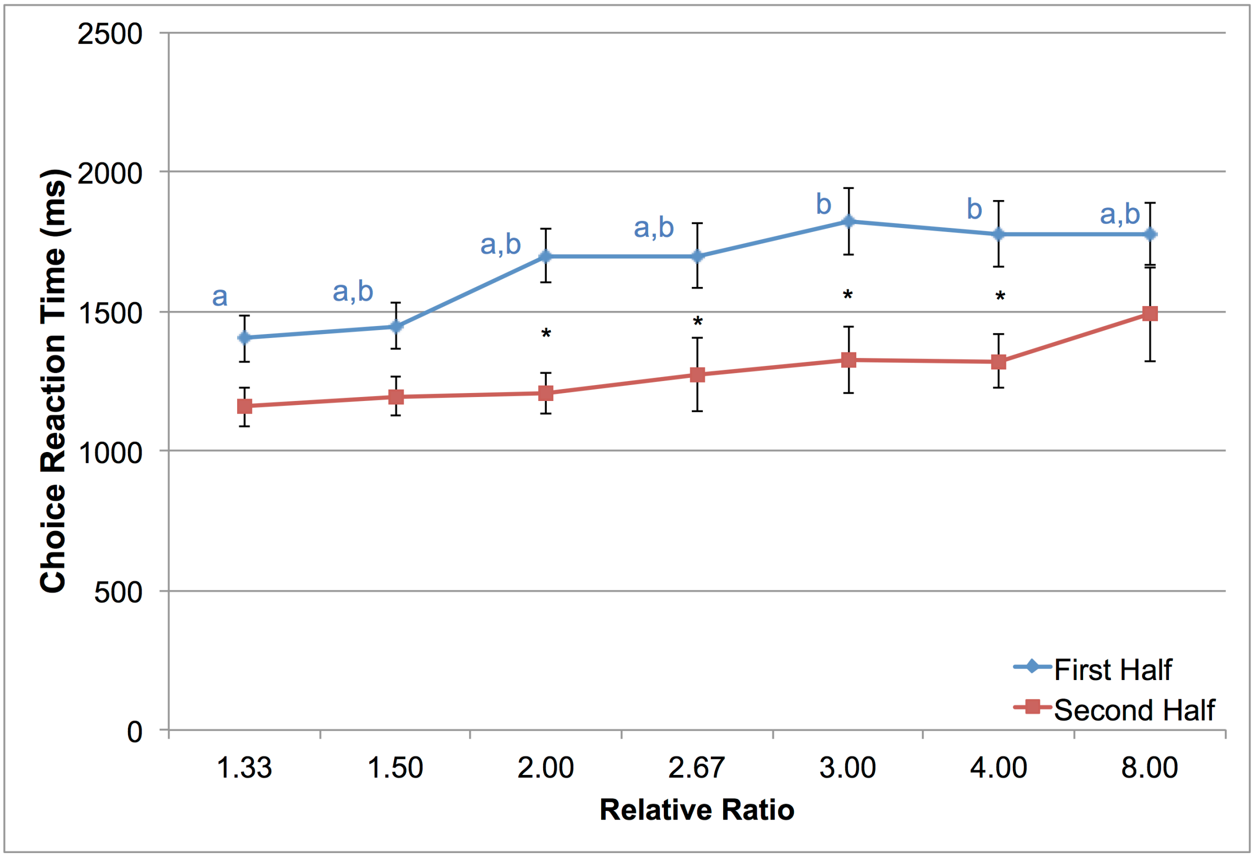

Figure 4. Reaction times of undergraduates by relative ratio. Relative ratios not sharing a common letter in the first half represents a significant difference of choices. Asterisks denote significant differences between halves at a specific relative ratio.

Study 2

In four separate Generalized Estimating Equations (GEEs), I examined the dependent variables of a) the proportion of hard choices made and b) participants' reaction time to make each choice. For each dependent variable, data across fiscal pairs were analyzed by both the a) absolute Difference (i.e., hard – easy reward value) and b) relative Ratio (i.e., hard/easy reward value) between reward options as within-subjects factors. Examining pairs by their absolute

difference assumes that individuals are making valuations between monetary amounts via subtraction. Examining pairs by their relative ratio assumes that individuals are making valuations between monetary amounts via division, which is a more complex mental operation and may be influenced by more of the biases listed above (e.g., the whole-number bias). Each GEE also included a) the group that each participant was categorized (depressed or control) to identify differences between depressed and typical reward processing and b) trials were in the first or second Half of the experiment to examine how participants may have changed their behavior across the experiment. Because not every pair had identical numbers of trials within it, we elected to aggregate data over halves of the experiment instead of analyzing data trial by trial.

Each GEE used a factorial model and an unstructured covariance matrix to analyze the data. We used a binomial distribution with a logit link function for GEEs analyzing the proportion of hard choices. For GEEs analyzing reaction times, we used a normal distribution with a logarithmic link for reaction times to correct for the significant skewness of 3.19 before transformation of absolute differences and 3.41 before transformation of relative ratios of these data. Participant number was the subject factor.

Significant results were followed up by sequential Sidak comparisons for each individual monetary pair to control Type I error. Group x Difference, Group x Ratio, Group x Half, Half x Difference, and Half X Ratio interactions were only compared by different monetary pairs within a specific half of the experiment and the same pair across halves of the experiment. A target α level of .05 was used for all analyses.

Preliminary Analyses

To ensure that no single value was associated with excessively high or low choices of the easy or hard task, I examined the Easy x Hard value interaction in a Generalized Estimating

Equation (GEE) with the proportion of hard choices made as the dependent variable. As displayed in Table 2, there was a significant interaction effect of easy choice value and hard choice value, Wald $\chi^2(3) = 15.0$, $p = .002$. This substantially qualified the main effects of easy choice value Wald $\chi^2(3) = 91.9$, $p < .001$, and hard choice value Wald $\chi^2(3) = 72.4$, $p < .001$. However, this pattern was similar across groups, Easy Value x Hard Value x Group Wald $\chi^2(3) = 4.26$, $p = .235$. The observed pattern of results suggests that although participants chose the $4.00 value more frequently than other values, it was not to such a degree that it deterred them from choosing other values.

Absolute Difference

Choices: Difference x Half. There was a significant Difference x Half interaction, Wald $\chi^2(6) = 13.1$, $p = .042$. This substantially qualified the main effect of absolute difference, Wald $\chi^2(6) = 153$, $p < .001$; there was no main effect of experiment half on the choice of easy versus hard trial, Wald $\chi^2(1) = 0.83$, $p = .361$. The relevant pairwise comparisons with a sequential Sidak adjustment are represented in Figure 5 significant differences among means are detailed below.

In the first half of the experiment, the hard task was chosen less often with pairs differing by $0.50 than all other pairs, Wald $\chi^2(1)$s > 35.0, ps < .002. The hard task was chosen less often during pairs differing by $1.00 than pairs differing by $1.50, $2.50 and more, Wald $\chi^2(1)$s > 25.7, ps < .002. Surprisingly, the hard task was chosen more often during pairs differing by $1.50 than those differing by $2.00, Wald $\chi^2(1) = 9.35$, $p = .003$. The hard task was chosen less often during pairs differing by $1.50 than those differing by $3.50, Wald $\chi^2(1) = 28.4$, $p = .003$.The hard task was chosen less often during pairs that differed by $2.00 than pairs that differed by $2.50 and

more, Wald $\chi^2(1)$s > 13.8, $p = .002$. The hard task was chosen less often during pairs differing by \$2.50 and \$3.00 than those differing by \$3.50, Wald $\chi^2(1)$s < 16.1, *ps* > .003.

In the second half of the experiment, the hard task was chosen less frequently in pairs that differed by \$0.50 than all other pairs, Wald $\chi^2(1)$s > 14.2, *p*s < .003. The hard task was chosen less frequently in pairs that differed by \$1.00 compared to those that differed by \$1.50 or more, Wald $\chi^2(1)$s > 13.4, *p*s < .003. The hard task was chosen less frequently in pairs that differed by \$1.50 compared to those that differed by \$2.50 and more, Wald $\chi^2(1)$s > 9.25, *p*s < .004. The hard task was chosen less frequently in pairs that differed by \$2.00 compared to those that differed by \$2.50 or more, Wald $\chi^2(1)$s > 20.3, *p*s < .003. The hard task was chosen less frequently in pairs that differed by \$2.50 compared to those that differed by \$3.50, Wald $\chi^2(1) = 10.8$, $p = .003$.

Choices: Difference x Group. There was also a significant Difference x Group interaction, Wald $\chi^2(6) = 21.1$, $p = .002$. This substantially qualified the main effects of absolute differences, Wald $\chi^2(6) = 153$, $p < .001$; there was no main effect of group, Wald $\chi^2(1) = 1.84$, $p = .175$. The relevant pairwise comparisons with a sequential Sidak adjustment are represented in Figure 5; significant differences among means are detailed below.

For individuals in the depressed group, the hard task was chosen less often with pairs differing by \$0.50 than all other pairs, Wald $\chi^2(1)$s > 41.1, *p*s < .002. The hard task was chosen less often during pairs differing by \$1.00 than pairs differing by \$1.50 and more, Wald $\chi^2(1)$s > 20.4, *p*s < .003. The hard task was chosen less often during pairs differing by \$1.50 than those differing by \$2.50 and more, Wald $\chi^2(1)$s > 11.5, *ps* < .004. The hard task was chosen less often during pairs that differed by \$2.00 than pairs that differed by \$2.50 and greater, Wald $\chi^2(1)$s >

13.1, *ps* < .003. The hard task was chosen less often during pairs differing by \$2.50 and \$3.00 than those differing by \$3.50, Wald $\chi^2(1)$s > 8.3, *ps* < .004.

For individuals in the control group, the hard task was chosen less frequently in pairs that differed by \$0.50 than all other pairs, Wald $\chi^2(1)$s > 14.4, *ps* < .003. The hard task was chosen less frequently in pairs that differed by \$1.00 compared to those that differed by all pairs except \$2.00, Wald $\chi^2(1)$s > 27.2, *p*s < .002. Surprisingly, the hard task was chosen more frequently in pairs that differed by \$1.50 compared to those that differed by \$2.00, Wald $\chi^2(1) = 11.2$, $p = .003$. The hard task was chosen less frequently in pairs that differed by \$1.50 compared to those that differed by \$3.50, Wald $\chi^2(1) = 18.5$, $p = .003$.The hard task was chosen less frequently in pairs that differed by \$2.00 compared to those that differed by \$2.50 or more, Wald $\chi^2(1)$s > 20.1, *p*s < .002. The hard task was chosen less frequently in pairs that differed by \$2.50 compared to those that differed by \$3.50, Wald $\chi^2(1) = 18.7$, $p = .002$.

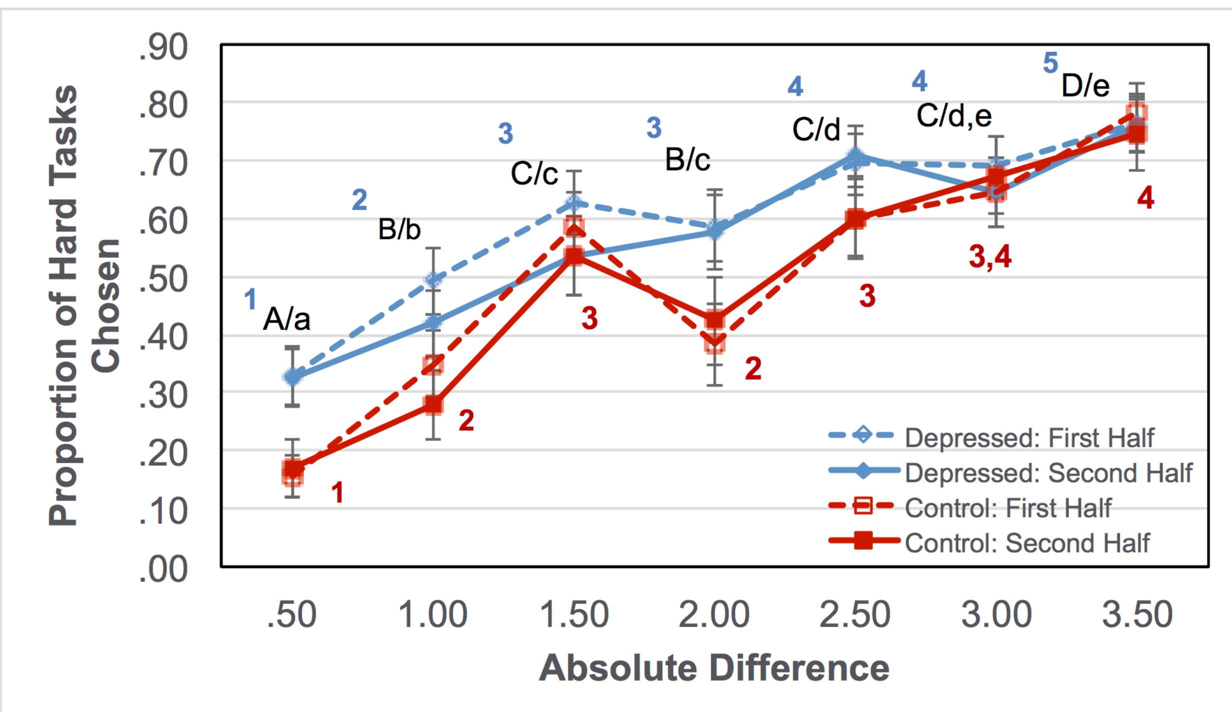

Figure 5. Choices of depressed and control participants by absolute difference. Absolute differences not sharing a common uppercase letter represents a significant difference of choices within the first half. Absolute differences not sharing a common lowercase letter represents a significant difference of choices within the second half. Absolute differences not sharing a common number represents a significant difference of choices within the corresponding color's group.

Reaction time. There was a significant Difference x Half interaction, Wald $\chi^2(6) = 26.9$, $p < .001$. This substantially qualified the main effects of absolute differences, Wald $\chi^2(6) = 31.8$, $p < .001$ and experiment half, Wald $\chi^2(1) = 6.33$, $p = .012$. There were no interactions involving or main effects of group, Wald χ^2s < 9.81, *ps* $> .133$. The relevant pairwise comparisons with a sequential Sidak adjustment are represented in Figure 6; significant differences among means are detailed below.

In the second half of the experiment, reaction times for choosing either the easy or hard task were faster for pairs that differed by \$0.50 than pairs that differed by \$3.50, Wald $\chi^2(1) = 16.6$, $p = .004$. Reaction times for choosing either the easy or hard task were faster for pairs that differed by \$1.00 than pairs that differed by \$3.50, Wald $\chi^2(1) = 13.1$, $p = .023$. Across halves of the experiment, pairs that differed by \$0.50 were chosen slower in the first half of the experiment than the second half of the experiment, Wald $\chi^2(1) = 19.0$, $p = .001$.

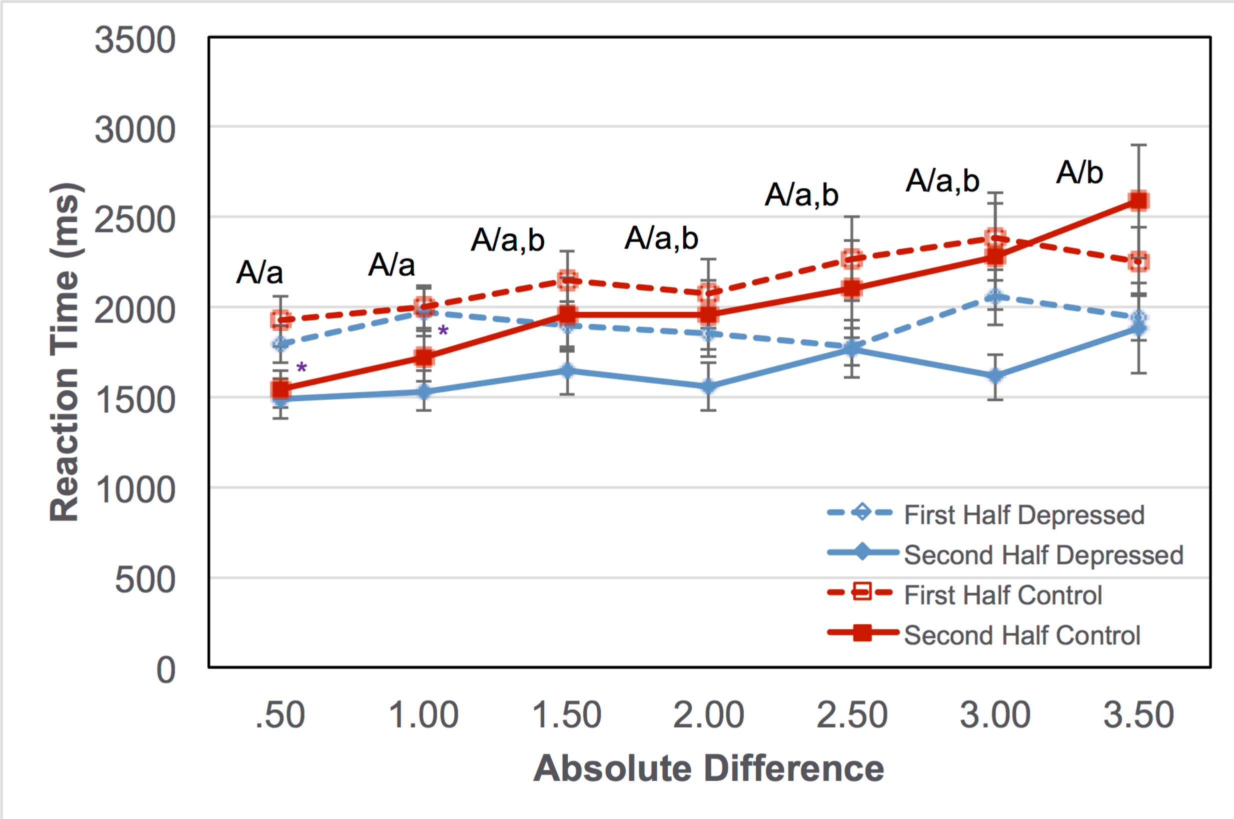

Figure 6. Reaction times of depressed and control participants by absolute difference. Absolute differences not sharing a common uppercase letter represents a significant difference of reaction times within the first half. Absolute differences not sharing a common lowercase letter represents a significant difference of reaction times within the second half. Asterisks denote significant differences between halves at a specific absolute difference.

Relative Ratio

Choices. There was a significant Ratio x Group interaction, Wald $\chi^2(6) = 18.17$, $p = .006$, which substantially qualified the main effect of relative Ratio, Wald $\chi^2(6) = 132.8$, $p < .001$; there was no significant main effect of Group, Wald $\chi^2(6) = 1.73$, $p = .188$. There were no significant interactions involving or main effects of experiment half, Wald χ^2s < 6.55, *ps* $> .365$.

The relevant pairwise comparisons with a sequential Sidak adjustment are represented in Figure 7 and summarized below.

Across groups, individuals in the depressed group chose the hard task for pairs that differed by 1.33 more often than those who were in the control group, Wald $\chi^2(1) = 17.3$, $p = .003$. In the depressed group, the hard task was chosen more often with pairs that had ratios of 1.33 than pairs that had ratios of 1.50, Wald $\chi^2(1)$s > 8.56, *p*s < .004. The hard task was chosen less often with pairs that had ratios of 1.33 than pairs that had ratios of 2.00 and greater, Wald $\chi^2(1)$s > 20.6, *p*s < .003. The hard task was chosen less often with pairs that had ratios of 1.50 than all other pairs, Wald $\chi^2(1)$s > 52.9, *p*s < .002. The hard task was chosen less often with pairs that had a ratio of 2.00 than pairs that had ratios of 2.67, 4.00, and 8.00, Wald $\chi^2(1)$s > 48.6, *p*s < .002. Although unexpected, the hard task was chosen more often with pairs that had ratios of 2.67 than pairs that had ratios of 3.00 and 4.00, Wald $\chi^2(1)$s > 15.2, *p*s < .003. The hard task was chosen less often with pairs that had ratios of 2.67 than pairs that had ratios of 8.00, Wald $\chi^2(1) = 8.87$, $p = .004$.The hard task was chosen less often with pairs that had ratios of 3.00 than pairs that had ratios of 4.00 and greater Wald $\chi^2(1)$s > 33.5, *p*s < .002. The hard task was chosen less often with pairs that had ratios of 4.00 than pairs that had ratios of 8.00, Wald $\chi^2(1) = 48.2$, $p = .002$.

In the control group, the hard task was chosen less often with pairs that had ratios of 1.33 than pairs that had ratios of 2.00 and more, Wald $\chi^2(1)$s > 12.8, *p*s < .003. The hard task was chosen less often with pairs that had ratios of 1.50 than pairs that had ratios of 2.00 and more, Wald $\chi^2(1)$s > 12.1, *p*s < .004. The hard task was chosen less often with pairs that had a ratio of 2.00 than pairs that had ratios of 2.67, 4.00, and 8.00, Wald $\chi^2(1)$s > 45.1, *p*s < .002. Although unexpected, the hard task was chosen more often with pairs that had ratios of 2.67 than pairs that

had ratios of 3.00, Wald $\chi^2(1) = 18.3$, $p = .003$. The hard task was chosen less often with pairs that had ratios of 2.67 than pairs that had ratios of 8.00, Wald $\chi^2(1) = 9.90$, $p = .004$. The hard task was chosen less often with pairs that had ratios of 3.00 than pairs that had ratios of 4.00 and greater, Wald $\chi^2(1)$s > 33.5, *p*s < .002. The hard task was chosen less often with pairs that had ratios of 4.00 than pairs that had ratios of 8.00, Wald $\chi^2(1) = 33.5$, $p < .001$.

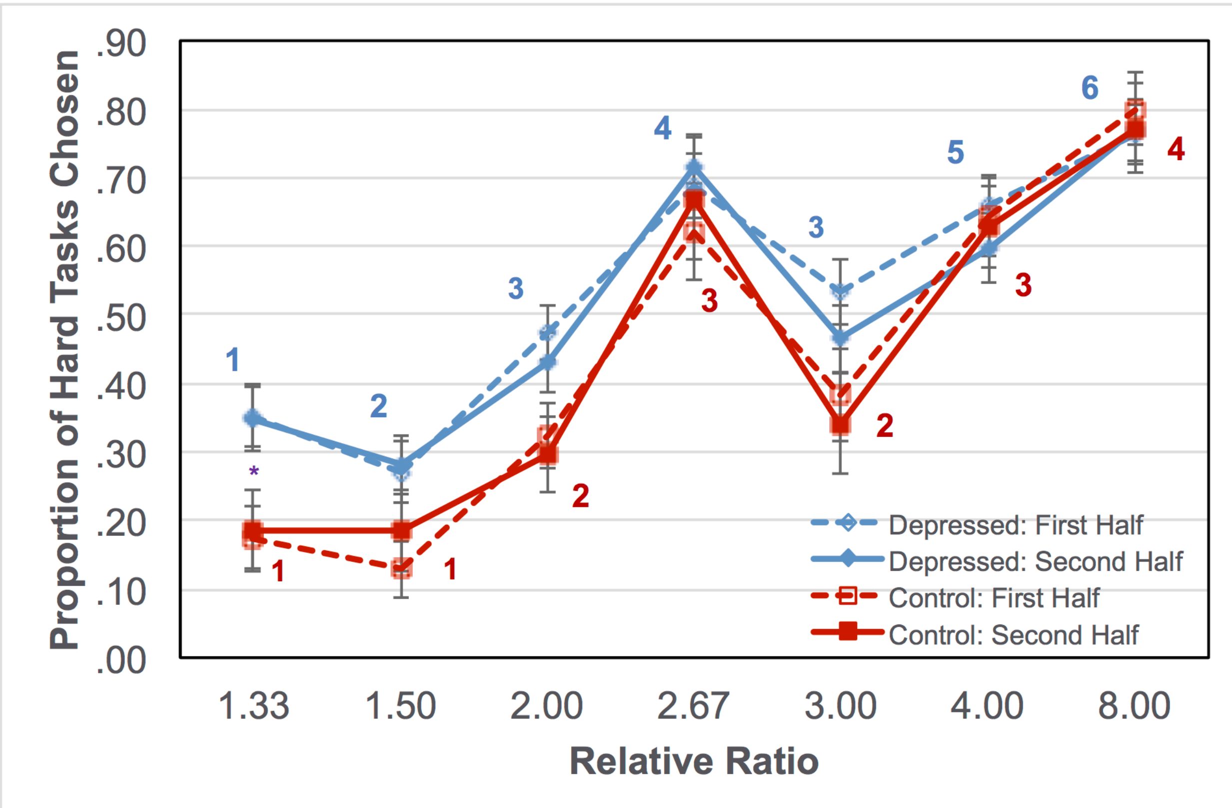

Figure 7. Choices of depressed and control participants by relative ratio. Relative ratios not sharing a common number represents a significant difference of choices within the corresponding color's group. Asterisks denote significant differences between halves at a specific relative ratio.

Reaction time. There was a significant Ratio x Half interaction, Wald $\chi^2(6) = 23.0$, $p = .001$, which substantially qualified the main effect of relative Ratio, Wald $\chi^2(6) = 40.79$, $p < .001$ and experiment half, $\chi^2(1) = 9.44$, $p = .002$. There were no interactions involving or main effects

of group, Wald χ^2s < 2.04, *ps* > .153. The relevant pairwise comparisons with a sequential Sidak adjustment are represented in Figure 8 and summarized below.

There were no significant differences in reaction times among ratios in the first half of the experiment, Wald $\chi^2(1)$s > 6.06, *ps* < .002. In the second half of the experiment, pairs with ratios of 1.33 and 1.50 were chosen faster than pairs with ratios of 8.00, Wald $\chi^2(1)$s > 12.5, *ps* < .033.

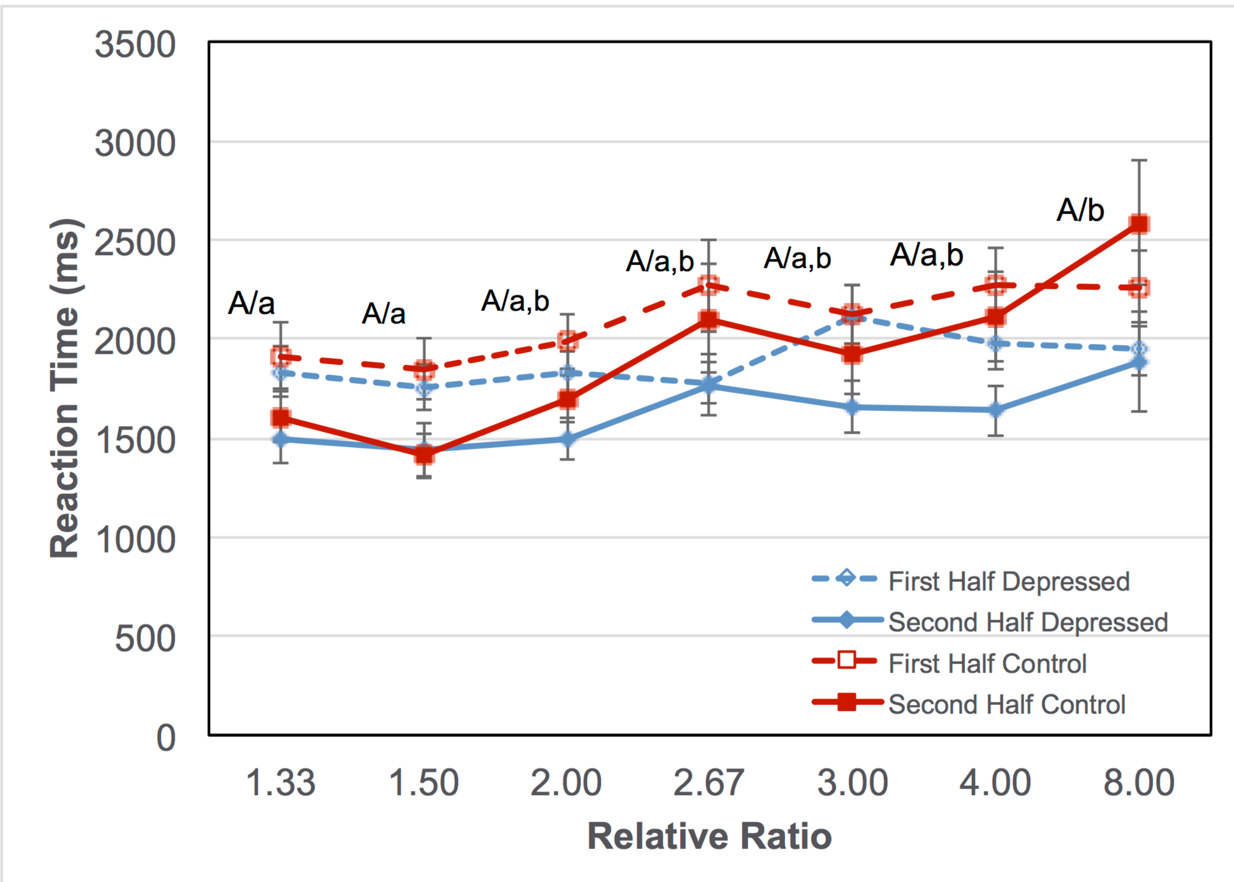

Figure 8. Reaction times of depressed and control participants by relative ratio. Relative ratios not sharing a common uppercase letter represents a significant difference of reaction times within the first half. Absolute differences not sharing a common lowercase letter represents a significant difference of reaction times within the second half.

Chapter 5: Discussion

The current studies examined reward preferences in three different populations: undergraduate students from the University of Nevada, Las Vegas; community members experiencing a major depressive episode; and community members not experiencing a major depressive episode. In Study 1, undergraduate students demonstrated a greater willingness to work harder for imaginary monetary rewards in the first half of the experiment than in the second half of the experiment. Contrary to my hypothesis, participants displayed nonmonotonic reward preferences by overvaluing monetary pairs that had an absolute difference of $1.50 or a relative difference of 2.67. In the second half of the experiment, participants corrected their overvaluation of pairs that differed by $1.50 to assume a roughly monotonic reward preference pattern. Although participants were able to correct their overvaluation for absolute differences, their overvaluation of pairs that had a ratio of 2.67 persisted throughout the entire experiment.

In Study 2, community members demonstrated a similar pattern of results as the undergraduate sample, which suggests the observed nonmonotonic reward preferences were not type I error. Community members as a whole were more willing to work harder for real monetary rewards in the first half of the experiment compared to the second half when the monetary pairs were examined by their absolute difference. This effect was not present when pairs were examined by their relative ratio. Community members who were not experiencing a major depressive episode also overvalued absolute differences of $1.50 and relative ratios of 2.67; these overvaluations persisted across both halves of the experiment. Those experiencing a major depressive episode overvalued monetary pairs with a relative ratio of 2.67 throughout the experiment, but they demonstrated monotonic preferences when the pairs were examined by their absolute differences. Although surprising and counter to my hypothesis, community

members experiencing a depressive episode were more willing to work harder for monetary pairs that had a relative ratio of 1.33 than the control group.

Numerical Reasoning while Working for Reward

Overall, participants were willing to work harder when the potential reward was real money (M = .51, SD = .30) rather than imaginary money (M = .37, SD = .32), $t(175) = 3.00$, p = .003. This became more apparent as the discrepancy in reward value within pairs became larger. In addition, participants spent more time making a decision when the potential reward was real money (M = 1809 ms, SD = 917.1) rather than imaginary money (M = 1437 ms, SD = 1019), $t(175) = 2.50$, $p = .013$. Although previous literature did not examine the initial valuation of real versus imaginary rewards, my findings are somewhat consistent with existing research demonstrating that imaginary rewards consistently elicit a similar *pattern* but an overall lower *level* of wanting after reward discounting compared to real rewards (Johnson & Bickel, 2002). Miyapuram, Tobler, Gregorios-Pippas, and Schultz (2012) found that individuals rate real and imaginary rewards as equally pleasant, but the current study suggests that this does not indicate that they are willing to exert the same level of effort for both types of rewards. Hübner and Schlösser (2010) observed a similar pattern of behavior in which participants were willing to work harder if they received monetary rewards were contingent on their performance (as our community participants did) rather than receiving a flat payment for simply being part of a study (as our undergraduate participants did for their participation credits). This is further supported by individuals' increased level of effort in occupational fields when payment is contingent on performance (Goldsmith, Veum, & Darity, 2000).

When examining monetary pairs by their relative ratios, all groups of participants throughout the entirety of both studies overvalued pairs with ratios of 2.67. This may be

explained by the difficulty individuals have mentally computing fractions. Unlike integer and decimal values, fractions are not automatically processed and require mental effort to manipulate into a value that is more easily processed (Bonato, Fabbri, Umiltà, & Zorzi, 2007). Fractions also are more difficult for individuals to manipulate in working memory than other types of numerical values (Iuculano & Butterworth, 2011). In fact, even when fractions are explicitly mentally manipulated, they are prone to more errors in value computation than other types of numbers (DeWolf, Grounds, Bassok, & Holyoak, 2014). A potential explanation for the overvaluation of the 2.67 ratio is the tendency for individuals to give greater attention to the numerator of a fraction than they do to the denominator. Individuals who focus more on the numerator of a fraction tend to make mistakes consistent with the whole number bias, such as comparing only one component of a fraction (Hurst & Cordes, 2016). This would explain why participants chose pairs with the ratio of 2.67 ($4.00 vs. $1.50) with similar frequency as pairs with ratios of 4.00 ($4.00 vs. $1.00) and 8.00 ($4.00 vs. $0.50) but did not overvalue ratios of 3.00 ($1.50 vs. $0.50). These findings suggest that the same monetary amount will not always be valued identically in different situations; instead, a monetary amount's value is affected by other available rewards. This is further supported by participants' approximately monotonic valuing of pairs with a ratio of 1.33 ($2.00 vs. $1.50) and pairs with a ratio of 1.50 ($1.50 vs. $1.00).

In both studies, participants demonstrated quicker decision when choosing either the easy or the hard task in second half of the experiment compared to the first half. This is most likely due to participants becoming aware of the available monetary pairs. Surprisingly, participants took longer to choose between the easy and hard task as the absolute difference or relative ratio became larger. This is probably due to participants defaulting to the easy task unless they are provided with a large enough discrepancy between the two amounts. Therefore it is likely that

participants spend extra time contemplating whether the increased effort is worth the monetary amount that can be obtained through the hard task. Although there is no previous research supporting this notion, it is difficult to argue that individuals would default to choosing the hard task without first examining the possible rewards.

Some of the difficulties involving basic mathematics may abate over time. Repeated exposure to the same math equations leads to a lesser error rate (Charness & Campbell, 1988). This may explain why participants in study 1 overvalued differences of $1.50 in the first half of the experiment, but then corrected their reward preferences to be roughly monotonic in the second half. This is further supported by depressed participants in study 2 also correcting their overvaluation of pairs with differences of $1.50 in the second half of the experiment. Unexpectedly, non-depressed participants in study 2 persisted in overvaluing pairs with differences of $1.50 throughout the entire experiment, suggesting that working for monetary rewards may cause continued overvaluation of this particular difference in non-depressed populations.

Depressive Realism and Elevated Wanting

It is difficult to explain why community members experiencing a major depressive episode demonstrated a monotonic reward preference when examining the absolute difference of pairs in the second half of the experiment while community members in the control group overvalued differences of $1.50 throughout the entire experiment. Previous research has found varying results regarding math performance between depressed and non-depressed individuals. Warren et al. (1984) observed no difference in performance on a mental mathematical task between depressed and non-depressed individuals while Marcotte, Lévesque, and Fortin (2006) found that individuals with depression performed worse in math classes.

Indeed, my study provides two pieces of evidence for the first demonstration of depressive realism in mathematically tractable effort-based decision making. Individuals with depression were more likely to work harder for monetary pairs with a ratio of 1.33. Additionally, corrected their reward preferences of absolute differences to a monotonic pattern in the second of the experiment while controls persisted with overvaluing pairs. However, depression is not always associated with performing in similar or superior ways to controls: High school students with depressive symptomatology performed worse in their math classes than students who did not display depressive symptomatology (Marcotte, Lévesque, & Fortin, 2006). This finding may be a consequence of the higher stakes of the evaluation in these classes along with the need to exert effort over the course of months rather than minutes, as in our study.

Contrary to the findings of Treadway, Bossaller, Shelton, and Zald (2012) that demonstrated individuals with MDD were less sensitive to rewards, individuals experiencing a depressive episode in our study showed greater sensitivity to rewards by choosing the hard task of the smallest absolute difference and relative ratio pairs more frequently than controls. A possible explanation for this contradiction is the differences in study design. Treadway et al. (2012) used varying amounts of rewards rather than ten fixed pairs. The easy task could be chosen for one dollar while the hard task varied from $1.24 to $4.30. These widely varying amounts prevented participants from creating decision-making strategies relative to other possible rewards and elicited a “gut level” response rather than a calculated and reasoned response. Additionally, Treadway et al. (2012) informed participants of the probability that they would actually receive the money if they successfully completed a given trial. This design was intended to engage the dopaminergic system through its sensitivity to probability and uncertainty. Rewards involving uncertainty are associated with longer lasting dopaminergic

responses and individuals with greater responses are more likely to work harder for low-probability rewards (Abler, Herrnberger, & Spitzer, 2009; Treadway et al., 2012).

Activity in the dopaminergic system increases when wanting a reward; the greater the release of dopamine, the more an individual is likely to report higher levels of wanting (Treadway, Buckholtz, Schwartzman, Lambert, & Zald, 2009; Treadway et al., 2012). However, the probability of receiving a reward also modulates dopaminergic activity. Specifically, dopamine is released only on trials in which receipt of reward is uncertain (Abler, Herrnberger, Grön, & Spitzer, 2009; Niv, Duff, & Dayan, 2005; Linnet et al., 2012). However, in my study, rewards were given with 100% certainty after successful trials and allowed participants to perform cost-benefit analyses for effort-based reward decision-making. Therefore, my findings suggest that uncertainty may be driving the apparent deficits in wanting in Treadway et al.'s (2012) behavioral findings. In summary, it does not appear that individuals with depression have fundamental deficits in wanting. Instead, only tasks that strongly stimulate the dopaminergic system, such as those with high levels of uncertainty, produce an apparent deficit.

Not engaging the dopaminergic system as strongly in the current study may also partially explain the depressed group's willingness to work harder for reward. Marcotte, Lévesque, and Fortin (2006) found that individuals with depression performed worse in their math class than their non-depressed peers. This study likely engaged the dopaminergic system due to the uncertainty of the points and grades that they would receive on each exam over the course of an entire semester. As previously mentioned, Warren et al. (1984) found no difference between depressed and non-depressed individuals' performance on a math test administered in a laboratory. This situation is unlikely to engage the dopaminergic system due to the lack of

uncertainty of the task; regardless of individuals' performance, it did not influence their compensation for participating.

My findings may have implications for the treatment of depression. For example, behavioral activation is a prevalent therapeutic technique that attempts to help individuals with depression address symptoms of decreased levels of energy and anhedonia (Soucy Chartier & Provencher, 2013). In light of the findings that individuals with depression do not have fundamental deficits in wanting (and are more willing to work for smaller relative rewards than controls), using small rewards to guide behavioral activation treatment could prove successful. Treatment may also benefit from the approach of depressive realism that was supported in my study. Individuals may be more likely to comply with smaller, *more realistic* behavioral changes.

Limitations and Future Directions

There were several limitations to this study. The differences observed between participants being offered imaginary money versus real money are confounded with participants being recruited from either an undergraduate study pool or Craigslist. We also did not have adequate data regarding participants' income and social economic status (SES). Individuals with a lower SES tend to report more depressive symptoms than those with a higher SES (Zimmerman & Katon, 2005). Additionally, we did not include all possible monetary pairs. For example, we did not include a pair with the absolute difference of $3.00. Another limitation is that we did not include more extreme discrepancies. While it appears that absolute differences reached an asymptotic pattern, the frequency of choosing the hard task was still increasing at the largest relative ratio of 8.00. In future studies, it would be helpful to assess participants' numeracy as a potential explanation for the observed nonmonotonic reward preference pattern across both studies. Another potentially worthwhile future study would be an exploratory

examination of moderating factors that explain the discrepancies found in the current study associated with decreased levels of energy and difficulty thinking and concentrating in regard to depression.

In summary, despite the assumption that individuals with depression would be less willing to work hard for rewards, I found that they were actually more willing. Participants frequently overvalued absolute differences of $1.50 and relative ratios of 2.67. Therefore researchers should be cautious when examining relative and absolute values because it cannot be assumed that individuals' choices are meaningfully and monotonically ordered.

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Curriculum Vitae

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Education

PhD Clinical Psychology (In progress) May 2019 (Projected)

University of Nevada, Las Vegas

M.A. Clinical Psychology (In progress) May 2017 (projected)
University of Nevada, Las Vegas

B.A. Intensive Psychology June 2013
University of California, Santa Cruz, CA
Honors in the Major
Junior/Senior GPA: 3.85
Cumulative GPA: 3.54
Psychology major GPA: 3.80

Practicum Experience

Clinical Doctoral Student Graduate Clinician August 2016 – Present
Counseling and Psychological Services at the University of Nevada, Las Vegas
Therapy and Intake Supervisors: James Jobe, Ph.D; Shauna Landis, Ph.D; Alexandria Moorer, M.A.

This 9-month practicum placement provides therapeutic services to students attending the University of Nevada, Las Vegas. Services include intake assessments and individual psychotherapy. Practicum therapists are all placed under the supervision of licensed psychologists. A weekly caseload of approximately six therapy clients and one intake client is maintained, with weekly individual and group supervision. Weekly case rounds are also conducted.

Clinical Doctoral Student Graduate Clinician August 2015 – August 2016
The PRACTICE Clinic University of Nevada, Las Vegas
Therapy Supervisors: Jason Holland, Ph.D; Kristin Culbert, Ph.D
Assessment Supervisor: Stephen Benning, Ph.D

This 12-month practicum placement provides low cost behavioral, cognitive and mental health assessment and therapy services to the university population and the community at large. Clients are primarily adult individuals who are diverse in socioeconomic status and ethnicity. A weekly caseload of approximate five therapy clients and one assessment client is maintained, with weekly individual and group supervision.

Other Clinical Experience

Instructor for Students with Autism July 2013 – June 2014
The Bay School, Santa Cruz, CA
Implement educational programs using the practice of Applied Behavior Analysis for clients ages five to twenty-one. Collect, summarize, and evaluate behavioral data. Create and modify treatment programs. Aid in the training of new employees.

Clinical Intern January 2013 – June 2013
Community Connection, Santa Cruz, CA
Facilitated individual and group counseling for outpatient adults diagnosed with a schizophrenia spectrum disorder or borderline personality disorder. Designed pre-employment counseling sessions for clients (emotional management in the work place, anxiety in the work place, conflicts in the work place). Billed Medi-Cal using the Data-Intervention-Response (DIR) format for client counseling sessions.

Volunteer Teaching Aid July 2012 – September 2012
Lokrantz Special Education Center School, Reseda, CA
Facilitated language, writing, and math skill building programs for children diagnosed with varying developmental disabilities. Reinforced behavioral goals.

Teaching Experience

Instructor
University of Nevada, Las Vegas August 2016 - present
Course: General Psychology
Teach undergraduate students; solely responsible for course content including lecture material, in-class activities, discussion, assignments, and exams.

Instructional Assistant September 2012 – December 2012
University of California, Santa Cruz
Course: Introduction to Psychology
Instructed undergraduate students. Designed and facilitated weekly review sessions regarding material covered in the course. Evaluated written assignments. Proctored, reviewed, and evaluated examinations.

Research Experience

Graduate Assistant August 2014 – Present
University of Nevada, Las Vegas
Professor: Stephen Benning
Subject: Psychophysiology of emotion and personality.
Duties: Analyzed data with SPSS. Screened for eligible participants by administering the Inventory of Depressive Symptomology. Placed peripheral sensors and EEG caps on participants and collected psychophysiological data. Managed participant payments. Customizing computers to be capable of running experiments. Overseeing experiments and training research assistants.

Graduate Assistant August 2014 – May 2015
University of Nevada, Las Vegas
Professor: Jennifer Rennels
Subject: Infants' abilities to discriminate between difference faces.
Duties: Created online surveys through Qualtrics. Smoothed heart rate data for further analysis. Updated data in participant database.

Research Assistant January 2013 – April 2013
University of California, Santa Cruz, CA
Professor: Nameera Akhtar
Supervisor: Jennifer Menjivar
Subject: Altruistic behaviors in children when exposed to individuals who speak a familiar language versus when exposed to those who speak an unfamiliar language.
Duties: Analyzed and transcribed data of altruistic behaviors. Scored, coded, and recorded individual trials. Scheduled appointments with participants.

Research Assistant April 2012 – December 2012
University of California, Santa Cruz, CA
Professor: Craig Haney
Supervisor: Joanna Weill
Subject: Risk factors experienced in the lives of capital defendants.
Duties: Examined social histories of capital defendants and coded present risk factors. Organized and filed legal materials. Reviewed and transcribed videos of mock juries.

Publications

Wagenmakers, E.-J., Beek, T., Dijkhoff, L., Gronau, Q. F., Acosta, A., Adams, R. B., Jr., Albohn, D. N., Allard, E. S., Benning, S. D., Blouin-Hudon, E.-M., Bulnes, L. C., Caldwell, T. L., Calin-Jageman, R. J., Capaldi, C. A., **Carfagno, N. S.**, … , Zwaan, R. A. (in press). Registered Replication Report: Strack, Martin, & Stepper (1988). *Perspectives on Psychological Science*.

Conference Posters

Carfagno, N., & Benning, S. D. (2015). Overvaluation of Absolute and Relative Rewards Involving Decimals. Poster presented at the 95th Annual Western Psychological Association Convention: Las Vegas, Nevada.

Isom, J., Carfagno, N., & Benning, S. D. (2015). Orthogonal Internalizing and Externalizing Factors of Psychopathology in Self-Reports. Poster presented at the 95th Annual Western Psychological Association Convention: Las Vegas, Nevada.

Clinical/Research Skills

Clinical Skills

Trained in Applied Behavior Analysis.
Trained to use the Data-Intervention-Response format of billing for mental health services.
Experienced facilitating individual and group counseling sessions.
Trained to administer the Wechsler Intelligence Scale for Children, 4th edition
Trained to administer the Wechsler Adult Intelligence Scale, 4th edition
Trained to administer the Wechsler Memory Scale, 4th edition
Trained to administer the Delis–Kaplan Executive Function System
Trained to administer the Woodcock-Johnson IV Tests of Achievement
Trained to administer the Test of Memory Malingering

Research Skills

Experienced with SPSS statistical software
Experienced with Microsoft Excel
Experienced with Psychopy
Placement and care of psychophysiological equipment

Certifications/Licenses

Registered counselor in the National Plan and Provider Enumeration System. (February 2013)

- National Provider Identifier (NPI): 1487993473

Honor Recognitions

Educational Honors

Honors in the Psychology Major

Under Graduate Dean's Honors
Member of the Psi-Chi Honor Society

Organization Memberships

American Psychological Association: 2016 - present
Western Psychological Association: 2014 - present
Psi-Chi Honor Society: 2010 - present