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Influence of Increased Options on Performance Generalization Across Two Variations of the Monty Hall Dilemma

Robert A. Southern

INFLUENCE OF INCREASED OPTIONS ON PERFORMANCE GENERALIZATION ACROSS TWO VARIATIONS OF THE MONTY HALL DILEMMA

by

ROBERT SOUTHERN

(Under the Direction of Lawrence Locker)

ABSTRACT

The Monty Hall dilemma (MHD) is a probability puzzle at which humans consistently fail to adopt the optimal winning strategy. The participant chooses between three identical doors, behind one of which is a valuable prize. After the participant makes their initial decision, the host reveals that there is nothing behind one of the two remaining doors, then asks the participant if they would like to stay with their originally selected door or switch to the remaining unopened door. The optimal choice is to switch to the previously unchosen door, which increases the probability of winning from 33% to 67%. Despite this basic solution, humans repeatedly perform suboptimally. Previous attempts to improve performance by increasing the number of available doors have been successful (Burns & Weith, 2004; Franko-Watkins et al., 2003; Saenen et al., 2015; Stibel et al., 2009; Watzek et al., 2018). However, prior studies that examined whether this improved performance could generalize to different contexts have been inconclusive (Franko-Watkins et al., 2003; Watzek et al., 2018). To examine whether human performance can generalize across two computerized variations of the MHD, the present study explored how previous experience involving trials presented with eight options affects switching percentages in subsequent trials with three options. The results failed to replicate findings from previous studies, which demonstrated that rates of switching increased as a function of more available options. Implications of and explanations for this replication failure are discussed. Further exploration of the MHD is needed before definitive conclusions can be made regarding humans' ability to generalize knowledge between task variations.

INDEX WORDS: Monty Hall dilemma, Probability matching, Generalization, Suboptimal choice, Decision making

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ROBERT SOUTHERN

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ROBERT SOUTHERN

Major Professor: Lawrence Locker
Committee: Kent Bodily
Jessica Stagner Bodily
Ty Boyer

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CHAPTER 1:

INTRODUCTION

The Monty Hall dilemma (MHD) is a basic probability puzzle with one optimal strategy that is notoriously challenging for humans. The dilemma originated on the game show “Let’s Make a Deal” hosted by Monty Hall. During the game show, the contestant was presented with three identical options, classically represented by numbered doors. Behind one of these doors was an expensive prize, while the remaining doors were empty. The host asked the contestant to select one of the doors that may contain the prize. After the initial choice was made, the host revealed another door that was not selected by the contestant and did not contain the prize. Then the host presents the dilemma to the contestant by asking whether they would like to stay with the door they initially chose or if they would like to switch to the final unopened door.

To maximize the probability of winning the prize, the contestant should always switch to the remaining door. When the contestant made their initial choice, they had a 33% chance of choosing the door that contained the prize. This outcome is referred to as a “lucky guess.” If the contestant made a lucky guess, the host could open either of the remaining doors since both doors do not contain the prize. By not switching, the contestant would be successful 33% of the time across a given number of trials. Alternatively, if the contestant switched, the likelihood of correctly choosing the door with the prize increased to 67%. An easier way to understand why switching is advantageous is to consider the dilemma when there are 100 doors available instead of just three. If a random door is selected and the host reveals 98 empty doors, the contestant can be almost certain that the prize is behind the unopened door that was not initially chosen. When 100 doors are available, switching results in a prize 99% of the time since the chances that the contestant’s initial choice is a lucky guess is 1%. Therefore, switching to the remaining door is the optimal strategy since any other strategy results in a lower probability of winning on average.

Despite the disparity between the winning probability for staying and switching, humans not only fail to recognize which strategy has the highest overall probability to result in a winning outcome, they repeatedly exhibit a bias for staying with their initial selection (Granberg, 1999). Granberg and Brown (1995) found that repeated exposure through multiple trials improved performance and found that participants began to plateau after approximately 20 trials, switching roughly two-thirds of the time. This plateauing effect in human participants has been observed repeatedly (Granberg & Brown, 1995; Efendic & Drace, 2015; Herbranson & Schroeder, 2010; Herbranson & Wang, 2014; Hirao et al., 2017; Mazur & Kahlbaugh, 2012).

To explore how other species would perform when presented with this dilemma, Herbranson and Schroeder (2010) compared pigeon performance to human performance using a nonverbal, computerized adaptation of this task. Human participants received 200 trials of the MHD with feedback after each trial. Like Granberg and Brown (1995), the participants' switching rates increased steadily until plateauing around 67%. Pigeons initially started with a slightly stronger stay bias, but after 30 training sessions, they developed a strong preference for switching. The pigeons continued performing better than the human participants, even when the researchers reversed the reinforcement contingencies so that staying became reinforced two-thirds of the time. These results indicate that pigeons had greater sensitivity to the reinforcement contingencies, which led pigeons to adopt the optimal strategy more efficiently and reliably than their human participants, even when the contingencies were reversed.

Further studies examined whether this suboptimal tendency was exclusive to humans by testing primates (Klein et al., 2013; Watzek, Whitham, Washburn, and Brosman, 2018) and rats (Stagner & Zentall, 2014). Klein et al. (2013) determined that the monkeys' performance indicated a substantial comparative similarity with human performance. The results of Watzek et al. (2018) also showed considerable similarities between response patterns of capuchin and rhesus macaques to human response patterns in both three-option and eight-option conditions. Stagner and Zentall (2014) concluded that rats, like pigeons, appeared to be influenced more by the overall probability of reinforcement, leading to similar performance between species. Overall, these studies illustrate that almost all subjects, regardless of species, had some difficulty adopting the optimal strategy, but humans seemed to have the most difficulty.

Theoretical Explanations

One explanation for the suboptimal performance by humans is known as probability matching. Probability matching is characterized by choice probabilities that match the pre-programmed probabilities for obtained reinforcement. This propensity to allocate responses based on associated reinforcement probabilities is typical when using probabilistic outcomes (Fantino & Esfandiari, 2002) and frequently results in less reinforcement overall. An example of this phenomenon occurs when participants attempt to predict which colored light (green or red) would appear on an upcoming trial. The participants received a small monetary reward each time they correctly predicted the colored stimulus. In this scenario, the green light appeared on 75% of trials while the red light appeared on the remaining trials. Participants can maximize their chance of success by only selecting green as the light that will appear. However, over time many participants chose green approximately three times more often than red, resulting in response patterns that mirrored the probabilities of reinforcement for each alternative.

Probability matching has a significant overlap with the theory of reinforcement matching, also referred to as the matching law (Herrnstein, 1961; Baum, 1974). The matching law theory states that the proportion of one behavior (B_1) divided by the total amount of behaviors will equal the proportion of reinforcement for one behavior (Rf_1) divided by the total amount of reinforcement. According to matching law, if B_1 results in reinforcement twice as often as B_2, there should be twice as many B_1 responses relative to B_2. Using the colored light example, matching law will predict that participants will choose green directly proportional to the relative ratio of obtained reinforcement following choosing green vs. choosing red. Therefore, matching law and probability matching predict that participants will select the green light on 75% of trials. Regardless of the locus of the pattern of responding, both theories predict that participants would utilize a suboptimal strategy (i.e., choosing green on 75% of trials rather than on all trials).

Increased amounts of anticipated regret have also explained suboptimal performance by humans in the MHD. Participants who experience a loss after switching report higher feelings of regret than losses resulting from staying (Stibel et al., 2009). This finding may also explain why Petrocelli and Harris (2011) discovered that participants often exaggerated the amounts of switch-losses they experienced when asked to estimate the frequencies of loss associated with switching and staying, respectively. This increased aversion to switching due to more anticipated regret following a switch-loss than a stay-loss could explain why humans consistently exhibit a stay-bias. Stibel et al. (2009) attempted to test this hypothesis by randomly selecting the participants' initial choice. Their results showed that participants switched more frequently when their initial selection was randomly determined than participants who freely selected their initial choice. Zentall, Case, and Collins (2015) used a similar methodology of forced initial choices to examine its effect on pigeons' performance. Unlike humans, pigeons that experienced forced initial selections performed worse overall by switching less frequently than pigeons with free selection.

Anticipated regret cannot explain the common misunderstanding of this problem in humans. Still, it can potentially explain the frequently observed stay-bias in human performance, despite reporting incorrect judgments of equivalent probabilities for winning associated with staying and switching. This phenomenon among human participants in the MHD is consistent with an equiprobability bias (Gauvrit & Morsanyi, 2014). Participants falsely report that both options are equally likely to contain the prize when they estimate the probabilities of winning for the two remaining options. Human participants that report equal probabilities should not exhibit a preference for one alternative over another. However, studies have shown that participant behavior reflects a clear preference for staying despite self-reported estimates of probabilities being equal for staying and switching (Franco-Watkins, Derks, and Doughtery, 2003; Granberg and Brown, 1995; Krauss and Wang, 2003; Stibel et al., 2009).

Previous Attempts to Improve Performance

While research has demonstrated that human performance in the MHD can improve through repeated exposure (Granberg and Brown, 1995), typical performance is still well below optimal. Several studies increased the number of options available for selection to provide additional performance improvements (Burns & Wieth, 2004; Franco-Watkins et al., 2003; Saenen et al., 2015; Stibel et al., 2009; Watzek et al. 2018). Increasing the number of available options increases the likelihood that switching will result in reinforcement when all but two options have been eliminated. When three options are available, switching results in reinforcement 67% of the time, but that amount is increased to 87.5% if the available options are increased to eight, and six of the options that were not initially selected are eliminated as options to which participants may switch. Therefore, the contestant should be more likely to switch when more options are added. Saenen et al. (2015) implemented three conditions, each with an increasing number of cups (3/10/50), then compared performance across ten trials. Stibel et al. (2009) examined whether performance on a single trial improved by initially using three boxes for one study and ending with a total of 100 possible boxes available for selection in a follow-up study. Burns & Wieth (2004) increased their total number of options to 128 for a single trial, while Franco-Watkins et al. (2003) implemented doors ranging from a total of three to 10 for three trials. Each study found that switching rates increased as a function of more available options. However, Stibel et al. (2009) found that increased switching rates remained stable, and no significant improvement occurred as additional options were added.

Previous studies have examined whether performance in one variation of the MHD can be generalized to other variations with mixed results. Franco-Watkins and colleagues (2003) found inconsistent effects of generalization, but their results have been criticized for their initial experiments' lack of a control condition. Watzek et al. (2018) attempted to address some of these concerns by testing whether performance from humans, capuchins, or rhesus macaques during a computerized version of the MHD would generalize to another variation of the MHD. Human participants were randomly assigned to a three-option, eight-option, or a control condition and tested using repeated trials during a 60-minute session. Participants in the control condition were given an unrelated computer task for the total testing duration. Once the participants completed testing, they were given a survey-based "one-shot" variation of the MHD adopted from Krauss and Wang (2003), while nonhuman subjects were tested using a contextually-similar computerized variation with three or eight options, depending on the condition. Watzek and colleagues (2018) predicted that subjects (human, capuchin, and rhesus macaques) in the eight-door condition would switch more frequently than subjects in the three-door condition during initial testing. They also hypothesized that participants in the eight-door condition would switch more frequently than other conditions in the one-shot survey-based variation of the MHD.

The study's results found that both human and rhesus macaques showed near-optimal responding patterns, which are highly unordinary, but only 19.8% of participants elected to switch in the one-shot variation of the task. However, generalization was observed in capuchins that experienced the eight-option condition before transitioning to the three-option condition in the computerized version of MHD. The researchers' affirmed their prediction that more frequent switching occurred in the eight-option condition. However, their participants were primarily unable to generalize their knowledge to a verbal MHD variation, with approximately 80% choosing to stay with their initial choice.

The Current Study

The current study expands from the findings of Watzek et al. (2018) by examining whether the generalization effects demonstrated by capuchin monkeys will also occur with human participants. This study utilized a similar methodology that Watzek and colleagues used with the following modifications. First, square stimuli were used to represent doors in the current study instead of the unique arrangement of circular stimuli that were used previously. This modification should ensure that the participants' near-optimal responding tendencies in the previous study were not a result of their novel experimental design. Secondly, Watzek and colleagues (2018) incorporated the natural reinforcement probabilities for staying and switching instead of holding these probabilities constant between three-option and eight-option variations. The current study will maintain consistent reinforcement probabilities across all task variations. This modification eliminates the possibility that performance differences could be attributed to shifting reinforcement probabilities rather than a perceived decrease in the likelihood that their initial choice is correct as a function of experience with an increased number of available options.

Generalization is more likely to occur when two task variations have a high degree of similarity (Sousa, 2016, p. 164). To provide the highest likelihood for generalization to occur, the researchers decided to test participants using two similar variations of the computerized MHD task, instead of one computerized MHD variation and another survey-based, one-shot variation of the dilemma used by both Watzek et al. (2018) and Franco-Watkins et al. (2003). The total number of trials given to each participant in the current study was decreased to 60, compared to the 493 trials participants completed on average in Watzek et al.'s (2018) study. The total number of trials was diminished so that acquisition could be monitored within each phase while drastically reducing completion time.

The most extensive change to the methodology used by Watzek et al. (2018) to demonstrate generalization in capuchins involves stimulus presentation structure. Watzek and colleagues presented the same number of stimuli in each condition while varying the order in which the stimuli were presented. One condition of capuchin subjects received 500 trials of a computerized MHD task with three options in their experiment, followed by 500 trials of a similar task with eight options. The other condition received 500 trials of the eight-option computerized MHD task before receiving 500 trials of the three-option variation. The current study modifies this A-B/B-A design into an A-B-A or A-A-A design for the experimental and control conditions, respectively. The A-phase consists of trials with three options, and the B-phase consists of trials with eight options. This adaptation also provides within-subjects points of comparisons as well as between-subjects comparisons while eliminating any potential order effects that might have been present previously.

Suppose performance improvements generalize despite reinforcement rates remaining constant. In that case, one potential explanation for why this generalization occurs is a change in the participant's perception of their initial choice being correct. During trials with three options available, participants are more likely to perceive their initial choice of having a higher likelihood of being correct (33%) than trials with eight options available (12.5%). This change in perception is expected to occur even though the participants are unaware that the likelihood of a "lucky guess" remains constant in both variations. If participants in the experimental condition switch more frequently in the second phase and continue switching at higher rates in the third phase, this finding suggests that the participants changed their perception regarding the likelihood that their initial choice was a lucky guess. This result would also indicate that this perceptual change was able to generalize to different variations of the dilemma, providing evidence that not only can human performance in this dilemma be improved but that this improvement can be translated into other contexts. If successful, this result would be the first step in demonstrating how improved performance in the MHD can generalize to other scenarios while providing the foundation needed to determine which mechanisms primarily determine how participants respond under uncertainty.

In summary, the present study will expand the previous findings by Watzek et al. (2018) in human participants by examining whether the prior experience with an eight-option computerized variation of the MHD can be generalized to improve performance in a computerized variation with three options. Specifically, if the introduction of more options decreases the perception of the participant's first choice being correct, then participants should switch more frequently when presented with eight options. The researchers predict that participants in the experimental condition should continue to switch more frequently, even after reverting to the three-option variation. This result is expected to occur despite reinforcement rates being held constant. To test these predictions, participants will first experience 20 trials of the classic MHD with three available options. Then participants in the experimental condition will complete the second phase with eight available options for an additional 20 trials before beginning the third phase consisting of 20 final trials, identical to the first phase (i.e., the same classic form of MHD). All reinforcement probabilities for switching (67%) and staying (33%) will remain constant across all phases and conditions. Therefore, any effect on performance can be attributed to manipulating the increased number of options available and not due to changes in reinforcement probabilities.

CHAPTER 2:

METHODOLOGY

Participants

A power analysis was completed using G*Power v. 3.1 (Faul et al., 2009) for a 2 (condition) by 12 (block) mixed analysis of variance (ANOVA). Based on Cohen's (1988, p. 25) recommendations, a conservative estimate was used for the minimum effect size of interest (d = .2). The correlational strength among repeated measures (r = .5) was assumed due to the nature of the task and the responding patterns of participants in similar tasks. The largest correlational discrepancy is expected to be found between the first and last block of trials. A precautionary non-sphericity correction of (ϵ = .5) was assumed to ensure the necessary power can be reached in the event of a violation of the assumption of sphericity. The alpha level was set to .05, and the associated power level was .80. The required sample size needed to reach sufficient power was determined to be 112 participants.

Participants (N = 112) were undergraduate psychology students from Georgia Southern University who participated for course credit. All participants were at least 18 years of age and provided informed consent before beginning the study. At the end of the session, participants were asked to indicate whether they were familiar with the Monty Hall dilemma and its optimal strategy before participating. If the participants answered "Yes" to both questions, their data were excluded from the analysis. Data from participants that indicated familiarity with the MHD but not its optimal strategy were not excluded. Data from one participant was excluded from analyses based upon these criteria, leaving a final total of 111 participants (82 females, 28 males, 1 other)

Materials

The experimental task was programmed using AngularJS version 1.8.0. The program was hosted using Bluehost web hosting services. After a participant registered via SONA Systems, a hyperlink was made available containing information about the informed consent policy and instructions for participants. A link to an external survey was also included so that participants could confirm their participation while their data remained anonymous. This link appeared at the beginning and end of the experiment. Once the participant provided informed consent, the instructions were presented (see Appendix), followed by the experimental trials.

Square stimuli measured 128 pixels, and the center square was located 13 cm from the top of the screen and 21.9 cm from the left-hand side of the screen. Subsequent squares were arranged equidistant from the center square by .635 cm. All measurements were made using a monitor with an aspect ratio of 1920x1080. Precise locations of stimuli varied based on the device used by each participant. When a square was selected, it was indicated by two intersecting lines in the form of an “X” for one second before reverting during the following selection process. Once a selection was made, one to six squares became “revealed” depending on the condition. These revealed squares remained black for the trial’s duration and could not be selected until a new trial began (see Figure 1).

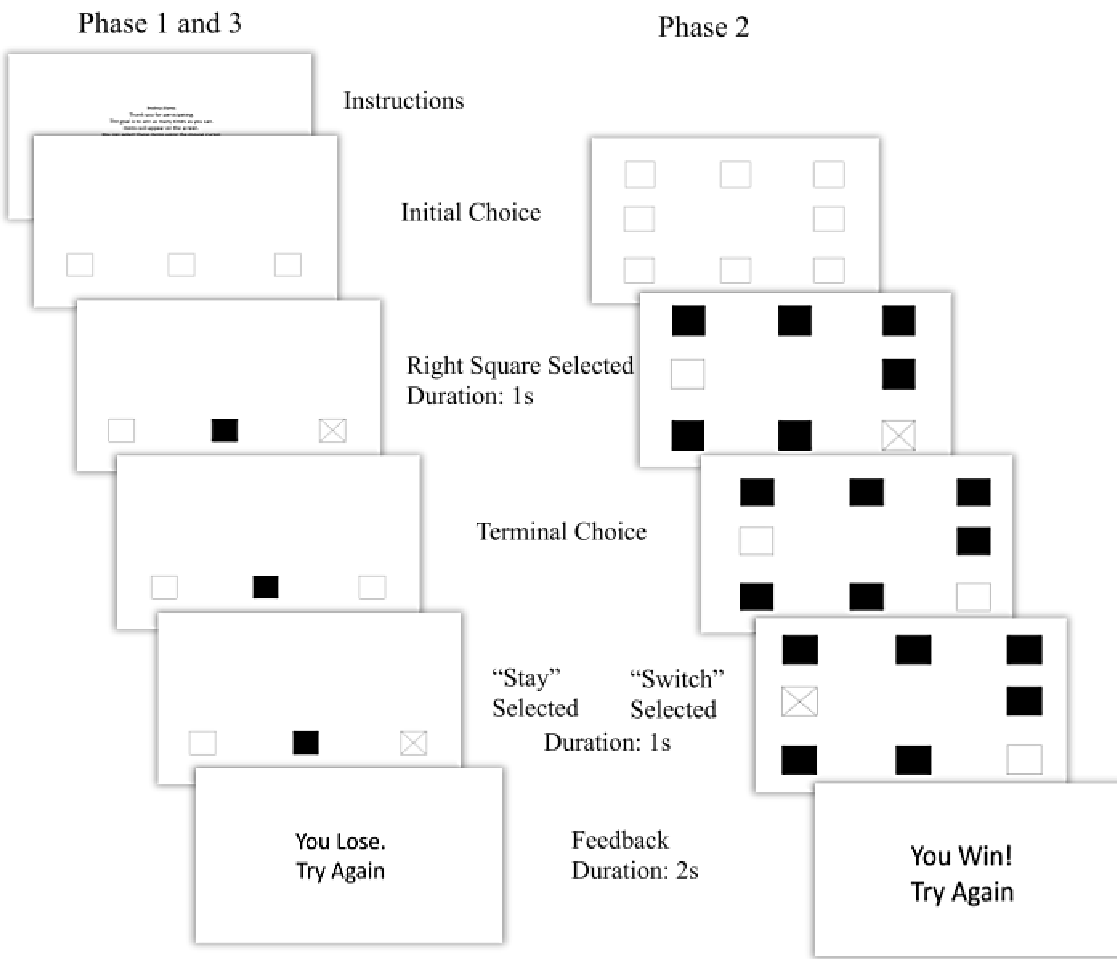

Figure 1. Experimental condition example trials. Black squares denote revealed options and cannot be selected. Intersecting lines represent selected squares. Instructions are only presented before the first trial commences.

Design and Procedure

Participants were randomly assigned to the Experimental Condition or the Control Condition. Participants in the Experimental Condition completed three consecutive phases in a standard A-B-A experimental design. To examine acquisition curves within each phase, all phases consist of 4 blocks for a total of 12 blocks. For the Experimental Condition, the first and third phases included three options for selection, whereas the number of available options increased to eight during the second phase. The number of options available for selection during the terminal choice remained the same regardless of phase. Participants in the Control Condition experienced three identical phases of trials with three options for selection across all trials. All participants were informed of their rights and provided informed consent before the experiment began. After obtaining consent, the participants were provided instructions for completing the task.

The experiment began after the participants clicked a button labeled “Begin.” For participants in the Experimental Condition, the first phase consisted of 20 trials with three options available to be chosen (see Figure 1). After the initial selection was made, the selected square became marked, while a different square, chosen at random, became solid black. After one second, the indicated square returned to its previous form, leaving two identical squares that could be chosen. Finally, the participant made their terminal choice (either retaining their initial selection or switching to the available option), and their selected square became marked once more. After one second, all stimuli disappeared, and feedback was delivered in the form of “You win! Try again” on winning trials or “You lose. Try again” on losing trials. Feedback remained visible for two seconds before an inter-trial interval (ITI) consisting of a blank white screen appeared for one second, after which a new trial commenced.

After 20 trials, the second phase began. Participants in the Experimental Condition were presented with eight available options rather than three. Note that reinforcement rates for staying and switching remained constant across every trial, block, and phase regardless of condition. Similar to the first phase, once an option was selected, it was marked while six of the remaining seven squares were simultaneously eliminated as choices that could not be selected. After the fixed interval of one second, the participant made their terminal choice. Again, the chosen square became marked for one second before feedback was delivered, and an ITI was presented. Once 20 more trials occurred, phase two was complete, and the third phase began. For the control condition, phases two and three are simply a continuation of the first phase (i.e., three available options). For both conditions, the first and third phases were identical in presentation.

Upon completing all three phases, participants in both conditions were presented with a series of questions. Participants were first asked to indicate their gender. Next, participants indicated whether they were familiar with the MHD, also known as the 3-Door problem, before beginning the experiment. Participants who responded yes to the first question were asked if they knew the dilemma's optimal strategy before beginning the experiment. Finally, participants described the strategy they used during the task in an open-response format. Upon completing the survey questions, participants were debriefed about the experiment's purpose and its potential implications. The researcher's contact information was provided along with the external survey link to ensure participants were properly compensated for participating.

CHAPTER 3:

RESULTS

Statistical analyses were conducted using IBM SPSS Statistics (version 27). Means are reported with 95% confidence intervals, and all significant effects are reported at $p < .05$. Each trial block consists of five unique trials (20 trials per phase for 60 total trials).

Phase

To assess the effects of condition as a function of phase, a 2 (condition: Experimental vs. Control) x 3 (phase: 1 - 3) mixed ANOVA was conducted with condition as the between-subjects variable and switch percentages as the dependent variable. Mauchly's test of sphericity indicated that the assumption of sphericity was violated, ($W = 0.913$, $p = .007$). Therefore, a Greenhouse-Geisser correction was used. Results revealed a main effect of phase [$F(1,1.84) = 5.849$, $p = .004$, $\eta 2 = .013$]. Bonferroni post-hoc analysis revealed that phase 1 differed significantly from phase 2 ($t = -3.05$, $p = .008$) and phase 3 ($t = -2.86$, $p = .014$), while phase 2 and phase 3 were not significantly different ($t = 0.19$, $p = 1.00$). There was no main effect of condition [$F(1,109) = 0.784$, $p = .378$, $\eta 2 = .005$] as the Control Condition ($MM = .718$, $SE = .027$) did not differ significantly from the Experimental Condition ($MM = .753$, $SE = .027$). A significant phase by condition interaction was observed [$F(1,1.84) = 3.154$, $p = .049$, $\eta 2 = .007$], suggesting that some perceptual changes occurred in the experimental condition that were not present in the control condition (see Figure 2).

The simple effect analyses showed that phase effect was significant for the experimental condition [$F(2,109) = 12.489$, $p < .001$] but not for the control condition [$F(2,109) = 0.16$, $p = 1.00$]. Within the experimental condition, Bonferroni post hoc tests revealed that phase 1 significantly differed from phase 2 ($t = -3.833$, $p = .002$) and phase 3 ($t = -3.738$, $p = .004$). All other post hoc comparisons were not significant (p’s = 1.00).

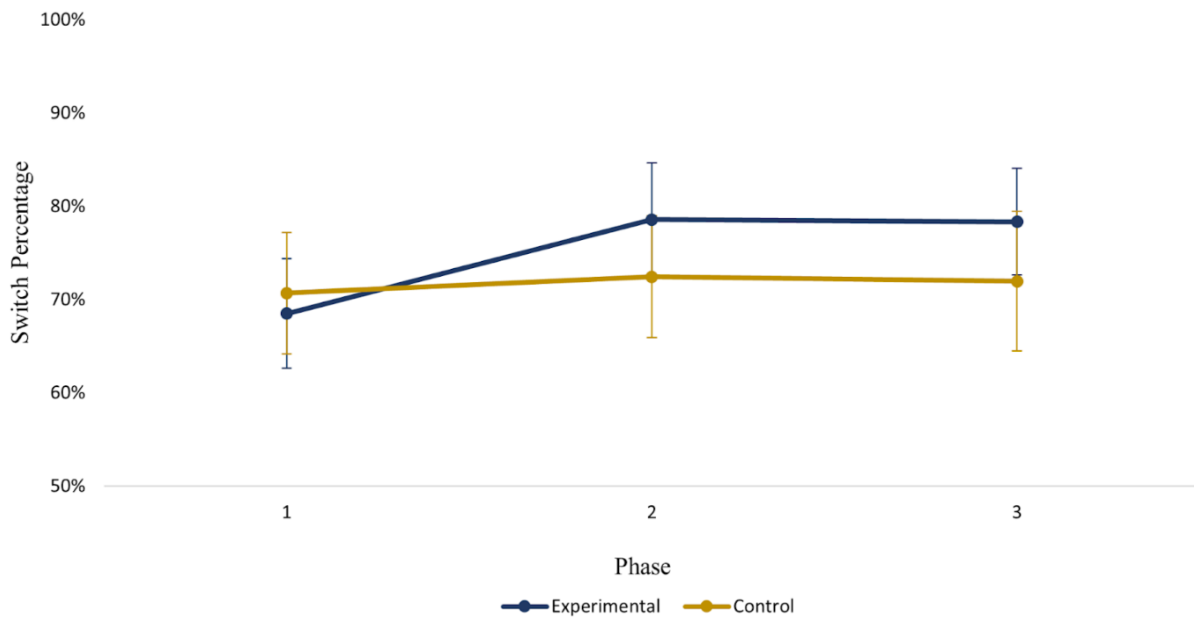

Figure 2. Mean switch percentage by phase. Error bars represent confidence intervals of 95%

Block

To assess the effects of condition across blocks, a 2 (condition) x 12 (block) mixed ANOVA was conducted. Mauchly's test of sphericity indicated that the assumption of sphericity was violated, and was corrected using the Greenhouse-Geisser method ($W = 0.129$, $p < .001$). Results revealed a main effect of block [$F(1,7.68) = 2.339$, $p = .019$, $\eta 2 = .011$] indicating a general trend of rates of higher switching among later blocks compared to earlier blocks, consistent with task-acquisition (see Figure 3). There was no main effect of condition [$F(1,109) = 0.784$, $p = .378$, $\eta 2 = .003$] as the control condition (*MM* = .718, *SE* = .027) did not differ significantly from the experimental condition (*MM* = .753, *SE* = .027). No block by condition interaction was observed [$F(1,7.68) = 1.528$, $p = .147$, $\eta 2 = .007$].

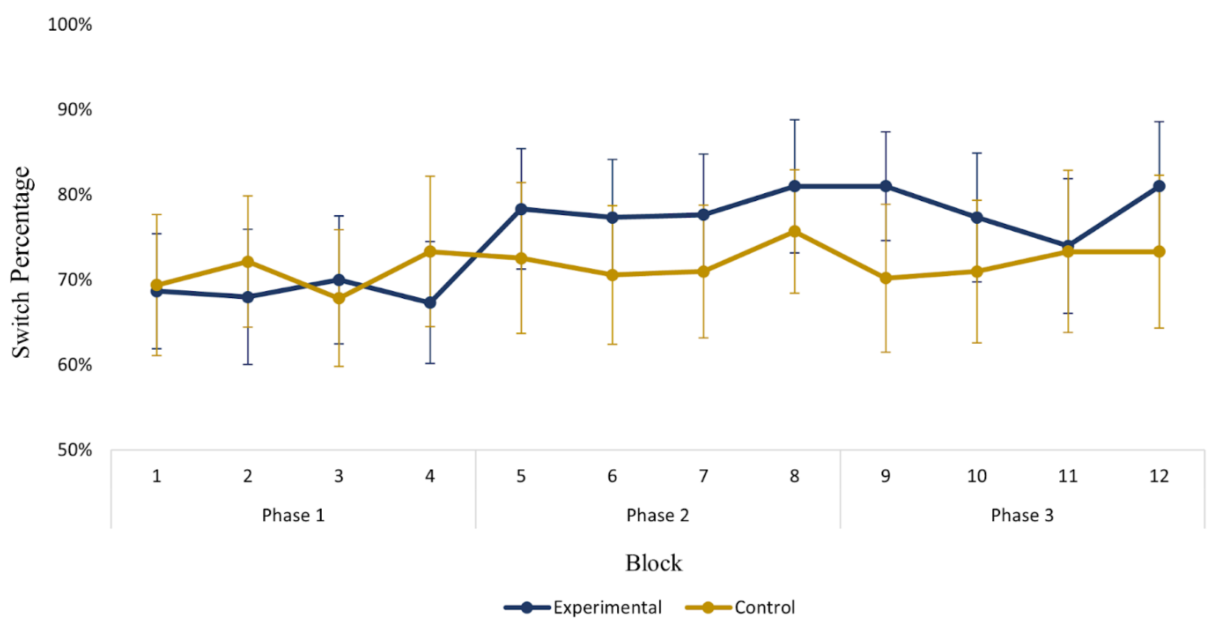

Figure 3. Mean switch percentage by block. Error bars represent confidence intervals of 95%.

One-sample *t*-tests were also conducted to examine the extent to which performance in each block differed from 67%. Table 1 shows results from one-sample *t*-tests, which revealed that Blocks 5 through 12 differed significantly from 67%, the metric of switch percentage predicted by the strategy of probability matching (*M*'s= 0.737 - 0.786, 95% CI's = ± 0.05 - ± 0.08). These findings do not support the predictions made by probability matching. Instead, participants in this study tended to switch at rates significantly higher than the programmed reinforcement ratios after some experience but were still well below the optimal rate of 100%.

Block	*t-score*	df	*p-value*	Mean	95% CI
1	0.767	110	0.445	0.69	[.638, .742]
2	1.047	110	0.297	0.699	[.644, .754]
3	0.736	110	0.463	0.69	[.636, .744]
4	1.103	110	0.273	0.701	[.645, .756]
5	3.115	110	0.002	0.757	[.702, .812]
6	2.753	110	0.007	0.742	[.690, .794]
7	2.883	110	0.005	0.746	[.694, .798]
8	4.311	110	< .001	0.786	[.732, .839]
9	3.384	110	< .001	0.76	[.707, .813]
10	2.642	110	0.009	0.744	[.689, .800]
11	2.202	110	0.03	0.737	[.677, .797]
12	3.602	110	< .001	0.775	[.717, .832]

Table 1. One-sample *t*-test comparing against probability matching predictions. CI = confidence intervals. Both conditions were collapsed. The alternative hypothesis specifies the mean is different from 0.67.

CHAPTER 4:

DISCUSSION

The results of the current study do not fully support results from previous studies which found that the addition of more options ultimately improved the participants' performance (Burns & Weith, 2004; Franko-Watkins et al., 2003; Saenen et al., 2015; Stibel et al., 2009; Watzek et al., 2018). However, the study revealed that performance improved throughout the experiment and that this improvement occurred regardless of condition. This finding suggests that participants successfully acquired the task as preferences for switching increased overall. The results from the 2 x 3 analysis also provide some evidence that improvement across trials was more pronounced in the experimental condition. However, this improvement was insufficient to lead to significant condition differences and was not observed when performance variance was examined as a function of blocks rather than phases. Therefore, this interaction must be interpreted with some caution.

One potential explanation for differences in the current study compared to prior research findings is that the reinforcement probabilities were held constant in the current study. Thus, these results suggest that the inclusion of more options without a commensurate increase in reinforcement was insufficient to increase switch rates compared to the condition in which the number of options was held constant. Furthermore, prior studies have shown that performance improved significantly when reinforcement ratios for switching were increased without adding additional options for selection (Franco-Watkins et al., 2003; Herbranson & Schroeder, 2010; Hirao et al., 2017; Mazur & Kahlbaugh, 2012) which might suggest that reinforcement ratios are the primary factor in terms of performance.

However, prior studies have shown that additional options improve performance (Burns & Wieth, 2004; Franco-Watkins et al., 2003; Saenen et al., 2015; Stibel et al., 2009; Watzek et al. 2018). Watzek et al. (2018) explored whether humans could generalize their performance between two variations of the dilemma that was first demonstrated with capuchins and rhesus macaques. The researchers hypothesized that the inclusion of more options would improve performance, and this improved performance would persist despite the reversal back to the original variation with three available options. Their results from human participants supported their first hypothesis, but their participants did not generalize their improved performance from a non-verbal computerized variation when tested on a verbal, survey-based variation.

Watzek et al. (2018) speculated that the inclusion of any verbal instructions commonly given to participants in prior studies (Klein et al. 2013; Mazur & Kahlbaugh, 2012), as well as the current study, could negatively affect participants' performance. According to Watzek et al. (2018), these verbal instructions could interfere with the participant's implicit learning abilities by promoting other explicit cognitive reasoning strategies and heuristics. Therefore, participants would be more likely to show a stay-bias during early trials when verbal instructions were included but are more likely to rely upon their implicit learning when no instructions were present, resulting in switch-biases similarly to those observed in pigeons (Herbranson & Schroder, 2010; Stagner & Zentall, 2014) and primates (Klein et al., 2013; Watzek et al., 2018). Contrary to the predictions made by Watzek et al. (2018), the participants in the current study showed a clear switch-bias during early trials despite having received verbal instructions before participating. The current study's results suggest that more research is needed to investigate how verbal cues influence which cognitive heuristics are being utilized and the extent to which reinforcement ratios or cognitive factors account for variation in performance. It is worth noting that the instructions used in the current study (see Appendix) provided participants with the least amount of information required to complete the study, unlike previous studies with more descriptive instructions (e.g., Mazur & Kahlbaugh, 2012).

Including verbal instructions or increasing the number of available options for selection is not the only method to alter how the dilemma is potentially perceived. Tubau and Alonso (2003) changed how participants perceived the dilemma by allowing them to take the host's perspective before being tested as the contestant. The researchers found that the participants who took the host's perspective before testing switched at significantly higher rates than the control participants. This study demonstrates that changing how the dilemma is potentially perceived can improve performance without manipulating the reinforcement probabilities. Other studies have had mixed success when attempting to improve performance by highlighting the nonrandom actions of the "knowledgeable" host, who is always aware of the prize's location (Burns & Wieth, 2003; Burns & Wieth, 2004; Idson et al., 2004; Krauss & Wang, 2003).

The results from the current study did reveal that participants demonstrated a tendency to switch more frequently as trial blocks elapsed. This finding could suggest that participants were overly sensitive to obtained reinforcement (switching more frequently than the obtained reinforcement would predict) and elected to switch at higher rates than predicted by probability matching and matching law. During blocks 1-4, participants switched during approximately 70% percent of the first 20 trials. While the steady, incremental improvement of performance across blocks suggests that participants successfully acquired the task, this switch-bias observed in the early trials is unexpected. Similar choice studies indicate that participants often begin at, or near, levels consistent with chance (50%) and only develop a preference for one option over another as the experiment progresses. While some studies have shown a tendency for participants to exhibit a stay-bias during early trials (Greenberg, 1999; Franco-Watkins, 2003), the results from the current study reflect the finding of Watzek and colleagues (2018), whose participants also exhibited a clear switch-bias from the beginning trials that remained consistent throughout the experiment.

Limitations and Future Directions

This switch-bias observed during the current study may have resulted from the novel experimental methodology. In the current study, the participant's initial choice would be marked with two intersecting lines that resemble an "X" (see Figure 1). Participants may have been interpreting this mark as an incorrect choice, unintentionally influencing them to switch during the terminal choice. However, these markings occurred following each selected item, including those made during the terminal choice portion of the trial. This would result in the scenario where the participant chooses an option initially, then believes it to be incorrect based on the so-called "marker effect." Then, the participant switches to a different option during the terminal choice, which is also marked in the same manner but still receives a winning outcome for that trial. This scenario results in a winning outcome on 67% of trials because the participants chose to switch. However, despite the six participants who exclusively switched on every trial, no participant indicated this as a source of confusion in their open-ended responses. Therefore, it is not clear the present results can be attributed to the "marker effect."

The results of this study were limited by the number of trials experienced by the participants. If the number of trials was increased, some unexpected results, like the early emerging switch-bias observed in early trials and the oversensitivity to obtained reinforcers, may become less pronounced as more experience is gained with the reinforcement contingencies. Future studies should control for any potential marker-effects by clearly designating which option was previously selected in a manner that does not potentially bias the participant's responses either implicitly or explicitly. Finally, this study was also conducted online due to COVID-19 restrictions on in-person research. Therefore, any influences of environmental stimuli that are typically controlled during in-person research remain unknown.

To further examine the extent to which cognitive and reinforcement factors may address the current research questions, the researchers intend to conduct a follow-up study in which reinforcement contingencies are also manipulated within the present methodology. The researchers will attempt to replicate and extend the current study's findings by incorporating a third condition to address this question. This third condition will be identical to the experimental condition, except the reinforcement contingencies for staying and switching will no longer be held constant. Instead, the contingencies will mirror the natural outcome frequencies throughout each experimental phase. This way, if increased switch rates are observed in the condition with natural reinforcement ratios, but are not observed in the other conditions, then one can be confident that the improvement results primarily from changes to the reinforcement contingencies, not cognitive factors as suggested by prior studies (Franco-Watkins, 2003; Saenen et al., 2018; Tubau, Aguilar-Lleyda, Johnson, 2015).

Additionally, an interaction between the change in perceptions and changes to the reinforcement contingencies may lead to the largest performance improvement. Together, these changes might direct participants' attention toward the optimal strategy, allowing for faster recognition and implementation of that strategy to occur. If such an interaction is observed, these new cognitive and behavioral insights could warrant using a more holistic, interdisciplinary approach when exploring complex problems like the MHD.

The final question focuses on whether humans can generalize their improved performance from the eight-option variation once reverting to the original variation. The manipulations must elicit a significant change in performance between conditions to determine whether these changes will persist into the next phase. Suppose that a significant improvement is found in the condition with natural reinforcement contingencies, and this improved performance generalizes into the final phase. Then the researchers would have successfully demonstrated that humans share the same ability to generalize knowledge between task variations that were previously established in primates but not humans (Watzek et al., 2018).

This ability to generalize prior experience and knowledge has direct implications for future studies exploring the MHD in scenarios that share more resemblance to the dilemma's original presentation on the T.V. show "Let's Make A Deal." The results of this study improve the overall understanding of the cognitive and behavioral processes that directly influence our ability to accurately estimate the appropriate response to decisions with uncertain outcomes. The preliminary evidence provided by the current study has direct implications for many scientific and medical fields that depend upon information being presented clearly and accurately. These fields can utilize these results and results from similar studies to promote optimal decision-making strategies while minimizing the likelihood that individuals succumb to certain cognitive biases that may negatively impact their ability to correctly perceive and conclude which outcome is optimal.

Conclusion

This current study demonstrates that altering the presentation of the dilemma, thus influencing how the dilemma is potentially perceived, is not sufficient to improve performance in isolation. This study conflicts with the well-replicated findings from previous studies investigating the effects of additional options on performance in the MHD. Further exploration is required to determine whether changes in the natural reinforcement probabilities are responsible for performance improvements and whether these improvements can persist from one variation to another.

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APPENDIX

Instructions Provided to the Participant

Thank you for participating.

The goal is to win as many times as you can.

Items will appear on the screen.

You can select these items using the mouse cursor.

Once your cursor is hovered over the item you wish to select, press the left mouse button.

This will select the item and progress the task.

Feedback will be given after each trial.

Do NOT refresh the page or close the window during the test.

Press the button below to begin!