May 2018

Effects of the Permutation of Reinforcement Magnitude on Measures of Delay Discounting in a Hypothetical Money Scenario

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EFFECTS OF THE PERMUTATION OF REINFORCEMENT MAGNITUDE ON MEASURES OF DELAY DISCOUNTING IN A HYPOTHETICAL MONEY SCENARIO

by

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A Dissertation Submitted in

Partial Fulfillment of the

Requirements for the Degree of

Doctor of Philosophy

in Psychology

at

The University of Wisconsin-Milwaukee

May 2018

ABSTRACT

EFFECTS OF THE PERMUTATION OF REINFORCEMENT MAGNITUDE ON MEASURES OF DELAY DISCOUNTING IN A HYPOTHETICAL MONEY SCENARIO

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The University of Wisconsin-Milwaukee, 2018
Under the Supervision of Professor Tiffany Kodak, PhD, BCBA-D

The current study analyzed the extent to which three common permutations of reinforcement magnitude – quantity, volume, and duration – affected the rate at which participants discounted hypothetical monetary rewards. College students served as participants. Hypothetical scenarios were presented using the Hypothetical Money Procedure (Kirby, 1996), and participants self-reported the subjective value of a delayed monetary reward. Conditions presented the monetary choices as (a) quantity of dollar bills, (b) heights (inches) of a stack of dollar bills, and (c) durations of time to spend in a hypothetical cash machine to collect dollar bills. For each condition, participants' combined subjective values were used to calculate area under the curve (AuC) and to generate discounting curves based on Mazur's (1987) hyperbolic model. The duration permutation yielded a statistically significant smaller AuC value and resulted in a higher *k*-value in comparison to the quantity and volume permutations. Response patterns also were used to group participants based on the permutation that yielded the highest idiosyncratic AuC value. The permutation of reinforcement magnitude was demonstrated to be a significant variable in controlling discounting rates for hypothetical money.

Keywords: delay discounting, permutation of reinforcement magnitude, hypothetical rewards

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ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to Dr. Tiffany Kodak for her valuable and insightful suggestions during the development and implementation of this research. Her thoroughness, support, and advisement has been greatly appreciated. I would also like to express my gratitude to Dr. Todd McKerchar for his support and guidance in designing an effective research methodology. His expertise in delay discounting has been an essential component to the completion of this research. I also wish to extend my thanks to Dr. Jeffrey Tiger, Dr. Raymond Fleming, and Dr. Susan Lima for their excellent suggestions early in the development of this project.

I would also like to extend my appreciation to Dr. Jay Moore and Dr. Marshall Dermer for their commitment to shaping my behavior analytic repertoire. Their advisement continues to guide my behavior as a scientist and educator.

Finally, I wish to thank my colleagues, friends, and family for their immense support throughout my graduate career.

INTRODUCTION

Effects of the Permutation of Reinforcement Magnitude on Measures of Delay Discounting in a Hypothetical Money Scenario

Delay discounting refers to the momentary decrease in subjective value of a reinforcer as a function of the delay to accessing a reinforcer (McKerchar & Renda, 2012). For example, an individual may choose to immediately consume one marshmallow instead of waiting for one hour to consume five marshmallows. The hypothesized behavioral mechanism for this choice is that the delay to reinforcement reduces the subjective value of the larger, delayed consequence in comparison to the smaller, immediate consequence. This phenomenon has been well established in both non-human animal and human research paradigms (see Green, Myerson, & Vanderveldt, 2014 for a review).

The value of reinforcers in the literature on delay discounting is typically measured with responses to hypothetical or real-choice scenarios in which organisms are prompted to select between an immediately available magnitude of reinforcement and a delayed magnitude of reinforcement (Green, Myerson, & Vanderveldt, 2014). In experiments with humans as participants, research has demonstrated that choices involving hypothetical, real, or potentially real reinforcement produce similar patterns of responding (e.g., Johnson & Bickel, 2002), though there have been reported exceptions (e.g., Green & Lawyer, 2014). In typical two-choice procedures – referred to as smaller-sooner and larger-later paradigms – the immediately available magnitude of reinforcement is sequentially increased or decreased (e.g., Maguire, Henson, & France, 2014). The subjective value of the delayed magnitude of reinforcement is determined by first identifying the point at which the organism shifts response allocation from the immediately available magnitude of reinforcement to the delayed magnitude of reinforcement, or vice versa. Following a preference reversal, iterative choices are presented to further hone in on the value of reinforcement at which the participant displays indifferent responding (Mazur, 1987). Researchers have calculated the subjective value of the delayed reinforcer from the indifference value. For example, a participant might self-report that s/he would prefer to receive immediate access to $9 over delayed access to $10. However, if the participant selected to receive delayed access to $10 rather than immediate access to $8, a preference reversal point of $8 is identified. Subsequent choices would iteratively hone in on the specific value between $8 and $9 to identify the subjective value (e.g., $8.50 now versus $10 after some delay). Thus, the subjective value of $10 at the given delay would be approximately $8.50 (i.e., delayed access to $10 is *subjectively* equal to immediate access to $8).

Researchers have demonstrated a hyperbolic function to model decreases in the subjective value as a function of increases in delays to reinforcement (see equation 1: Mazur, 1987).

(Equation 1)

$$S_V = \frac{A}{(1 + k\mathrm{D})}$$

Where the subjective value of a reinforcer (S_V) is determined by dividing the actual value of a reinforcer (*A*) by the delay to reinforcement (*D*). The rate at which a participant discounts delays to reinforcement is determined by fitting a parameter (*k*) to equation 1: The parameter is determined by the participant's idiosyncratic response patterns to hypothetical or real scenarios that produce indifference values at various delays to reinforcement. Relatively low *k*-values are indicative of shallow discounting (i.e., the subjective value of the delayed reinforcer decays to a lesser degree across delays to reinforcement). Relatively high *k*-values are indicative of steep discounting (i.e., the subjective value of the delayed reinforcer decays to a greater degree across delays to reinforcement). The hyperbolic model produces functions in which there is rapid decay in value among early delays and decreased relative decay at later delays. In general, hyperbolic models fit the observed response patterns very well (McKerchar, Green, Myerson, Pickford, Hill, & Stout, 2009).

Another common method for describing and measuring the rate at which subjective values decay is to measure the area under the curve (AuC: Myerson, Green, & Warusawitharana, 2001). This method of calculation has been used to measure both individual and group data (Oberlin et al., 2015; Weatherly, Guddding, & Derenne, 2010). The AuC is calculated by measuring the area of the polygon created by successive data points plotted as a function of standardized subjective values on the y-axis (range, 0% to 100% of delayed reinforcer value) and standardized delays to reinforcement on the x-axis (range, 0% to 100% of maximum delay to reinforcement). The equation for calculating AuC is described below:

(Equation 2)

$$AuC = \sum (x_2 - x_1)\left[\frac{y_1 + y_2}{2}\right]$$

In the above equation, x_2 and x_1 refer to adjacent standardized delays to reinforcement, and y_1 and y_2 refer to adjacent standardized subjective values at x_1 and x_2 delays, respectively. If a reinforcer did not lose any value across delays (i.e., participants reported waiting for the delayed reinforcer across all delays), the AuC measure would be 1.0. In comparison, steeper discounting of subjective values is associated with smaller AuC values (Myerson et al., 2001). This measure produces parametric data that fit most necessary assumptions for statistical analyses that can compare AuC measures across participants, conditions, or experiments because of the standardization of data points (Dallery & Raiff, 2007).

Recently, the effects of experimental parameters on discounting of delays to reinforcement have been investigated (e.g., delay phrasing, DeHart & Odum, 2015; opportunity costs, Johnson, Hermann, & Johnson, 2015; intertrial intervals, Smethells & Reilly, 2015; reinforcer deprivation, Roewer, Wiehler, & Peters, 2015; pre-exposure to delays, Renda, Stein, Hinnenkamp, & Madden, 2015; stress level, Owens, Ray, MacKillop, 2015). For example, DeHart and Odum (2015) investigated the extent to which framing delays as specific dates (e.g., March 23) instead of the standard calendar method (e.g., 6 months) affected the rate at which participants discounted hypothetical monetary rewards. Time framed as dates resulted in less discounting (i.e., higher AuC values) compared to the calendar method.

One experimental parameter that has yet to be investigated in the delay discounting literature is the permutation of reinforcement magnitude (i.e., the method for increasing or decreasing the magnitude of a reinforcer). Furthermore, there is a paucity of research on the effects of different arrangements of reinforcement magnitude in the extant literature (see Hoch, McComas, Johnson, Faranda, & Guenther, 2002; Neef, Shade, & Miller, 1994 for notable exceptions). In general, previous studies have manipulated one permutation of reinforcement magnitude and examined its effect on responding. In delay discounting investigations for example, discounting based on the quantity of a reinforcer has been investigated by presenting choice scenarios that included an immediate choice to gain access to a *few* reinforcers versus a delayed choice to gain access to *many* reinforcers (e.g., quantity of cigarettes and money: Green & Lawyer, 2014). Discounting of reinforcer volume has been investigated by presenting choice between immediate access to a *small* reinforcer versus delayed access to a *large* reinforcer (e.g., magnitude of milk: Pinkston & Lamb, 2011). Finally, researchers examining discounting based on the duration of access to a reinforcer have typically presented an immediate choice to access a reinforcer for a relatively short duration versus delayed access to the same reinforcer for a longer duration (e.g., duration of grain reinforcement: Mazur & Biondi, 2009; probabilistic access to different durations of access to leisure activities: Hirst & DiGennaro Reed, 2016).

The choice of the permutation to manipulate in each study is most likely dependent on the putative reinforcer. For example, it is feasible to alter the duration of access to an iPad®. It would be less feasible and relevant to alter the quantity of iPads®. However, much of the delay discounting literature has examined choice among reinforcers that can be altered according to several parameters of reinforcement (e.g., money: Weatherly, 2012). For example, it is feasible to alter the quantity of money (e.g., $5 versus $20 dollars), the volume of money (e.g., the size of a stack of one-dollar bills), and the duration of access to money (e.g., the amount of time to obtain money). Examinations that compare discounting of delays to a commodity along several permutations of reinforcement magnitude will provide more accurate interpretations of the variables that affect an individual's allocation to immediately available and delayed commodities. Thus, a comparison of the effects of different reinforcement magnitude manipulations on response allocation among immediate and delayed reinforcers will extend the delay discounting literature. Furthermore, if different permutations produce different discounting functions, then this parameter will be especially important to note in subsequent experiments investigating the mechanisms responsible for delay discounting.

The current study examined the extent to which three common permutations of reinforcement magnitude (i.e., quantity, volume, and duration) affected the rate at which participants discounted the subjective value of a delayed reinforcer. To assess such effects, the current experiment used a version of the hypothetical money-scenario procedure (Kirby, 1996) and participants were instructed to assign subjective values to delayed sums of money presented across the three different reinforcement magnitude arrangements (quantity of dollar bills, volume of a stack of dollar bills, and time to access dollar bills while inside a cash machine).

Importantly, participants were provided sufficient information so as to highlight that the overall delayed sums of money were all equivalent; thus, the permutation of reinforcement magnitude served as the only difference between conditions.

METHOD

Participants, Setting, and Materials

Seventy-two college students participated in the experiment. All participants were recruited through an online recruitment system used by the Department of Psychology. In order to meet the inclusionary criteria to participate, participants were required to (a) be fluent in English, (b) have normal or corrected vision, and (c) pass pre-experimental training procedures (described below). All participants received compensation for their participation in the form of extra credit in a selected course.

All experimental sessions were conducted in a private laboratory room that contained a table, chairs, materials for pre-experiment tasks, and a laptop computer. The laptop computer contained PsychoPy software (PsychoPy: Pierce, J.W., 2007) that was used to create and run the hypothetical money procedure (described below).

The hypothetical money procedure contained three different sets of scenarios in which participants were instructed to first read a brief introduction to the scenario (presented on the laptop screen for at least 5 s), and then were prompted to respond to eight different hypothetical questions. Table 1 contains the written introductions for each of the three conditions. Each of the eight questions contained a unique delay to reinforcement (e.g., “What is the minimum amount of money you’d be willing to accept now, instead of waiting 1 MONTH to receiving $1000?”).

Quantity condition. Participants read scenarios with choices between different sums of money. Following the initial instruction, participants were prompted to input the minimum amount of money that they preferred now, instead of waiting [delay] to receive $1000. Participants responded to each question by adjusting a slider on the computer screen. The slider was grounded at $0 and capped at $1000. An example of the scenario interface is presented in Appendix A.

Volume condition. Participants read scenarios with choices between different stacks of one-dollar bills that varied according to the height (inches) of the stack. Following the initial instruction, participants were prompted to input the minimum height of one-dollar bills that they preferred now, instead of waiting [delay] to receive a 4.3 stack of one-dollar bills. Participants were instructed to assume that the height a one-dollar bill was 0.0043". Participants responded to each question by adjusting a slider on the computer screen. The slider was grounded at 0.0 inches and capped at 4.3 inches. An example of the scenario interface is presented in Appendix B.

Duration condition. Participants read scenarios with choices between different durations of time in seconds to access a cash machine (e.g., Money Tornado) that contained 200 five-dollar bills. Following the initial instruction, participants were prompted to input the minimum duration of time that they preferred now, instead of waiting [delay] to receive 100 s to access the cash machine. Participants were instructed to assume that they could grab two bills per second while in the machine. Participants responded to each question by adjusting a slider on the computer screen. The slider was grounded at 0 s and capped at 100 s. An example of the scenario interface is presented in Appendix C.

Dependent Variables

For each participant, we measured the slider value at each delay for each condition. These values were used to calculate the mean indifference value at each delay for each condition. For example, if a participant preferred $200 (exposure 1), $250 (exposure 2), and $232 (exposure 3) now instead of $1000 in two weeks, the mean indifference value would be $227 (i.e., the average across all three exposures). This value was then standardized by dividing the indifference value by the delayed amount: $227 / $1000 = 0.227. The mean indifference values were used to calculate the total AuC and the value of *k* to best fit Mazur's (1987) hyperbolic model for each condition for each participant (*k* values were calculated using the Discounting Model-Selector; Franck, Koffarnus, House, & Bickel, 2015; Gilroy, Franck, & Hantula, 2017).

For each participant, condition-specific AuC and *k* values were compared to determine idiosyncratic differences in discounting across the three permutations of reinforcement magnitude. Condition-specific AuC and *k* values also were aggregated across participants to determine group-level differences in discounting across the three permutations of reinforcement magnitude and to create sample discounting curves.

Data omission criteria. A participant's data were not included in the final analyses if response patterns met either of the following criteria (Johnson & Bickel, 2008): (a) if any indifference value was greater than the preceding indifference value by 20%, or (b) if the first (0-day delay) and last (5-year delay) indifference values did not differ by at least 10%. Five participants' data met the omission criteria (6.9% of participants); thus, data from 67 participants were included in the final analyses.

Pre-Experimental Training

Participants completed several training procedures prior to advancing to the experiment. Training established that participants could (a) discriminate ordinal values of permutations of reinforcement magnitude, (b) correctly use the virtual slider, and (c) respond to several practice trials that closely resembled the format of experimental trials. Failure to correctly perform each skill following two practice opportunities resulted in exclusion from participating in the experiment. No participant failed the pre-experimental training skills assessment.

Ordinal ranking. Participants were instructed to order index cards from left to right according to their ordinal rank, based on each permutation of reinforcement magnitude. The discrimination of quantity was assessed by having participants order amounts of money printed on index cards from the smallest to largest amount of money. The discrimination of volume was assessed by having participants order heights (measurements in inches) printed on index cards from the smallest to largest height. The discrimination of duration was assessed by having participants order values of time (e.g., 1 day, 1 month, 1 year) printed on notecards from the smallest to largest amount of time. If the participant made an error in ordering the stimuli, the experimenter pointed out the error, re-presented the same index cards, and repeated the instruction to order the stimuli from smallest to largest. The experimenter provided brief praise following each instance of correct ordering of the index cards.

Virtual slider training. Participants practiced and received feedback on their use of an adjusting, virtual slider in the computer program. The experimenter provided brief oral and written instructions on the use of the slider which was followed by several practice opportunities for the participant to adjust a slider to match a number on the computer screen. For example, if the sample number was 63, the participant was required to adjust the virtual slider to match 63. The slider had a range of values from 0 to 100. The experimenter provided brief descriptive praise for each correct match (e.g., "Nice work matching the slider to the sample number"). If participants made an error, the experimenter provided corrective feedback via a vocal and model prompt (e.g., "Match the slider to the sample number, 63, like this." [moved slider to correct position]) and repeated the trial.

Practice trials. Participants completed several exemplar training scenarios, referred to as practice trials. The practice trials were conducted on the laptop using the same program interface as the experimental procedure. Each practice scenario included a brief introduction and two questions. The questions presented choices between an immediately available reinforcer and a delayed reinforcer (question 1: 30 days; question 2: 60 days). An approximation of the indifference value (point at which preference shifted from delayed amount to immediate amount) was calculated using a modified version of the adjusting-amount procedure (Mazur, 1987). That is, participants were instructed to select between an immediately available sum of money (e.g., $1) and a delayed sum of money ($50 in 30 days); the immediately available sum of money was sequentially increased to identify the sum of money at which the participant shifted his or her responding from the delayed sum of money to the immediate sum of money. Twenty practice trials (10 trials for each delay) were conducted for each of the three permutations of reinforcement magnitude. These initial practice trials were referred to as the adjusting-amount practice trials.

After completing the adjusting-amount practice trials, participants were told about the availability of a more rapid method to measure their choices between options, referred to as open-ended practice trials (cf., fill-in-the-blank method; Weatherly, Derenne, & Terrell, 2011). For example, participants were asked, “What is the minimum amount of money you’d be willing to receive now, instead of waiting [30 days or 60 days] to receive $50?” Participants responded by adjusting a virtual slider on the computer screen to a value between $0 and $50. Comprehension of the question was measured by the degree of correspondence in indifference values between the adjusting-amount practice trials and the open-ended practice trials. That is, approximately the same indifference value (within 10%) was required in each type of trial. The participant continued to respond to the open-ended exposure trials until the slider values were within 10% of the adjusting-amount practice trials for two consecutive practice opportunities.

Experimental Procedure

Participants responded to 72 questions (8 delays x 3 conditions x 3 exposures) during a 1-hour session. The experimental conditions were presented in a randomized order for each participant. Each condition included eight delays to reinforcement presented in a randomized order. The delay values in each condition included: 0 days, 1 day, 1 week, 2 weeks, 1 month, 6 months, 1 year, and 5 years. Once the participant responded to all the question in one condition, the next condition was introduced. Following completion of every condition once, the order of the conditions was randomized and presented again. Conditions were presented in a similar fashion for a total of three times each. That is, participants responded to the same question on three separate occasions.

Participants independently responded to all questions presented in the computer program while the experimenter sat on the other side of the room or in an adjacent lab room with a one-way mirror. An index card with a picture of the slider and a description of how to use the slider remained present throughout the experiment (see Appendix D).

Within each condition, a written introduction to a scenario was presented on the computer screen for at least 5 s (see Table 1). The subsequent questions following each introduction incorporated eight delays to reinforcement. The three experimental conditions altered the presentation of hypothetical permutations of money as differences in the (a) *quantity* of dollar bills, (b) *volume* of stacks of one-dollar bills, and (c) *duration* access to a cash machine. The overall delayed value of reinforcement remained constant across conditions (i.e., $1000 = 4.3" stack of one-dollar bills = 100 s in a cash machine in which participants were instructed to assumed that s/he can grab two five-dollar bills per second).

After the participant read the introduction of the scenario and clicked on the button to progress, questions were presented. In each question, the participant read written instructions to "Adjust the slider to the smallest [permutation of money] you'd be willing to accept now, instead of waiting [delay] to receive [delayed permutation of money]". For example, one of the written instructions read, "Adjust the slider to the smallest amount of money you'd be willing to accept now, instead of waiting 6 months to receive $1000." After the participant responded to all 72 questions, the participant was debriefed, and the experimental session ended.

Data Analyses

The results were analyzed in two ways. First, the experimenter aggregated participants discounting curves, which were created from delay- and permutation-specific indifference values and used the median indifference value to create a set of sample-wide discounting curves. Aggregate discounting curves were visually analyzed to identify any trends or patterns across participants. Furthermore, the aggregate curves produced sufficient indifference values to calculate *k*-values to fit the Mazur (1987) hyperbolic model. The curves were further analyzed to identify differences in the rate at which a reinforcer decayed as a function of the permutation of reinforcement magnitude. R^2 values were examined to determine the percent of variance accounted for by the hyperbolic model.

Second, the experimenter conducted statistical analyses to supplement the previously discussed analyses. Aggregate AuC measures were calculated from the indifference values across participants for each condition. A one-way repeated-measures analysis of variance (rANOVA) was used to analyze whether significant differences were present between the mean AuC measures in the three conditions. Follow-up analyses compared specific conditions and used a Bonferroni alpha-correction procedure to control for the inflated probability of Type I errors.

Tertiary to the above analyses, the results were further examined to identify patterns in discounting hierarchies. To analyze these patterns, participants were grouped based on the idiosyncratic permutation of reinforcement magnitude that yielded the shallowest discounting curve (i.e., highest AuC value). The observed frequency distribution of generated by grouping participants based on the permutation that yielded the highest AuC value was compared to the expected frequency distribution of participants using a chi-square goodness of fit test. A rANOVA was conducted to further evaluate differences in discounting between the permutations of reinforcement magnitude in each group of participants. Subsequently, a repeated-measures *t*-test was used to analyze whether significant differences were present between the highest AuC value and the second highest AuC value in each group.

RESULTS

Participants' median subjective values for each permutation of reinforcement magnitude are displayed in Figure 1. Subjective values for quantity and volume permutations decayed to a lesser extent across delays to reinforcement than the duration permutation of reinforcement magnitude. The quantity and volume permutations yielded nearly identical discounting curves. Divergence in the discounting curves was most apparent at delays greater than one month; the greatest range in subjective values occurred at the 5-year delay (range = 0.1630).

Participants' mean AuC measures were used to assess the extent to which the three discounting curves showed statistically significant differences from one another (see Figure 2). The quantity and volume permutations yielded nearly identical mean AuC measures (M_Q = 0.5420, s = 0.1810, M_V = 0.5407, s = 0.2001). The duration permutation yielded the lowest mean AuC measure (M_D = 0.4481, s = 0.1770). The data fit all assumptions for parametric analyses.

The initial results from the rANOVA demonstrated that significant differences were present in the mean AuC measures, $F = 15.14$, $p < 0.001$. Furthermore, these differences represented a medium effect size, $\eta^2 = 0.05$ (Cohen, 1988). Planned post-hoc analyses (repeated-measure t statistic with adjusted alpha, $\alpha = 0.025$) showed significant differences between the quantity and duration permutation ($t = 4.78$, $p < 0.001$) and the volume and duration permutation ($t = 4.82$, $p < 0.001$).

The median subjective values across participants were used to generate hyperbolic discounting functions according to Mazur's (1987) single-parameter model. Figure 3 displays the discounting functions produced for each of the three permutations of reinforcement magnitude. The representative functions for the quantity and volume permutations yielded discounting models with k-values of 0.0463 and 0.0366, respectively. In comparison, the discounting function for the duration permutation yielded a relatively higher k-value, 0.0943. Each of the three discounting functions accounted for greater than 90 percent of the variance when compared to the actual median subjective values observed (see Figure 4 for R^2 values and comparisons to actual subjective values).

The final analyses evaluated the extent to which participants could be grouped according to the permutation that yielded the highest AuC (i.e., least discounting). The observed distribution of participants across the three groups – quantity, volume, and duration – significantly differed from the expected frequency distribution ($X^2 = 8.805$, $p < 0.05$). The quantity permutation produced the highest AuC measure for 27 participants (40% of sample), the volume permutation produced the highest AuC measure for 29 participants (43% of sample), and the duration permutation produced the highest AuC measure for 11 participants (16% of sample). Within each group, a rANOVA was conducted to determine the extent to which mean AuC measures significantly differed from one another (ps < 0.001; see Table 2). Furthermore, follow-up repeated-measures t-tests all yielded significant differences (ps < 0.001) between the highest AuC value and second highest AuC value in each group. Thus, each group was characterized by an AuC value that was significantly higher than at least the next highest AuC value. Figure 5 displays the AuC measures for each group as well as the hyperbolic functions for each permutation of reinforcement magnitude for each group. This set of analyzes highlighted the fact that, though the general response patterns yield the highest AuC values for the quantity and volume permutation and the lowest AuC value for the duration permutation (a response pattern describing approximately 83% of our sample), this was not necessarily the case for all participants. That is, for 16% of participants, the duration permutation yielded the highest AuC value. Thus, we identified idiosyncratic differences across the permutations of reinforcement magnitude.

DISCUSSION

The current study found that the permutation of reinforcement magnitude was a significant variable in determining the rate at which participants discounted delayed access to hypothetical money. In general, quantity and volume permutations yielded the shallowest discounting curves (i.e., the delayed reinforcer retained relatively more of its subjective value), whereas the duration permutation yielded the steepest discounting curve (i.e., the delayed reinforcer retained relatively less of its subjective value). However, the current study also found significant idiosyncratic deviations from the general response patterns. For the majority of participants (n = 56, 83%) the quantity or volume permutation yielded the greatest resistance to decay in subjective value of the delayed reinforcer. Nonetheless, for a proportion of the participants (n = 11, 16%), the duration permutation yielded the greatest resistance to decay in subjective value of the delayed reinforcer.

The results of the current study expand upon findings from that of previous studies that have investigated changes in discounting rates across parameters of reinforcement. For example, Weatherly and colleagues (2010) examined the extent to which different commodities (i.e., a quality of reinforcement) yielded different discounting rates using a within-subjects design. College-aged participants responded to sets of discounting scenarios, via a fill-in-the-blank method similar to that used in the current study, consisting of (a) money ($1,000 and $100,000), (b) body image, (c) romantic partners, and (d) cigarettes. The researchers found that participants discounted different commodities differently: The discounting rates (i.e., *k*-values) differed depending on the commodity used in the scenario. Some commodities yielded relatively shallow discounting curves (e.g., romantic partners and body image) whereas other commodities yielded relatively steep discounting curves (e.g., cigarettes). That is, participants assigned relatively greater subjective value to delayed rewards depending on the commodity. The results of the current study expand upon the findings of Weatherly et al. (2010) such that different permutations of reinforcement magnitude yielded different discounting curves for the *same* commodity ($1,000). Some permutations yielded relatively shallow discounting curves (e.g., quantity and volume) whereas other permutations yielded relatively steep discounting curves (e.g., duration). Furthermore, the current study found that the permutation of reinforcement magnitude that yielded the shallowest discounting curve varied from participant-to-participant. Such idiosyncratic analyses were absent in the research by Weatherly and colleagues (2010).

The results of the current study also add to the extant literature concerned with identifying the conditions under which manipulations of reinforcement magnitude yield changes in behavior. Specifically, our findings demonstrate that the permutation used to manipulate reinforcement magnitude exerted independent control over the rate at which subjective values decay in the context of delays to reinforcement. For most participants, quantity and volume permutations resulted in approximately equal decay rates, whereas the duration permutation resulted in an accelerated decay rate. A potential explanation for these findings is that the different permutations may have occasioned differential levels of discriminability (deVilliers, 1977). That is, the effects of changes in reinforcement magnitude are likely related to the extent that such changes are readily discernable.

Quantity and volume permutations may result in increased subjective values because the immediately available and delayed magnitudes of reinforcement are more discriminable. For quantity and volume permutations, the discrimination of differences in magnitude can occur at any point. For example, a small quantity of money is immediately distinguishable from a large quantity of money. In contrast, for duration permutations, the opportunity to discriminate a short duration of access to reinforcement from a long duration of access to reinforcement cannot occur at any point in time. Rather, an organism must have experience with the passage of time before an opportunity for discrimination is available. Relatedly, researchers have found that manipulations of reinforcement duration exert stronger and more consistent effects on behavior when duration-specific discriminative stimuli are paired with the delivery of reinforcement (e.g., Harman & Moore, unpublished manuscript; Mariner & Thomas, 1969). That is, when a discriminative stimulus (e.g., red or green light) accompanies a duration of reinforcement (e.g., 50 s or 55 s), changes in reinforcement duration have more reliable and robust effects. The presence of a discriminative stimulus exerts these effects as it allows an organism to more immediately and reliably discern a duration of reinforcement that is available for responding.

It’s also possible that participants were differentially sensitize to subtle changes in the magnitude of reinforcement in the quantity condition and volume condition, and less sensitive to changes in the amount of time in the duration condition. (i.e., the different permutations yielded different just noticeable difference thresholds). For example, if a participant preferred to 750 dollars now to 1000 dollars in 1 month, that would require the participant to adjust the (a) quantity slider by 250 units (i.e., from $1000 to $750 via one-dollar intervals), (b) the volume slider by 1075 units (i.e., from 4.300” to 3.225” via 0.001” intervals), and (c) the duration slider by 25 units (i.e., from 100 s to 75 s). Using the metrics of the current study, the discriminability of a change in reinforcement magnitude may not be equal across the permutations of reinforcement magnitude (deVilliers, 1977). Participants in the present investigation did not receive programmed opportunities to experience different durations of reinforcement, nor is it clear whether participants could discriminate differences in durations to the same extent as differences in quantities or volumes. Taken together, inaccurate discriminations among durations may explain why this permutation yielded subjective values that decayed at an accelerated rate in the current study.

The delay discounting patterns for the duration permutation also may have differed from those of the other magnitude permutations based on uncertain outcomes. For example, if a participant selected to receive 20 s in the Money Tornado, the amount of money earned would be dependent on his or her ability to rapidly collect money while in the Money Tornado. Although the current study included pre-condition instructions for participants to *assume* that they could collect two five-dollar bills per second, the fact that most participants (83%) assigned relatively lower subjective values to duration permutation could be explained by (a) a lack of attending to the relevant instruction, or (b) assumptions of less-than optimal responding while in the hypothetical Money Tornado. In the context of a delay-discounting paradigm, uncertainty concerning the magnitude of the immediate or delayed reinforcer could increase the rate at which subjective values decay. For example, Cox and Dallery (2016) compared hypothetical scenarios that incorporated delays to certain reinforcement and delays to uncertain reinforcement. The researchers used a repeated-measures design to assess the extent to which systematic changes in the certainty of a delayed reward (i.e., 10% certainty to 100% certainty) affected the rate at which participants discounted the value of a delayed reward across five delays (1 day – 5 years). The steepness of participants' discounting curves (i.e., *k* values) were negatively correlated with the certainty of obtaining a delayed reward. That is, as more uncertainty was introduced to the delivery of the delayed reward, participants assigned relatively decreased subjective value to the delayed reward which resulted in steeper discounting curves (i.e., greater *k* values). Thus, one potential explanation for the relatively higher discounting rate in the duration permutation in the present investigation is that participants' subjective values of delayed durations of reinforcement may have been controlled by both temporal variables and probabilistic variables (Cox, Dallery, 2016; Myerson & Green, 2004; Ostaszewski, Green, & Myerson, 1998; Rachlin, Raineri, & Cross, 1991). The subjective values may have decayed at a relatively higher rate because the amount of money earned in the hypothetical Money Tornado was uncertain.

It also may be possible to explain the finding that, for some participants (16%), the duration permutation yielded relatively higher subjective values. For example, a lack of attending to relevant instructions may have led to assumptions concerning participants' hypothetical reaction times while in the Money Tornado or probability of obtaining more money than possible in the other magnitude permutations. It's possible that the perceived uncertainty in reward magnitude increased the subjective value of the delayed duration of reinforcement relative to the delayed quantity and volume of reinforcement (cf. risk-prone, risk-averse: Mazur, 2004). For example, Mishra and Lalumière (2017) presented adult participants – self-identifying as problem gamblers (risk prone) or non-problem gamblers (risk averse) – with two types of probabilistic scenarios. One of the two tasks completed by participants was the Balloon Analogue Risk Task (BART) in which participants clicked a button on a keyboard that resulted in a virtual balloon inflating on a computer screen. The balloon was programmed to "pop" after a random number of clicks (average: 65 clicks). Every successful click resulted in gaining points exchangeable for actual money. Clicks that popped the balloon resulted in the loss of all accumulated points. Participants could collect their accumulated points at any time during the BART by clicking a second button labeled, COLLECT. The researchers found negative correlations between *k*-values in probabilistic discounting scenarios and the number of clicks in the BART in both groups. That is, preference for the certain smaller outcome (i.e., non-risky responding) was negatively correlated with the number of clicks in the BART. These findings suggest that associating greater subjective value to uncertain hypothetical outcomes may be an indicator to making risky decisions. In relation to the current study, for the 16% of participants who had the shallowest discounting curve for the duration permutation, it is possible that perceived uncertainty in outcome increased the subjective value of the delayed reward. Though the current study did not use methods to measure preference for certain and uncertain outcomes (i.e., systematic manipulations of certainty), it's possible that the participants who had the shallowest discounting curves for the duration permutation were engaging in risky decision-making behavior similar to the BART in Mishra and Lalumière (2017). Nonetheless, it remains an empirical question as to the extent to which subjective values for durations of reinforcement correlate to measures of risky decision making. Future researchers might find it beneficial to assess correlations between

BART measures and delay discounting rates in the context of uncertain delayed outcomes, particularly when the magnitude of reinforcement for outcomes includes a duration permutation.

The current study contained several limitations. The first limitation is that the selected commodity in the current study (i.e., money) likely has a lengthy history of pairing with one of our selected permutations of reinforcement magnitude (i.e., quantity). That is, it is likely that most of our participants have had the opportunity to practice differentiating between quantities of money prior to the experiment. In comparison, participants may have less frequent opportunities to practice differentiating between stack sizes (i.e., volume) of money or durations of time to collect money. Nevertheless, our results showed that participants had similarly shallow discounting curves for quantity and volume. Thus, more frequent exposure to a permutation of reinforcement magnitude alone does not likely account for the results.

A second limitation to the current study is that it used hypothetical choices to measure changes in the subjective value of a reinforcer. Although previous research has demonstrated that approximately equivalent results are found when comparing hypothetical and experiential rewards (Johnson & Bickel, 2002), it remains an empirical question if this same finding will occur between verbal descriptions of a permutation of reinforcement and physical artifacts of the permutation of reinforcement magnitude. Investigations may address this question by having participants complete the hypothetical money procedure via the computer program and then complete a version of the hypothetical money procedure *in vivo*. For example, participants could be presented different stacks of money and delays to reinforcement and asked to create a stack of money they perceive to be subjectively equivalent to the stack of money available after the specified delay.

Researchers also may find it beneficial to extend the current study's methodology and findings to other procedures designed to measure differences in the subjective value of a reinforcer. For example, the value of a reinforcer in applied studies is often determined by measures of responding to commodities that the individual accesses in their environment (e.g., food, leisure items; Roane, Lerman, Vorndran, 2001). The value of these commodities are evaluated within a progressive-ratio (PR) schedule. During a PR schedule, the response requirement to access reinforcement is increased following each consumption of the reinforcer. For example, after an individual completes one math problem and consumes the reinforcer, the requirement to obtain access to that reinforcer may increase to two, then four, then six math problems (e.g., Chance, 2014). The response requirement often increases arithmetically (e.g., an increase in the response requirement by 2 following reinforcement) or geometrically (e.g., doubling the response requirement following reinforcement) until the individual stops responding or no longer completes the required number of responses to access the reinforcer (e.g., Roane, Lerman, & Vorndran, 2001). The PR schedule at which responding ceases to occur is referred to as a break point (Chance, 2014). Break points have been used to determine the value of different quantities (e.g., quantities of an edible; Tiger et al., 2010), volumes (e.g., volume of sucrose solution; Rickard, Body, Xhang, Bradshaw, & Szababi, 2009) and durations of access to reinforcement (e.g., duration of time to access tangible items; Trosclair-Lasserre, Lerman, Addison, & Kodak, 2008).

It is possible that PR break points in applied studies and the changes in subjective value of a commodity identified in delay discounting studies provide similar types of information regarding the value of a commodity under changing contingencies of reinforcement (e.g., response requirement, delay to reinforcement). Thus, the behavioral mechanisms controlling responding in delay-discounting and PR-schedule procedures may overlap. Findings from comparisons of these procedures may (a) highlight the extent to which similar behavioral mechanisms control responding in each procedure, (b) demonstrate the effects of different permutations of reinforcement magnitude on responding in other contexts, and (c) help to develop a feasible assessment method to account for idiosyncratic differences in the control exerted by different permutations of reinforcement magnitude.

In conclusion, results of the current study indicate that the permutation of reinforcement magnitude is a significant determinate of the rate at which hypothetical, delayed monetary rewards decay in subjective value. Whereas some research has found that individual discounting rates tend to remain relatively stable in the context of a singular commodity (Weatherly et al. 2010), the present investigation found significant differences among discounting curves for the same commodity manipulated across three permutations of reinforcement magnitude. Taken together, observed measures of delay discounting should be interpreted in the context of (a) the commodity of reinforcement (Weatherly et al., 2010) and (b) the permutation of reinforcement magnitude. A lack of attending to the commodity of reinforcement and the permutation of reinforcement magnitude may lead researchers to make faulty predictions of future behavior (e.g., pathological gambling, substance use; Petry, 2001) based on measures of delay discounting that are artifacts of experimental parameters and are not necessarily representative of behavioral decision making.

Figure 1. Participants' median subjective values across permutations of reinforcement magnitude.

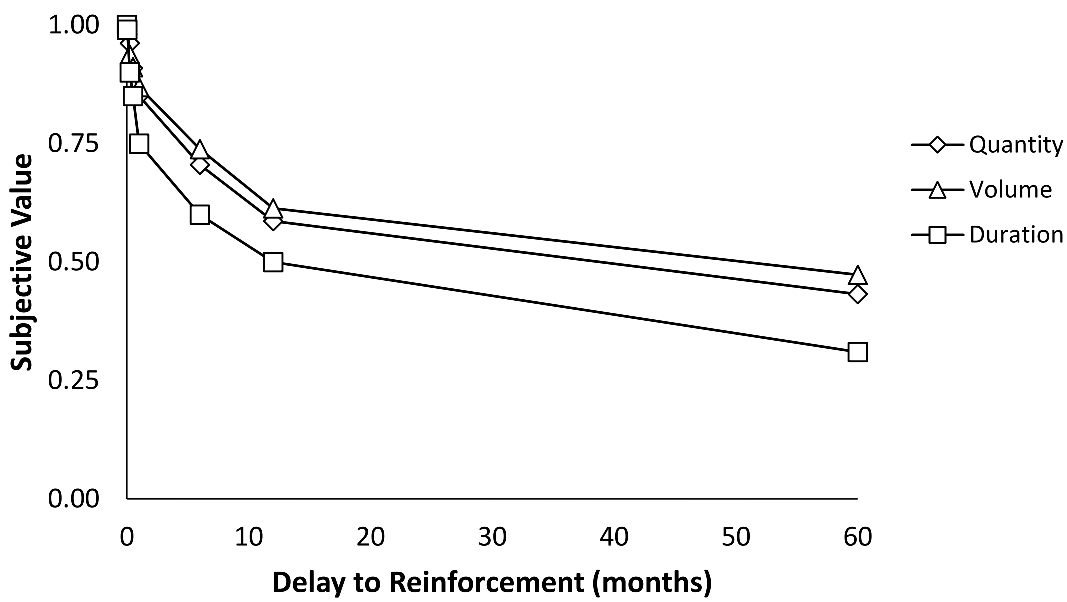
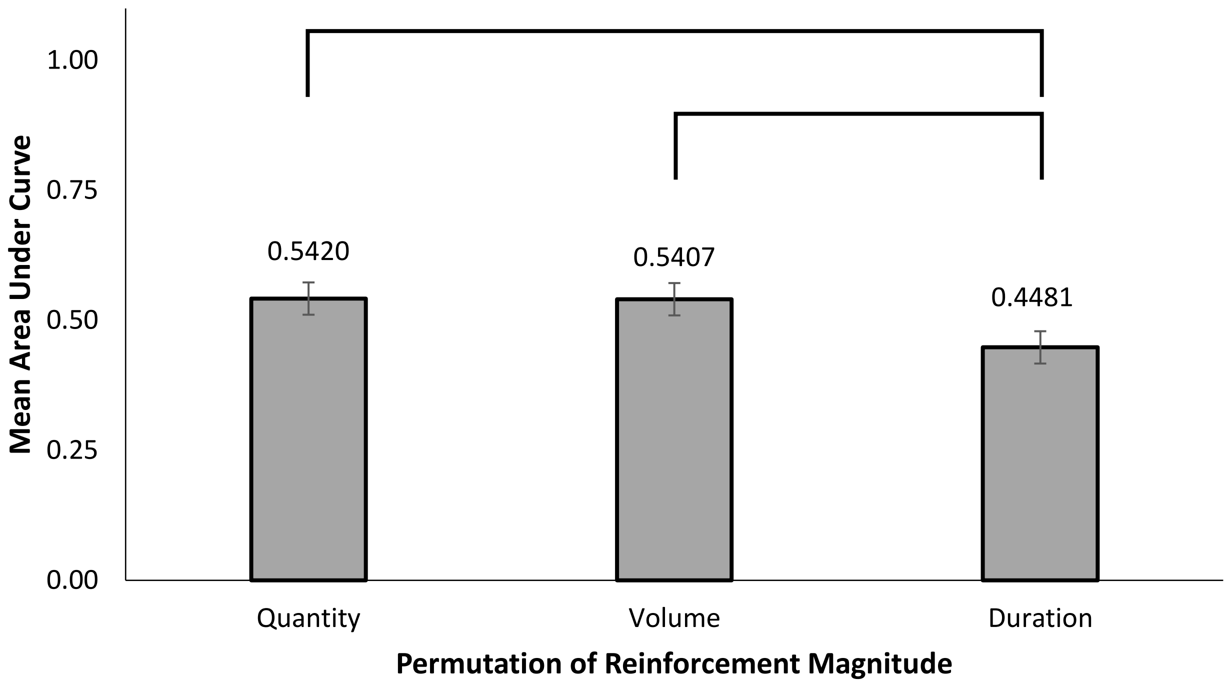


Figure 2. Mean area under curve across participants and permutations of reinforcement magnitude.



Note: The brackets indicate significant post-hoc comparison ($p < 0.001$).

Figure 3. Model-generated discounting curves across permutations of reinforcement magnitude.

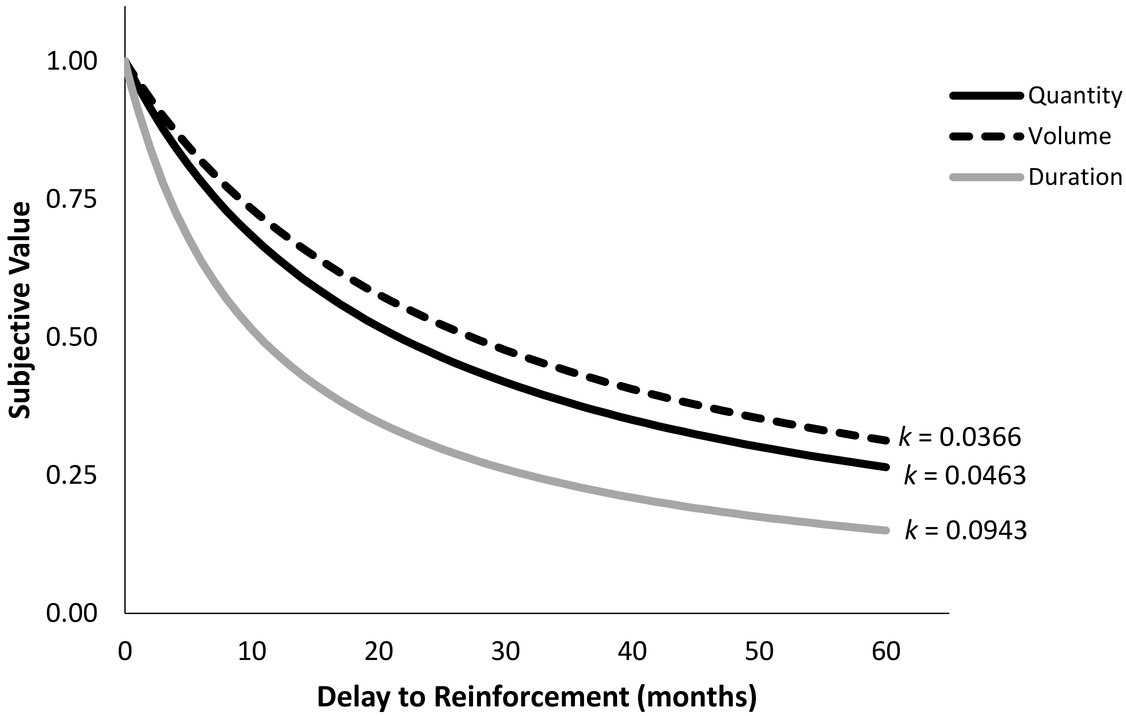


Figure 4. Comparisons between actual subjective values and model-derived subjective values across permutations of reinforcement magnitude.

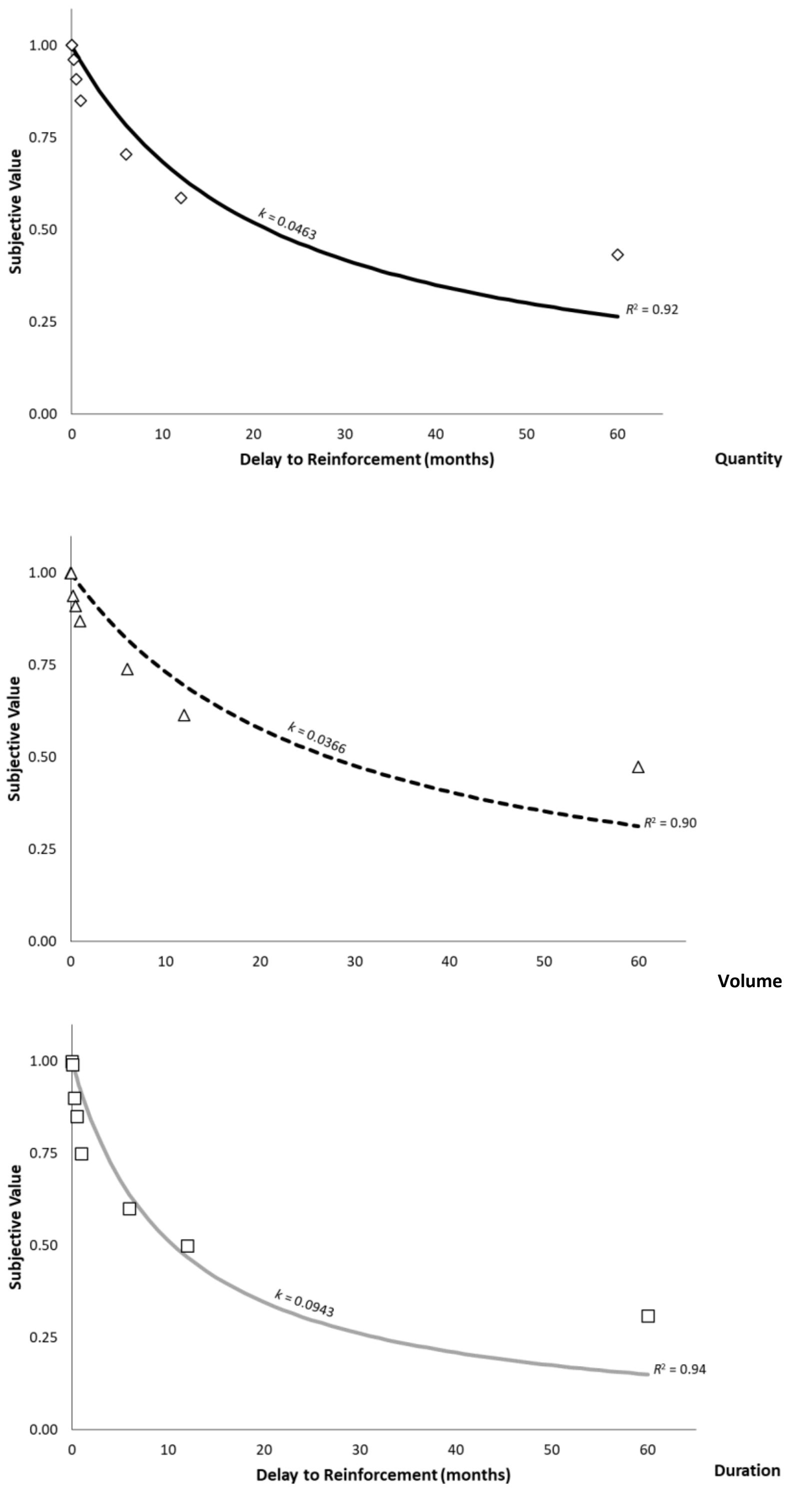
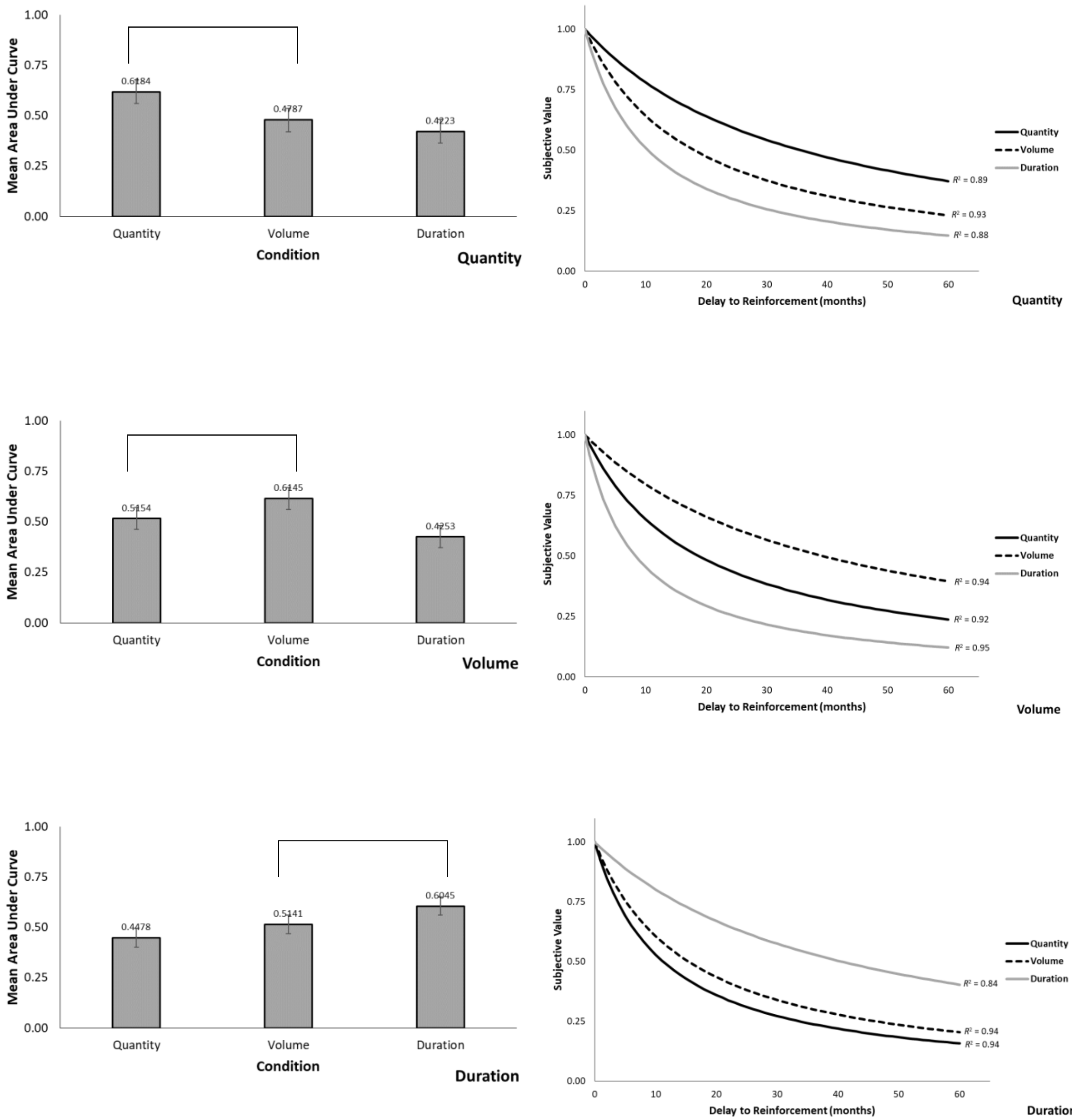


Figure 5. Group-level mean area under curve measures and discounting functions across permutations of reinforcement magnitude.



Note: The top, middle, and bottom panel displays the AuC measures (right) and hyperbolic discounting functions (left) for the three permutations of reinforcement magnitude for participants belonging to the Quantity group (n = 27), Volume group (n = 29), and Duration group (n = 11), respectively. The brackets indicate significant ($p < 0.001$) post-hoc findings between the highest AuC value and the second highest AuC value.

Table 1. Instructions for conditions in hypothetical money procedure.

Condition	Instructions
Quantity	Imagine that you have been award $1000 dollars as a lottery prize. You will have the opportunity to select between different amounts of money you'd prefer to receive now, instead of waiting to receive your full $1000 lottery prize.
Volume	Imagine that you have randomly been awarded a 4.3-inch stack of one-dollar bills. You will have the opportunity to choose different heights of stacks of one-dollar bills you'd prefer now instead of waiting to receive the 4.3-inch stack of one-dollar bills. Assume that the height of a singular one-dollar bill is 0.0043 inches.
Duration	Imagine that you have been awarded the opportunity to spend 100 seconds in a cash machine (e.g., Money Tornado). This machine contains 200 five-dollar bills ($1000 total). While in the machine, you can grab as much money as possible. You will have the opportunity to choose amounts of time to spend in the machine now instead of waiting to spend 100 seconds in the machine. Assume that you can grab 2 bills per second.

Note: For each condition, the maximum sum of money that can be selected is $1000 (Quantity: 1000 one-dollar bills = $1000; Volume: 4.3 inches of one-dollar bills = $1000; Duration: 2 five-dollar bills per second x 100 seconds = $1000).

Table 2. Comparisons of subjective values and area under curve measures.

Group*	Condition	Median Indifference Values: 0 Days	1 Day	1 Week	2 Weeks	1 Month	6 Months	1 Year	5 Years	AUC	Initial Statistic	Post-hoc Statistic
Overall (n = 67)	Quantity	1.00	1.00	0.96	0.91	0.85	0.71	0.59	0.43	0.54	$F = 15.14$	
	Volume	1.00	1.00	0.94	0.91	0.87	0.74	0.61	0.47	0.54	$p < 0.001$	
	Duration	1.00	0.99	0.90	0.85	0.75	0.60	0.50	0.31	0.45	$\eta^2 = 0.05$	
												1st vs. 2nd
Quantity (n = 27)	**Quantity**	**1.00**	**1.00**	**0.95**	**0.91**	**0.86**	**0.75**	**0.68**	**0.50**	**0.62**	$F = 36.04$	$t = 5.097$
	Volume	1.00	1.00	0.93	0.85	0.82	0.74	0.54	0.38	0.48	$p < 0.001$	$p < 0.001$
	Duration	1.00	0.97	0.90	0.81	0.67	0.60	0.53	0.30	0.42	$\eta^2 = 0.16$	$d = 0.770$
Volume (n = 29)	Quantity	1.00	1.00	0.98	0.93	0.85	0.69	0.55	0.42	0.52	$F = 40.41$	$t = 5.338$
	Volume	**1.00**	**1.00**	**0.98**	**0.96**	**0.93**	**0.78**	**0.70**	**0.49**	**0.61**	$p < 0.001$	$p < 0.001$
	Duration	1.00	0.99	0.92	0.87	0.75	0.59	0.40	0.30	0.43	$\eta^2 = 0.20$	$d = 0.578$
Duration (n = 11)	Quantity	1.00	1.00	0.92	0.90	0.77	0.60	0.50	0.32	0.45	$F = 17.91$	$t = 3.885$
	Volume	1.00	0.92	0.88	0.91	0.88	0.68	0.50	0.39	0.51	$p < 0.001$	$p = 0.001$
	Duration	**1.00**	**1.00**	**0.96**	**0.87**	**0.80**	**0.75**	**0.75**	**0.50**	**0.61**	$\eta^2 = 0.11$	$d = 0.447$

Note: Participants were grouped based on the permutation of reinforcement magnitude that yielded the highest AuC value with respect to other permutations. Participants' AuC values were greatest for the quantity permutation in the Quantity group; participants' AuC values were greatest for the volume permutation in the Volume group; participants' AuC values were greatest for the duration permutation in the Duration group. Data in the initial statistic column refers to the outcomes of the initial rANOVA. The post-hoc statistic column displays data from the follow-up repeated-measure *t*-test comparing the highest AuC group and second highest AuC value in each group.

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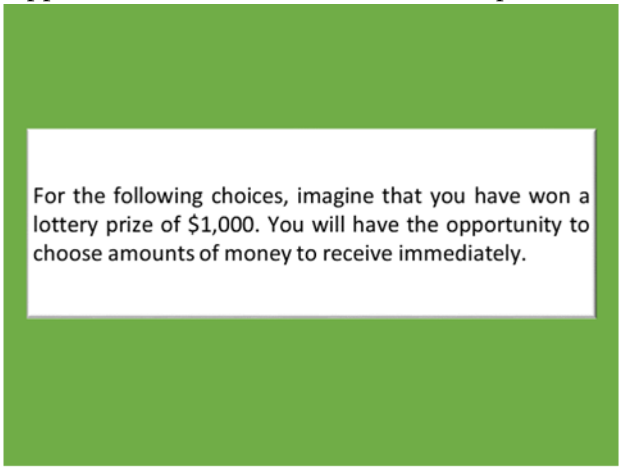
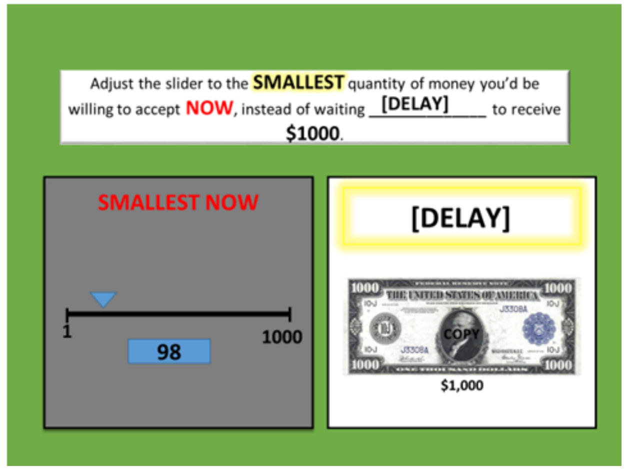
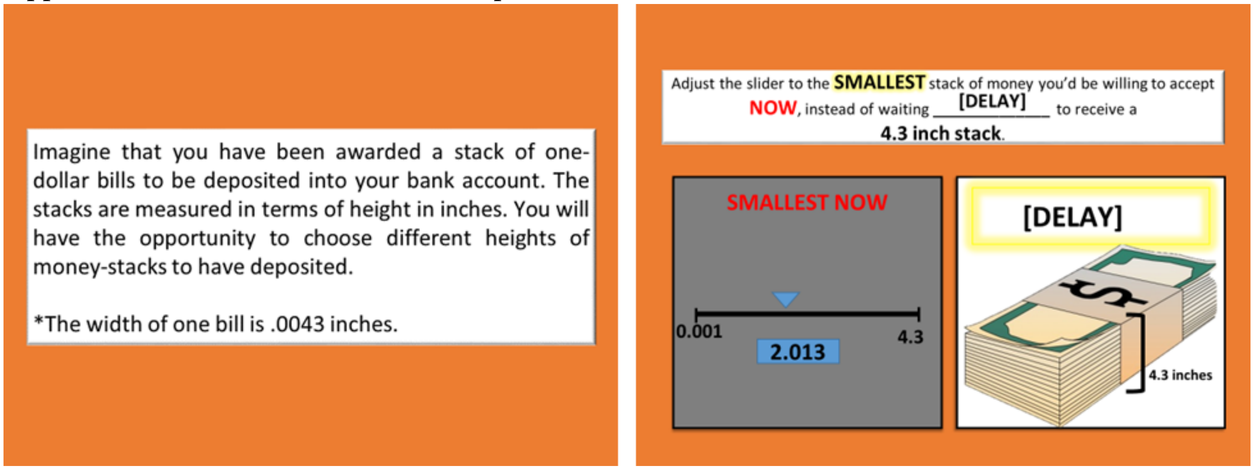
APPENDICES

Appendix A. Instructions slide and response interface for Quantity condition.

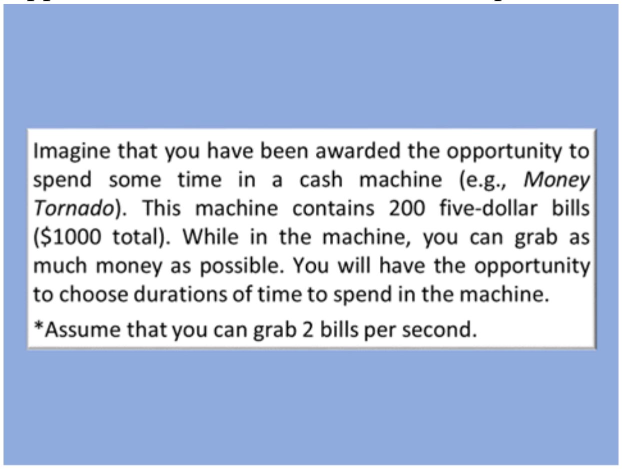


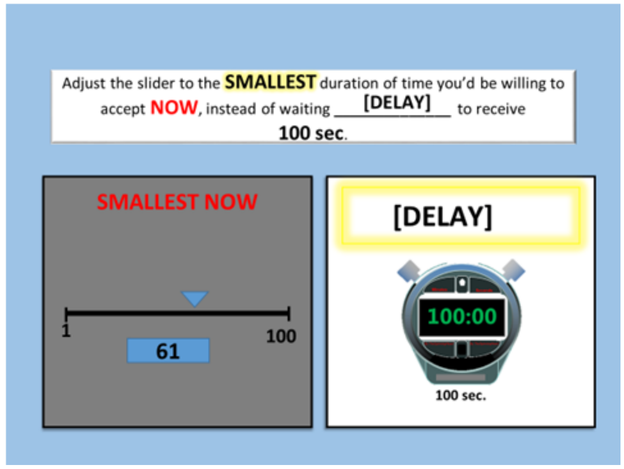


Appendix B. Instructions slide and response interface for Volume condition.

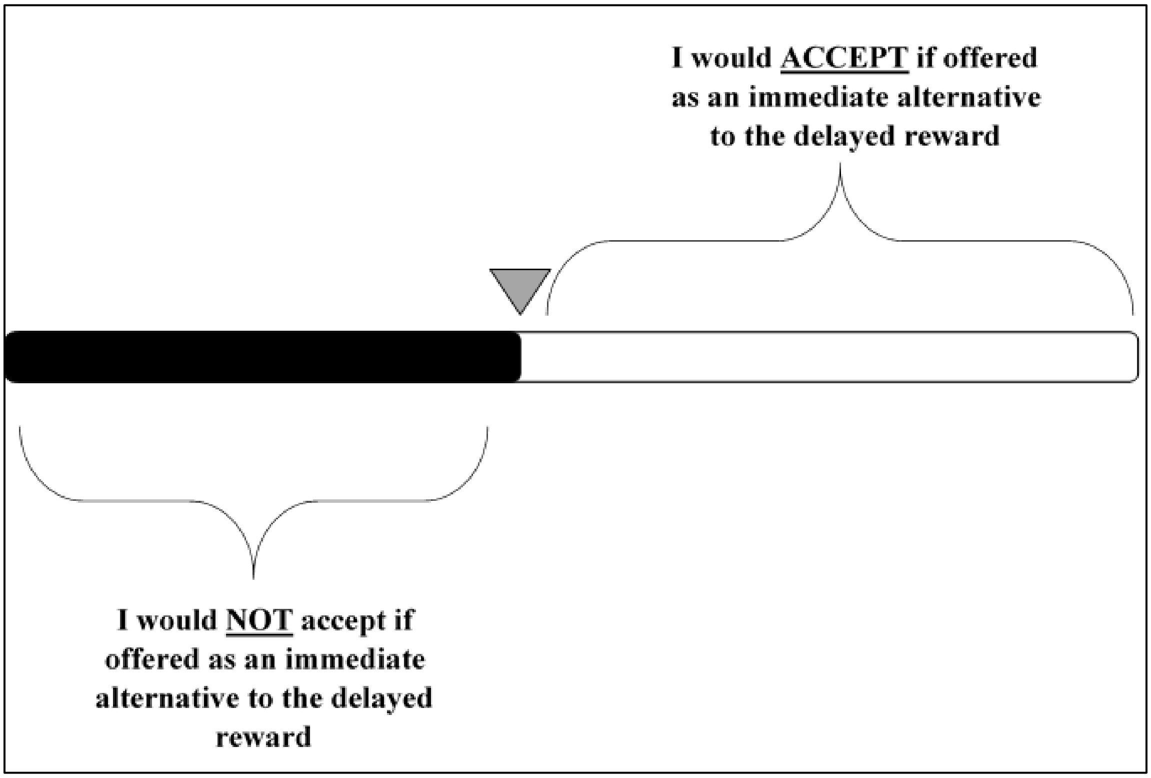


Appendix C. Instructions slide and response interface for Duration condition.





Appendix D. Slider cheat sheet.



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Courses Taught: Cardinal Stritch University, Milwaukee campus

PSYCH 309 Psychopathology, *Lecture*
PSYCH 308 Personality Psychology, *Lecture*
PSYCH 190 Developmental Psychology, *Lecture*
PSYCH 101 General Psychology, *Lecture*

Courses Taught: University of Wisconsin-Milwaukee

PSYCH 101 Introduction to Psychology, *Lecture*

Guest Lecturer

PSYCH 502 Applied Behavior Analysis
PSYCH 714 Conditioning and Learning

***Teaching Assistant*:** 2014-2016

PSYCH 502 Applied Behavior Analysis, *Laboratory*
PSYCH 210 Quantitative Methods in Psychology, *Discussion*
PSYCH 514 Conditioning and Learning, *Laboratory*

Professional Applied Research Experience

(2018-) Program Director of Behavior Analysis at Briar Cliff Univ.
(2017-2018) Early Intervention Lead Therapist, Center for Language Acquisition and Social Skills and Kodak Early Intervention Laboratory, Univ. of Wisconsin-Milwaukee

(2016-2018) Associate Research Analyst: Consulting Office of Research & Evaluation, Univ. of Wisconsin-Milwaukee

Other Professional Experience

(2013-2014) Program Assistant: Academic Support Services, Univ. of Wisconsin-Milwaukee
(2013-2014) Supplemental Instruction Leader, Univ. of Wisconsin-Milwaukee

Internships

(2012 – 2013) Undergraduate Teaching Internship, Univ. of Wisconsin-Superior

Appointments

(2016-2017) President, Association of Students in Behavior Analysis (UWM)
(2015-2017) President, Association of Graduate Students in Psychology (UWM)
(2014-2015) Vice President, Association of Graduate Students in Psychology (UWM)

Research Publications – *Submitted for Publication, In Prep & Manuscripts*

Submitted for Publication

Harman, M., & Moore, J. Effects of Reinforcement Parameters on Preference for an Increased Magnitude of Reinforcement in Pigeons. Manuscript submitted for publication in *The Psychological Record.*
*Under Review

Kodak, T., Bergmann, S., Juban, L., Harman, M. J., & Ayazi, M. Examination of the effects of auditory and textual stimuli on response latency and accuracy during a math task and tangram puzzle. Submitted to *The Analysis of Verbal Behavior*.
*Under Review

Chapters

In Press

Harman, M. & Kodak, T. (2017). Applied Behavior Analysis. In J. Kreutzer, J DeLuca, & B. Caplan (Eds)., *Encyclopedia of Clinical Neuropsychology*. New York, NY: Springer-Verlag.

Presentations – *Symposia, Posters, & Invited Talks*

Symposia

Harman, M., Kodak, T., & McKerchar, T. (2018, May). Effects of Three Permutations of Reinforcement Magnitude on Measures of Delay Discounting. Symposium presented at the Association for Behavior Analysis International 44th Conference, San Diego, California.

Olsen, M., Halbur, M., Kodak, T., Davies, H. & Harman, M. (2018, May). An Analysis of Parents' Preference for Graph Topography. Symposium presented at the Association for Behavior Analysis International 44th Conference, San Diego, California.

Bergmann, S., Harman, M., & Kodak, T. (2018, May). Comparing the Efficacy and Efficiency of Procedures to Teach Auditory Discriminations: Effects of the Differential Outcomes Procedure on Auditory Discriminations. Symposium presented at the Association for Behavior Analysis International 44th Conference, San Diego, California.

Costello, D., Kodak, T., Harman, M., & Van Den Elzen, G R. (2018, May) Training and Generalization of Yes and No Responding Across Operants. Symposium presented at the Association for Behavior Analysis International 44th Conference, San Diego, California.

Harman, M., Kodak, T., & McKerchar, T. (2018, April). Effects of Three Permutations of Reinforcement Magnitude on Measures of Delay Discounting. Symposium presented at the 20th Annual Research Symposium of the Association of Graduate Students in Psychology, Milwaukee, Wisconsin.

Bergmann, S., Kodak, T., Vladescu, J., & Harman, M. (In prep). Establishing Quality Standards for Applied Behavior Analytic Skill-Acquisition Interventions: A Translational Model with Undergraduate Students. Symposium presented at the 20th Annual Research Symposium of the Association of Graduate Students in Psychology, Milwaukee, Wisconsin.

Harman, M., Kodak, T., & McKerchar, T. (2018, March). Effects of Three Permutations of Reinforcement Magnitude on Measures of Delay Discounting. Symposium presented at the University of Wisconsin-Milwaukee Behavior Analysis Colloquium Series, Milwaukee, Wisconsin.

Bergmann, S., Kodak, T., Van Den Elzen, G.R., Cliett, T., Harman, M., & Wood, R. (2017, May). Matrix Training: Considerations for Recombinative Generalization and Efficiency of Acquisition. Symposium presented at the Association for Behavior Analysis International 43rd Conference, Denver, Colorado.

Halbur, M., Kodak, T., LeBlanc, B., Bergmann, S., & Harman, M. (2017, May). An Examination of Treatment Integrity Criteria: Comparison of Training Outcomes Using Different Mastery Criteria. Symposium presented at the Association for Behavior Analysis International 43rd Conference, Denver, Colorado.

Harman, M., Kodak, T., Bergmann, S., LeBlanc, B., Baumann, C., Bohl, L., & Van Den Elzen, G. (2017, May). Examining the Role of Verbal Thinking while Responding to a Math Task. Symposium presented at the Association for Behavior Analysis International 43rd Conference, Denver, Colorado.

Harman, M., Kodak, T., Bergmann, S., LeBlanc, B., Baumann, C., Bohl, L., & Van Den Elzen, G. (2017, February). Examining the Role of Verbal Thinking while Responding to a Math Task. Presented at University of Wisconsin-Milwaukee Behavior Analysis Colloquium Series, Milwaukee, Wisconsin.

Harman, M. (2016, February). The Striatum's Role in Positive Reinforcement Learning: Heterogeneity in Action-Outcome and Stimulus-Response Learning. Presented at University of Wisconsin-Milwaukee Behavior Analysis Colloquium Series, Milwaukee, Wisconsin.

Harman, M. & Moore, J. (2015, October). Effects of reinforcement duration and duration-correlated stimuli on preference in pigeons. Presented at University of Wisconsin-Milwaukee Behavior Analysis Colloquium Series, Milwaukee, Wisconsin.

Harman, M., & Moore J. (2015, April). Effects of reinforcement duration and duration-correlated stimuli on preference in pigeons. Presented at the University of Wisconsin-Milwaukee: Association of Graduate Students in Psychology, 17th Annual Research Symposium, Milwaukee, Wisconsin.

Harman, M., & Moore, J. (2014, September). Effects of reinforcement magnitude and presentation on preference in pigeons. Presented at University of Wisconsin-Milwaukee Behavior Analysis Colloquium Series, Milwaukee, Wisconsin.

Posters

Mayland, T., Harman, M., & Kodak, T. (2018, April). *An Experimental Analysis of Verbal Behavior: Effects of Auditory Content, Thinking Aloud, and an Inescapable Context on Measures of Responding in a Math Task.* Poster presented at The University of Wisconsin System Undergraduate Research Symposium, Green Bay, Wisconsin.

Harman, M., Bohl, L., Mayland, T., Farhan, S., & Kodak, T. (2017, November). *An Experimental Analysis of Verbal Behavior: Effects of Blocking Intermediacy Behaviors on the Latency to Respond in a Math Task*. Poster presented at the at Mid-American Association for Behavior Analysis, Milwaukee, Wisconsin.

**Poster competition winner, Applied research Category*

Olsen, M, Kodak, T., Harman, M., & Van Den Elzen, G.R. (2017, November). *An analysis of the effects of Headsprout interactive program and speaker-response training on reading fluency*. Poster presented at the at Mid-American Association for Behavior Analysis, Milwaukee, Wisconsin.

Van Den Elzen, G.R., Bergmann, S., Kodak, T., Cliett, T., Harman, M., & Wood, R. (2017, September). *Matrix training: Considerations for recombinative generalization and efficiency of acquisition.* Poster presented at the at Mid-American Association for Behavior Analysis, Milwaukee, Wisconsin.

Harman, M, Kodak, T., & McKerchar, T. (2017, September). *An Evaluation of Temporal Discounting in a Hypothetical Money Scenario: Effects of Four Common Parameters of*

Reinforcement Magnitude. Poster presented at the 2017 Minnesota Northland Association for Behavior Analysis Conference, Bloomington, Minnesota.

Van Den Elzen, G.R., Bergmann, S., Kodak, T., Cliett, T., Harman, M., & Wood, R. (2017, September). *Matrix training: Considerations for recombinative generalization and efficiency of acquisition.* Poster presented at the 2017 Minnesota Northland Association for Behavior Analysis Conference, Bloomington, Minnesota.

Olsen, M., Halbur, M., Kodak, T., & Harman, M. (2017, September). *An evaluation of parent preference for visual inspection*. Poster presented at the 2017 Minnesota Northland Association for Behavior Analysis Conference, Bloomington, Minnesota.

Harman, M, Kodak, T., & McKerchar, T. (2017, May). *An Evaluation of Temporal Discounting in a Hypothetical Money Scenario: Effects of Four Common Parameters of Reinforcement Magnitude*. Poster presented at the Association for Behavior Analysis International 43rd Annual Conference, Denver, Colorado.

Bohl, L., Mayland, T., Farhan, S., Harman, M., & Kodak, T. (2017, April). *An Experimental Analysis of Verbal Behavior: Effects of Blocking Intermediacy Behaviors on the Latency to Respond in a Math Task*. Poster presented at the 9th Annual Symposium for Undergraduate Research at the University of Wisconsin-Milwaukee, Milwaukee, Wisconsin.

Bohl, L, Harman, M., Bergmann, S., LeBlanc, B. Gorgan, E., & Kodak, T. (2017, April). *An Experimental Analysis of Verbal Behavior: Effects of an Unrelated Auditory Stimulus on the Accuracy and Latency to Respond in a Math Task*. Poster presented at the 31st National Conference for Undergraduate Research, Memphis, Tennessee.

Bergmann, S., Kodak, T., Van Den Elzen, G.R., Cliett, T., Harman, M., Wood, R. (2017, April). *Matrix Training: Considerations for Recombinative Generalization and Efficiency of Acquisition.* Poster presented at the 31st National Conference for Undergraduate Research, Memphis, Tennessee.

Mayland, T., Farhan, S., Harman, M., Bohl, L, & Kodak, T. (2017, April). *An Experimental Analysis of Verbal Behavior: Effects of Blocking Intermediacy Behaviors on the Latency to Respond in a Math Task*. Poster presented at the 19th Annual Association of Graduate Students in Psychology Research Symposium, Milwaukee, Wisconsin.

Harman, M, Kodak, T., & McKerchar, T. (2016, October). *An Evaluation of Temporal Discounting in a Hypothetical Money Scenario: Effects of Four Common Parameters of Reinforcement Magnitude*. Poster presented at Mid-American Association for Behavior Analysis, Wisconsin Dells, Wisconsin.

**Poster competition winner, Basic research Category*

Harman, M & Moore, J. (2016, May). *Effects of Reinforcement Parameters on Preference for an Increased Magnitude of Reinforcement in Pigeons.* Poster presented at the Association for Behavior Analysis International 42nd Annual Conference, Chicago, Illinois.

Benitez, B., Kodak, T., Bergmann, S., LeBlanc, B., Harman, M., & Ayazi, M. (2016, May). *Examination of Auditory and Visual Stimuli on the Accuracy and Latency to Respond in a Mental Arithmetic Task*. Poster presented at the Association for Behavior Analysis International 42nd Annual Conference, Chicago, Illinois.

Harman, M., LeBlanc, B., Bergman, S., Kodak, T., Baumann, C., Bohl, L., & Van Den Elzen, G. (2016, April). *The Effects of Different Auditory Stimuli on the Completion of Math Problems*. Poster presented at the UW-Milwaukee Undergraduate Research Symposium, Milwaukee, Wisconsin.

Harman, M., LeBlanc, B., Bergman, S., Kodak, T., Baumann, C., Bohl, L., & Van Den Elzen, G. (2016, April). *The Effects of Different Auditory Stimuli on the Completion of Math Problems*. Poster presented at the 18th Annual Association of Graduate Students in Psychology Research Symposium, Milwaukee, Wisconsin.

Harman, M & Moore, J. (2015, October). *Effects of reinforcement duration and duration-correlated stimuli on preference in pigeons*. Poster presented at Mid-American Association for Behavior Analysis, Kansas City, Missouri.

**Poster competition winner, Basic research Category*

Harman, M., & Moore, J. (2015, May). *Effects of reinforcement magnitude and magnitude-correlated stimuli on preference in pigeons.* Poster presented at the Association for Behavior Analysis International 41st Annual Conference, San Antonio, Texas.

Harman, M., & Einerson, M. (2013, May). *A constructionalist approach to gender: A response to gender-based conclusions*. Poster presented at University of Wisconsin-Superior Undergraduate Research Day, Superior, Wisconsin.

Harman, M., & Pinnow, E. (2013, April). *Experience of stereotype threats and the effect on imagined self-rotation abilities*. Poster presented Undergraduate Research, Scholarship and Creative Activity Day of Celebration, Superior, Wisconsin

Harman, M., & Pinnow, E. (2013, March). *Experience of stereotype threats and the effect on imagined self-rotation abilities*. Poster presented at Twin Ports Undergraduate Research conference, Superior, Wisconsin.

Harman, M., & Pinnow, E. (2013, March). *A reflection on a course in applied behavior analysis: Application of techniques in a dog shelter*. Poster presented at Twin Ports Undergraduate Research conference, Superior, Wisconsin.

Harman, M., & Pinnow, E. (2011, December). *Imagined self-rotation: Gender and degree of athleticism.* Poster presented at University of Wisconsin-Superior Undergraduate Research Day, Superior, Wisconsin.

Professional Associations

(2017-2018) Minnesota Northland Association for Behavior Analysis – Student Member

(2015-2018) Mid-American Association for Behavior Analysis – Student Member
(2013-2018) Association for Behavior Analysis International – Student Member
(2013-2018) American Psychological Association – Student Affiliate
(2013-2018) Midwestern Psychological Association – Graduate Member
(2013-2018) Wisconsin Association for Behavior Analysis, Inc. – Student Member

Honors and Recognition

(2017-2018) Mid-American Association for Behavior Analysis, Poster Presentation Winner
(2016-2017) UW-Milwaukee Student Excellence Award, Exemplary Leadership
(2016-2017) Mid-American Association for Behavior Analysis, Poster Presentation Winner
(2015-2016) Mid-American Association for Behavior Analysis, Poster Presentation Winner
(2015-2016) UW-Superior Alumni Excellence Recognition
(2014-2015) John and Lynn Schiek Behavior Analysis Stipend Awardee
(2014-2015) Golden Key International Honour Society Inductee
(2014-2015) Outstanding Service Recognition, Academic Support Services
(2014-2015) CRLA International Certification: Level II & Level III
(2014-2015) Excellence in Volunteerism, Academic Affairs: Accessibility Resource Center
(2013-2014) CRLA International Certification: Level I
(2012-2013) Nomination for Spring 2013 Commencement Speaker
(2012-2013) Undergraduate Research Excellence Recognition
(2011-2013) Dean's Honor List, University of Wisconsin-Superior
(2011-2013) Wisconsin Undergraduate Research Celebration Recognition
(2011-2012) National Undergraduate Research Nomination

Awards and Scholarships

John and Lyn Schiek Behavior Analysis Research Award. Harman, M. Awarded to help fund high impact research projects in behavior analysis. 2016.

John and Lyn Schiek Behavior Analysis Stipend. Harman, M. Awarded to doctoral students in high academic standing. 2014.

Women's and Gender Studies Essay Runner-up – *University of Wisconsin Superior*. Harman, M. Awarded to scholarly research in Women's and Gender Studies. 2014.

Swenson Foundation Scholarship Grant. Harman, M. Grant awarded based on collegiate academic merit. 2009-2013.

Conferences Organized

(2017, April) University of Wisconsin-Milwaukee Association of Graduate Students in Psychology 19th Annual Research Symposium
Keynote Speaker: Dr. Brian Kangas, Harvard Medical School

(2016, April) University of Wisconsin-Milwaukee Association of Graduate Students in Psychology 18th Annual Research Symposium

Keynote Speaker: Dr. Lynn Nadel, University of Arizona

(2015, April) University of Wisconsin-Milwaukee Association of Graduate Students in Psychology 17th Annual Research Symposium
Keynote Speaker: Dr. Kevin LaBar, Duke University