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# Alternatives: The Video Game. An Assessment of Bias and Preferences in Uncertain Situations

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ALTERNATIVES: THE VIDEO GAME. AN ASSESSMENT OF BIAS AND PREFERENCES IN UNCERTAIN SITUATIONS

by

VINCENT EDWARDS

(Under the Direction of Kent Bodily)

ABSTRACT

Going against working assumptions of what is "natural," animals have been observed to "gamble" when choosing between a high-risk choice with a high reward, and a consistent alternative with a low reward that feeds them more over time. The Energy Budget Rule (EBR) claims that animals have a foraging goal they must reach to survive, and each attempt to forage has a cost; under certain conditions, a high-risk "gamble" is the best option for survival. The present study attempts to observe human choice behavior in a task that tests EBR and assesses shifts in behavior over time as an increase or decrease in "cost" is introduced. Using a virtual videogame task, participants were randomly assigned to either a positive or negative budget condition and given 30 opportunities to reach either an obtainable (in positive conditions) or unobtainable (in negative conditions) goal by choosing between a low-risk option with a consistent reward, or a high-risk alternative with an infrequent high reward. Participants experiencing a positive budget condition were expected to be risk averse. Participants experiencing a negative budget were expected to be risk prone. Cost was manipulated mid-game for the participants. The results of the study conflicted with the predictions of EBR. Participants experiencing a positive budget chose the high-risk option more often than participants experiencing a negative budget. The results showed that all participants quickly learned that it was advantageous to choose the low-risk option. The results reveal the role of situational factors on human gambling behavior.

INDEX WORDS: Behavior, Choice, Decision making, Risk, Gambling, Energy budget, Suboptimal choice, Human analog

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MASTER OF SCIENCE

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# CHAPTER 1:

# INTRODUCTION

Gambling is generally viewed as a risky, maladaptive behavior; the gambler enters a risk-for-reward situation in which the victor and victim are determined by chance – which almost always favors the house. Interestingly, previous research has observed higher levels of gambling behavior in individuals living in lower socioeconomic groups and in individuals with fewer expendable resources (Barnes, Welte, Tidwell, & Hoffman, 2011). That is, individuals with fewer expendable resources are most likely to engage in high-risk behavior, though according to logic, they should avoid risking the limited resources they have. Gambling behavior, however, is not exclusively observed in humans; gambling analogs have been used in prior research to observe decision making in animals (e.g., Spetch, 1990; Zentall & Stagner, 2011; McDevitt, 2018). The results of which suggest that humans are not the only organisms to prefer choices of high-risk for a high reward.

Zentall and Stagner (2010) created a gambling analog that was used to observe pigeon decision making behavior. Their goal was to observe pigeon-choice responses when presented with an alternative that had a low probability of reinforcement and a high reward, and an alternative with a higher probability of reinforcement that reinforced them with a lower reward. The analog employed a concurrent chain schedule procedure in which two alternatives (initial links; IL) were presented (Figure 1). When the initial link was chosen, a colored light was displayed. This light was the terminal link (the stimulus in the concurrent chain that precedes reinforcement), and in the experimental condition, the colors were indicative of reinforcement. Reinforcement followed the terminal link. In the case of the aforementioned pigeons, responses were reinforced with food pellets. The terminal links that followed the suboptimal initial link (the initial choice in the concurrent chain) were either red or green, while the terminal links that followed the optimal initial link were either yellow or blue. Red indicated that the pigeon would receive zero pellets; green indicated that the pigeon would receive 10 pellets; both yellow and blue indicated that the pigeon would receive 3 pellets. The alternative associated with the green and red terminal links resulted in a payout of zero pellets 80% of the time, and a payout of 10 pellets 20% of the time. The alternative associated with the yellow and blue terminal links had a payout of 3 pellets. The yellow terminal link was displayed 80% of the time, and the blue terminal link was displayed 20% of the time. Choosing the alternative that gave consistent payouts of 3 pellets resulted in an overall average of 3 pellets over ten trials; this was the optimal option. Choosing the alternative that included the inconsistent payout of 10 pellets resulted in an average of two pellets over ten trials; this was a suboptimal option.

The results of the study showed that even though the optimal choice provided on average more food pellets over time than the suboptimal choice, the pigeons preferred the suboptimal choice. The pigeons chose the high-risk alternative (the choice with high variability reinforcement payoffs) over a low-risk alternative (the choice with a consistent reinforcement payoffs). This observation of maladaptive decision making has been argued to be analogous to human gambling (Zentall, 2017), but it goes against working assumptions about what is natural. Optimal foraging theory posits that an organism will maximize their intake opportunity (MacArthur, 1966). Hungry pigeons have also been observed to choose a suboptimal option that feeds them less food overall (Laude, Zentall, & Pattinson, 2012). As noted, research with humans has shown that individuals with fewer expendable resources are more likely to engage in gambling and risk-prone behavior (Barnes et. al, 2011).

In an effort to extend the methodology to humans, Molet and colleagues created a similar decision making task for undergraduate student participation (2012). Molet's decision making task was presented in the form of a videogame to simplify differences and similarities in learning processes across species. In Molet's study, students completed a survey where they were separated into either a self-reported gambler or self-reported non-gambler group. The self-reported gamblers group were compared to those in a self-reported non-gamblers group. Self-reported gamblers were more likely to choose suboptimally than self-reported non-gamblers. Molet's findings suggested that Zentall and Stagner's suboptimal task may be a reasonable analog for human gambling behavior.

Research has observed pigeons engaging in suboptimal, maladaptive decision making. There remains, however, the question of why this phenomenon occurs. This type of behavior has a negative impact on an animal's chance of survival. In terms of the studies above, optimal foraging theory posits that an organism will maximize their intake opportunity. However, in both studies discussed above, pigeons did not follow this rule. At its core, when you remove the labels of "suboptimal" and "optimal" from the options provided in the studies mentioned earlier, you are left with "high" and "low variability" options. The behavior observed in these studies begs the question, "why is the high-risk alternative being chosen?" Why would an organism choose a high-risk choice that causes their intake to rely on chance? There is, however, a theory that suggests that in some conditions a high-risk choice is the best bet for survival.

**Gambling to Survive: The Energy Budget Rule**

The Energy Budget Rule is a risk sensitive Optimal Foraging Theory. As explained by Stephens (1981), animals are risk-prone when exposed to conditions in which a high-risk choice increases the probability of survival. According to this model, an animal that fails to eat the amount of food required for its daily survival will perish. The energy budget rule presents two conditions for risk sensitivity (Searcy & Pietras, 2011):

$$\mathbf{Mn - nr + Sn > R(positive\ energy\ budget)}$$

$$\mathbf{Mn - nr + Sn < R(negative\ energy\ budget)}$$

In the model above, M represents the average amount of energy units that the animal can earn from choosing between the available foraging options. n represents the number of opportunities left for the animal to choose between these options. r represents cost (i.e. the number of energy units expended every time that the animal makes a choice). Sn represents the total amount of energy units the animal has reserved (i.e. all of the energy units collected from the food gathered throughout the day). R serves as the energy requirement for survival; without meeting the energy requirement, the animal will perish.

Depending on their net gains, an animal either experiences a positive or negative energy budget from which their behavior can be predicted. This model assumes that after a day of foraging, an animal will be faced with two choices of either high or low variability (risk). Both options have the same mean payout, but only the low variability option yields a consistent payout. The high variability option mostly yields a lower payout on average than its low variability counterpart, but on occasion yields a significantly higher payout.

According to the model, if the animal is in a position where it has had a successful bout of foraging for the day and must meet a low energy requirement by the end of the day, they are experiencing a positive energy budget condition. Making a high-variability choice when foraging would only put the animal’s survival at risk but choosing the low variability option will guarantee the animals’ survival. In terms of foraging, an animal in a positive energy budget condition is predicted to be risk averse.

Alternatively, an animal experiencing a negative energy budget has not had a successful day of foraging. As the opportunity to forage decreases, the animal is in a position where it must meet a high energy requirement for the day. Under these conditions, given the choice between a high or low variability option, the model predicts that the animal will choose the high variability option. Animals experiencing a negative energy budget condition are so far from the daily energy requirement that choosing the consistent option will not let the animal reach the energy requirement for the day. Though success is not guaranteed, choosing the high variability (i.e. higher risk) option offers an occasional higher payout that can meet or exceed the energy requirement. (Stephens, 1981; Caraco, Martindale, & Whittam, 1980). This suggests that, under certain conditions, high-risk choices may not be suboptimal depending upon the context.

Human analogs of the energy budget procedure have been used to test the model using hypothetical scenarios of varying budget conditions. Previous studies replaced energy units and the energy requirement with earnings and an earnings requirement (Pietras et al, 2008; Searcy et al., 2011). When working with humans, the positive or negative energy budget conditions are controlled by the researcher and participants are randomly assigned to one group or the other. Human observations are consistent with energy budget predictions – participants were risk averse in positive energy budget conditions and risk prone in negative energy budget conditions (Pietras et al, 2008; Searcy et al., 2011).

The implications of the energy budget rule suggest that it is advantageous to make risky decisions in situations of high need in order to maximize desirable outcomes (Mishra, & Lalumière, 2010). Previous studies investigated risk-sensitive decision making in tasks in which decision making scenarios were explained to the participant through detailed instructions (Hertwig, 2005). These studies demonstrated that participants could make risk-sensitive decisions with the use of descriptive information alone. Mishra et al. replicated these results in 2010.

Mishra et al. (2010) developed a decision making task based on experience to observe participant behavior in an ecologically relevant foraging scenario. In this task, participants were randomly assigned to positive and negative energy budget conditions; these conditions were created through the use of forced trials. In the task, participants went through an acquisition phase where they were given the opportunity to become familiar with the payouts of certain images. Afterwards, they were notified of a requirement that they were needed to meet in each block to succeed. Each block presented the participant with five forced trials where they were only able to choose one image resulting in the payout associated with that image, and two choice trials where they were able to choose between two different options. The researchers observed the participant's responses in the second of the two choice trials across all blocks. This seventh trial represented a risk-sensitive decision that was immediately based on need. The results were consistent with the predictions of the energy budget rule: there was a significantly higher proportion of participants making risky choices in the high need condition than the low need condition.

**The Significance of Previous Research**

Studies investigating human analogs to the energy budget rule report observations of high-risk behavior under certain conditions. Unlike previous studies that observe high-risk decision making in both pigeons and humans (Zentall & Stagner, 2011; Molet, 2012), studies testing the predictions of the energy budget rule introduce a goal or requirement that must be fulfilled. The observation of suboptimal, maladaptive behavior has been compared to the risky behavior observed in gambling. The energy budget rule suggests that a high-risk choice, like gambling, is more frequently observed in an organism that is far from meeting an established requirement. Gambling has been observed to be present in higher rates for individuals in lower socioeconomic groups and individuals earning low income (Barnes et. al, 2011), the implications of which suggest that gambling and other high-risk behaviors may be driven by an individual's attempt to meet a requirement. The present study attempts to address gaps in previous research and introduce a modification of the energy budget rule that may allow a shift in behavior to be observed within participants over time.

**The Current Study**

Gambling is a high-risk choice where the gambler is rarely rewarded with a 'win'. The alternative to gambling, of course, is not gambling. Just as the energy budget rule states that there is a cost associated with foraging, there is a cost associated with the opportunity to choose between gambling and not gambling. Before an individual has the opportunity to choose between these options, they must earn the opportunity to choose by first completing a simple task. In this study, the act of earning the opportunity to choose is 'cost'. While prior research has observed human behavior in risk-sensitive tasks, participants were given the opportunity to choose without earning the opportunity to choose. There was no cost that was required to proceed with their choices. This is a gap in the existing literature that this study hopes to address.

The aim of the current study is to develop a risk-sensitive task that accounts for cost, and to observe differences in behavior between energy budget conditions. The design of the proposed task incorporates designs used in the studies cited above. The task is designed as a 2-D, top-down game that is played with a computer in the laboratory. The task utilizes a concurrent chain schedule similar to Zentall and Stagner's pigeon studies (2010; 2011). It also introduces an earnings requirement, energy budgets, and cost -- a part of the energy budget model that has not been considered in previous research with humans.

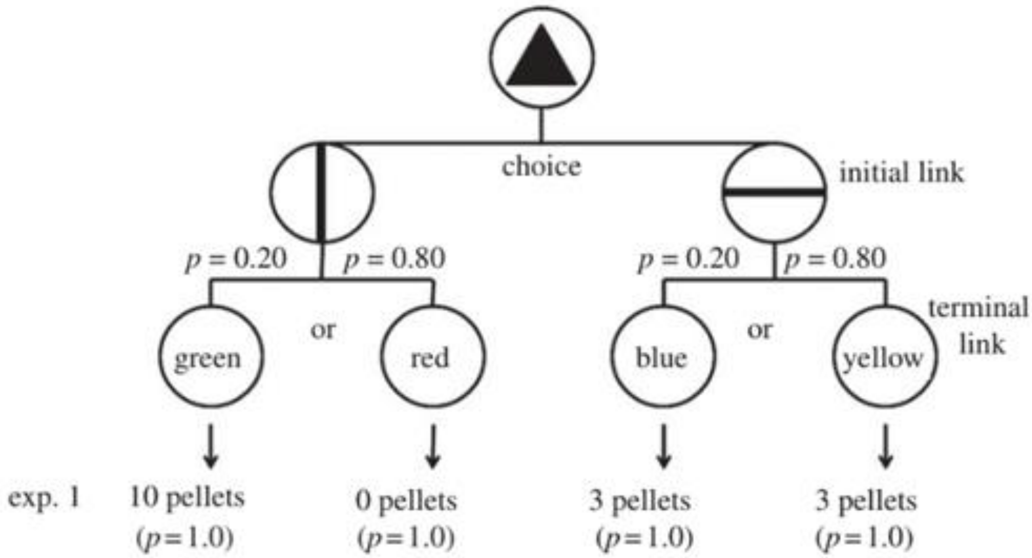


Figure 1. Schematic of the concurrent chains procedure used in Zentall & Stagner's suboptimal choice task (2010).

# CHAPTER 2:

# METHODOLOGY

## Participants

The procedures in this experiment were approved by the Human Subjects Institutional Review Board at Georgia Southern University. Participants (N=49) were recruited from Undergraduate Psychology Classes at Georgia Southern University who participated for course credit. Participants chose and signed up for this experiment through the SONA-Systems Research Management Software (www.sona-systems.com). Participants were awarded research credit for their participation - not solely for completion. Data from two participants were excluded due to incomplete data collection, leaving a final total of 47 participants (28 female; 19 male). Participants were asked to sign a consent form before beginning the task and participants were randomly assigned to an energy budget condition (Negative/Positive) and a Cost Sate (Control/High/Low).

## Apparatus

Participants completed the study on a computer within the laboratory. The task was designed using the Python 3.7 programming language (Van Rossum, 1995), the Tiled Map Editor (Lindeijer, 2008) and was launched through Python's Integrated DeveLopment Environment (IDLE). All participant input was entered via keyboard; participant input and the choices were recorded though Atom.

The task consisted of a 2-D video game map made of 35 x 21 tiles. In each top corner of the map was a 'generator'. In the middle of the map was a black hexagon from which the participant's avatar would respawn after performing any action aside from movement. The participant's avatar was a red figure referred to as a ‘robot’. Along the bottom of the map were 30 wooden barrels. All art used in the map was obtained through open source game art websites.

Participants controlled their avatar (A in Figure 2) via keyboard. The left and right arrow keys rotated their avatar accordingly, while the up and down arrow keys moved their avatar either forwards or backwards. The ENTER key was used to fire ‘lasers’ (B) that could only destroy wooden boxes (C). The SPACEBAR key was used to deposit ‘battery boxes’ (D) that could only be deposited into generators (E). Depositing a battery box earned the participant ‘points’ that were added to the power bar at the top of the screen (F). The number of points earned was also displayed on the screen. Upon depositing each battery box, a sound effect was played; the sounds effects are described as ‘short’, ‘medium’, and ‘long’ and were dependent on the payout of points received from depositing a battery box into a generator. The sounds used in the study were acquired from an open source website.

In the task, the participant was required to break a box in order to earn the chance to deposit a battery box into a generator. Boxes were broken by pressing ENTER (i.e. the avatar would shoot a laser into a box, breaking it). Once a box was destroyed, the participant’s avatar was moved back to the middle of the screen. When the participant broke a box, either “LEFT” or “RIGHT’ was displayed (Figure 3). This directed the participant to the generator they needed to deposit their battery box in. The order of these directions were randomized; the participant was directed to both generators an equal number of times.

The “SPACEBAR” key was used to deposit battery boxes into the generators. There were two generators - one on the left side of the screen, and one on the right side of the screen. When the participant deposited a battery box into a generator, the game paused for 1s. During this time, the payout associated with the choice was displayed (Figure 4). The low-risk generator consistently had a payout of “+5,” whereas the high-risk generator had a payout of “+3” 80% of the time and “+13” 20% of the time. There were also unique sounds specifically paired with these payouts. When the participant deposited a battery box into a generator, the power bar was shaded in to reflect the payout that the participant earned. Upon depositing a battery box into a generator, the payout that they received was displayed on the screen. The power bar at the top of the screen served as the energy requirement for the task. Participants had to fill this power bar completely three times to complete the task. In the first stage of the task, the power bar ‘filling’ was red. After this bar was filled the second stage of the task would begin, and a yellow filling would be used as the participant re-filled the power bar - covering the previous red filling. Finally, a green filling was used to cover the yellow filling in the third stage of the task.

**Procedure**

Participants were greeted by the researcher and asked to complete an IRB approved consent form. After the participant completed the form, the researcher led them to a private room in which the task was conducted. The participant was seated in front of a computer and the instructions for the task were taped to the desk for their reference during the study. The researcher read from a script (Appendix 1). After reading this script to the participant, the researcher informed the participant that they would first complete a practice level before playing the actual game. The researcher left the room until the participant indicated that they had successfully completed the practice level. The main task was then initiated for the participant.

The experiment was comprised of two phases: an acquisition phase, followed by the main task. Participants were randomly assigned to one of three tasks (control, high cost, and low cost) and one of two conditions (positive energy budget, and negative energy budget).

*The Acquisition Phase*

The practice game that the participant played at the beginning of the study was the acquisition phase. During the acquisition phase, the participant played the game in a virtual room with only ten boxes. All of the boxes directed the participant to deposit a battery box into a specific generator. They were not able to deposit a battery box in any generator other than the one instructed. The mean payout for both generators was 5 points. The energy requirement in the task was 50 points.  Participants completed ten trials during this phase. After completing the acquisition phase, they began the main task that they were assigned to.

*The Main Phase*

The tasks used in the main phase manipulated cost. In the task, the participant was required to approach and break a box before they were able to approach a generator and deposit a battery box. In this study, the measure of time between the participant's last and next opportunity to deposit a battery box is referred to as the participant's response duration. The response duration is measured to establish the cost associated with earning an opportunity to choose. By manipulating the participant's avatar speed within the game, response duration is either increased or decreased. As the participant's avatar speed decreases, response duration increases. As the participant's avatar speed increases, response duration decreases. A low response duration means that the cost of choosing is low, while a high response duration means that the cost of choosing is also high.

The design of the control task was similar to the task used in the acquisition phase, except there was no cost manipulation. The participant now had 30 boxes to choose from. There were no choice trials in this task - each time the participant broke a box, the instructions "YOU CHOOSE" were displayed on the screen. The mean payouts of both generators remained at 5.

Throughout the entire task, the participant's avatar moved at 150 frames per second (FPS). Participants were either assigned to a "positive" or "negative" energy budget. The maximum number of energy units the participant could collect in the game was 150 (participants could collect 50 units for each time the energy bar filled). Participants in the positive energy budget condition had an energy requirement of 120 (40 units were required to fill each bar). Participants in the negative energy budget condition had an energy requirement of 180 (60 units were required to fill each bar). Once the energy bar was completely filled three times, the task was over.

In the low and high cost tasks, there were no changes made to the task as described above, aside from the addition of cost manipulations. Cost was consistent in the control task; the low and high cost tasks followed an ABA design to potentially observe a shift in behavior after introducing the cost manipulation. The shift from each stage in the ABA design occurred once the participant completely filled a power bar. In the low-cost task, the participant's avatar moved at 150 FPS during the first stage. In the second stage, the participant's avatar speed increased to 300 FPS. The increase in the avatar's speed indirectly reduced the participant's response duration. In the third stage, the avatar speed was reduced back to 150 FPS. In the high cost task, participants shifted from 150 FPS in the first stage to 50 FPS in the second stage, increasing their response duration. Afterwards, the avatar speed was increased to 150 FPS in the third stage. Generator payouts and averages did not differ from the control task.

The average proportion of high-risk choices made across all choices in each condition were analyzed. The average proportion of high-risk choices made within the last five was also analyzed. The Energy Budget Rule gives an account for animal foraging behavior as they attempt to reach a resource goal before the end of the day. In the case of an animal foraging in its natural environment, the assumptions of this account become stronger as the day draws closer to an end. In terms of this study, the assumptions of the Energy Budget Rule are predicted to become more relevant as the participant nears the completion of each stage. Mishra and colleagues (2010) observed participant responses on their final choice in each block; doing so gave them the opportunity to observe behavior in an immediate situation of low or high need. The final five choices of each stage represent a period during the task in which immediate need becomes more pronounced.

**Study Predictions**

The current study's predictions were derived from the Energy Budget Rule. Participants experiencing a negative energy budget (i.e., fewer opportunities than necessary to complete the task) were predicted to choose the high-risk alternative more frequently than participants experiencing a positive energy budget (i.e., more opportunities than necessary to complete the task). Participants were also predicted to exhibit an observable shift in behavior between stages after a Cost State (i.e., choosing was made more or less difficult) was introduced in stage two, and a second shift in behavior after the Cost State was removed in phase three. There was no expected change in high-risk responding between stages expected for participants in control conditions.

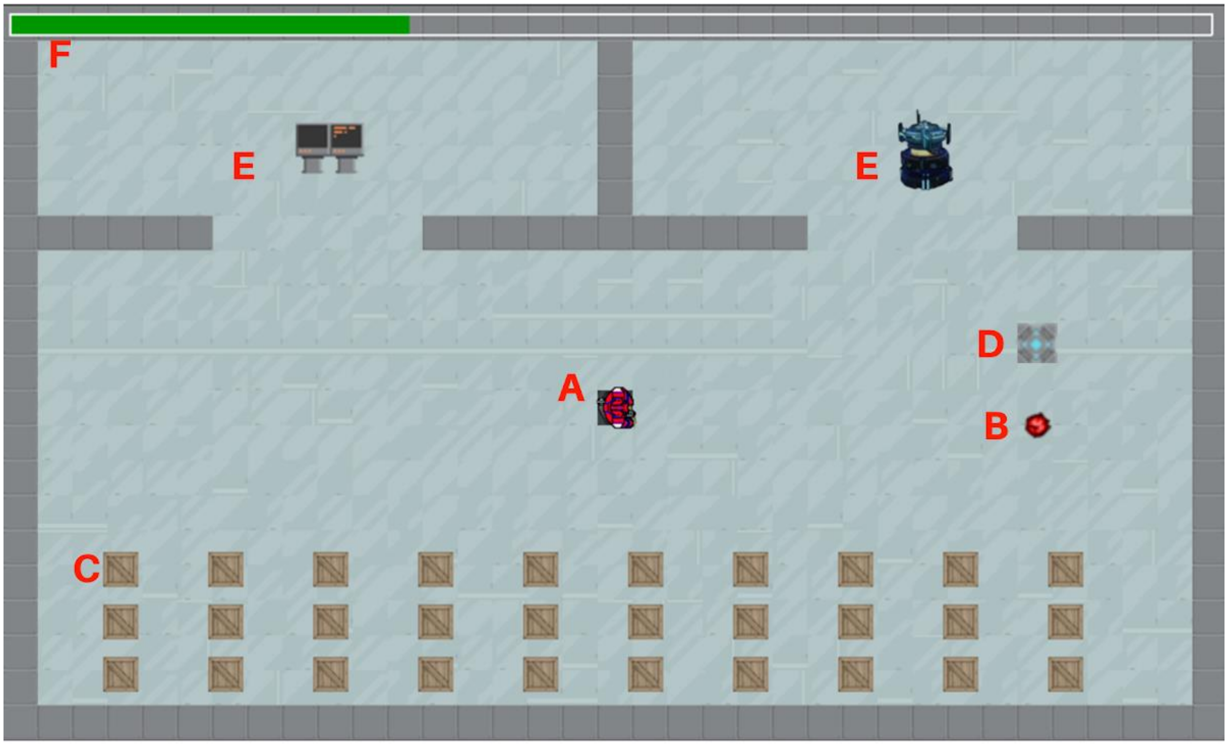


Figure 2. A depiction of the task developed for the current study. The participant used keyboard keys to move a robot (A) around the space. The robot shot fireballs (B) at boxes (C) to release energy cubes (D). The energy cubes were then deposited into one of the choice locations (E), filling the progress bar (F).


Figure 3. An example of the directions displayed after a participant broke a wooden box. The participant could only deposit a battery box into the generator they were instructed to use (unless instructed to choose a generator)


Figure 4. Participants were given awarded points after depositing a battery box into a generator. The number of points received was displayed underneath the generator chosen.

# CHAPTER 3:

# RESULTS

Data were submitted to a (2 x 2 x 3) Mixed Analysis of Variance (ANOVA) with Budget Condition (Negative vs. Positive) and Cost State (Control vs. High vs. Low) as between-subjects factors. A Greenhouse-Geisser correction for violation of sphericity was used for the repeated measures factor. The standard $p < .05$ criteria was used to determine significance.

## Across All Choices

The proportion of high-risk choices across all of the choices made during the task was analyzed. Mauchley's test indicated that the assumption of sphericity was violated ($X^2(2) = 17.29$, $p < .001$). Degrees of freedom were corrected with a Greenhouse-Geisser correction for violation of sphericity. Analysis revealed a main effect of Stages [$F(1.48, 60.70) = 10.718$, $p < .001$] (Figure 5). Bonferroni post hoc tests revealed that the proportion of high-risk choosing in stage one was significantly different from stage two ($p < .001$) and stage three ($p = .003$); The proportion of high-risk choosing in stage two was not significantly different from stage three ($p = 1.000$). There were no two-way interactions of Stages with Budget Condition [$F(1.480, 60.70) = 0.356$, $p = .356$] or Cost State [$F(1.480, 60.70) = 0.622$, $p = .893$], nor was there a three-way interaction [$F(1.480, 60.70) = 0.599$, $p = .613$]. There was no main effect of Budget Condition [$F(1, 41) = 3.240$, $p = .079$] or Cost States [$F(2, 41) = .110$, $p = .896$] and no three-way interaction(s) between conditions [$F(2, 41) = .118$, $p = .889$].

## Across the Last Five Choices

The proportion of high-risk choices across the last five choices made during the task was analyzed. Mauchley's test indicated that the assumption of sphericity was violated ($X^2(2) = 7.20$, $p = .027$). Degrees of freedom were corrected with a Greenhouse-Geisser correction for violation of sphericity. Analysis revealed no main effect of Stages [$F(1.72, 70.40) = 1.717$, $p = .310$].

There were no two-way interactions of Stages with Budget Condition [F(1.717, 70.40) = 0.339, p = .681] or Cost State [F(3.434, 70.40) = 0.622, p = .624], nor was there a three-way interaction [F(3.434, 70.40) = 0.599, p = .640]. There was a main effect of Budget Conditions [$F$(1, 41) = 10.105, $p$ = .003] (Figure 6). There was no main effect of Cost States [$F$(2, 41) = .200, $p$ = .820], nor was there a two-way interaction of Budget Conditions and Cost States [$F$(2, 41) = .177, $p$ = .838].

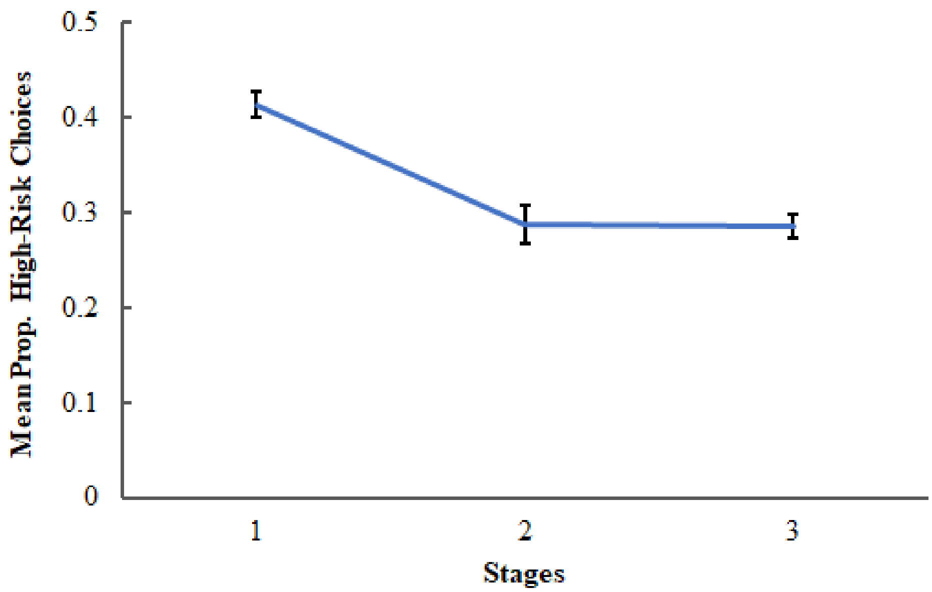


Figure 5. Mean proportion of high-risk choices across the three stages of the task. Error bars represent 95% Confidence Intervals.

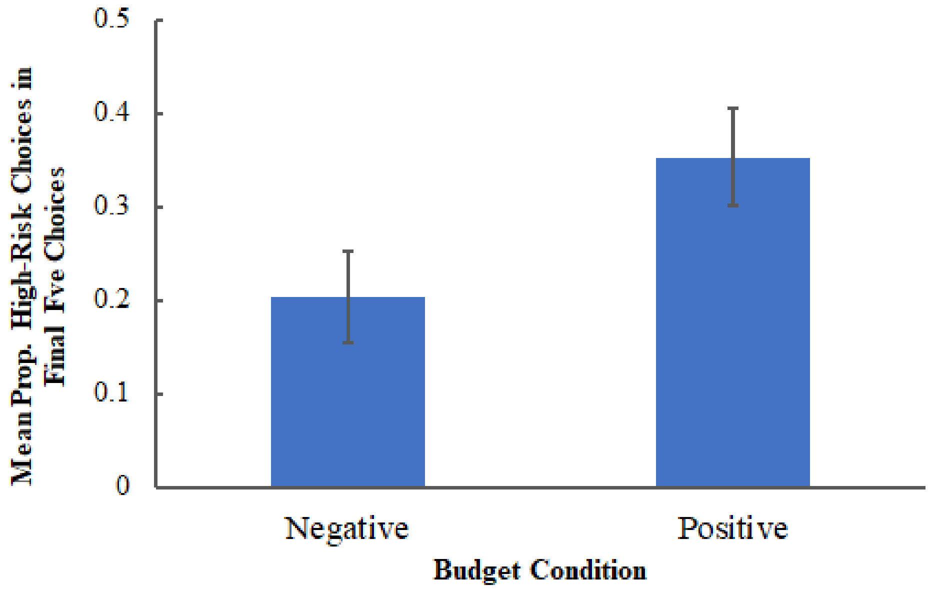


Figure 6. Mean proportion of High-Risk choices in the final five choices across budget conditions of the task. Error bars represent 95% Confidence Intervals.

# CHAPTER 4:

# DISCUSSION

## Stages

The purpose of this study was to observe participant behavior in a risk-sensitive decision making task. Significance testing of participant responses throughout the entire task revealed a within-subjects effect of Stages. Across all conditions there was a significant difference in high-risk choosing observed in stage one compared to stages two and three. According to these results, participants chose the high-risk alternative less often after experiencing the first stage of the task. These results suggest that over the course of stage one, participants learned to choose the low-risk option more often than the high-risk alternative. However, this pattern did not hold true when analyzing the proportion of high-risk choosing in participant's last five choices. This result suggests that acquisition was reached by the final five choices within the first stage of the task.

## Cost States

The participant's avatar speed was manipulated in an effort to introduce a 'cost' into the task -- a part of the energy budget model that was not previously considered in human research. It was predicted that a manipulation of the Cost State would have some effect on participant responding. Across all conditions and phases, no main effect of Cost State was found. This lack of effect may indicate that the manipulation of avatar speed did not effectively represent cost in this particular task.

## Budget Conditions

According to the predictions of the Energy Budget Rule, participants experiencing a negative energy budget were expected to be relatively more risk prone, while those experiencing a positive energy budget should have been relatively more risk averse. When analyzing the proportion of high-risk choosing across all choices, significance testing revealed no main effect of Budget Condition, however, an effect of Budget Condition was observed in the analysis of participant's last five choices (Figure 6). The Energy Budget Rule accounts for foraging behavior when an organism experiences a budget state of either low or high need (positive or negative energy budgets); either they will meet their goal or will ultimately perish. This need becomes more pronounced as the day passes. A possible explanation for an effect of Budget Condition being present in the participant's final five choices is that the budget state they experienced throughout the task may have become more pronounced as the participant neared the end of the task.

Abreu & Kacelnik observed risk-sensitive decision making in starlings (1998). In their study, starlings were assigned to an energy budget condition (starlings experiencing a negative budget would only be fed half of their *ad libitum* intake while starlings experiencing a positive energy budget would be fed their full *ad libitum* intake), and chose between an alternative that provided them with five units of food consistently, and an alternative that provided them with either eleven units of food 33% of the time or two units of food 66% of the time. Starlings in both conditions were risk averse, and there was not a significant difference between groups (Abreu et al., 1998). A more recent publication posits that the Energy Budget Rule is not a realistic model of risk-sensitivity, and that its account for foraging behavior is derived from small organisms whereas the assumptions of the rule are less critical for larger organisms for which a short-term energy requirement poses less of a threat (Lim, Wittek, & Parkinson, 2015).

Though there is an effect of Budget Condition present within participant's final five choices in the present study, the results do not support the predictions of the Energy Budget

Rule. There is an overall preference for the low-risk choice across both conditions. Interestingly, participants in the positive energy budget condition chose the high-risk alternative more often than participants in the negative energy budget condition. Participants experiencing a negative energy budget were more risk averse than participants experiencing a positive energy budget, implying a conflicting account of choice behavior in this particular task.

**Addressing Potential Limitations**

Studies that observe behavior in high-risk situations present an empirical account in a controlled environment. One limitation of such research is that participants participate in a low-stakes environment. A controlled analog may not match the situation of an individual with few expendable resources, or the pronounced need of an organism foraging to survive. In the current study, participants engage in a high-stakes hypothetical task, but they do so in a low-stakes environment that will reward them with class credit regardless of the outcome of the task. One potential limitation to this study is that an empirical study cannot recreate the high-stakes that one experiences when they are foraging to survive, or gambling at a casino. The predictions of The Energy Budget Rule are stronger as need becomes more pronounced. Perhaps need did not become more pronounced in this study because it took place in a low-stakes controlled setting where the participant was rewarded for participating regardless of the outcome. Need cannot become pronounced if it is not perceived by the participant. Another potential limitation of this study is that the reinforcement received may not have been salient enough to affect behavior. Participants were rewarded with points in this task. The use of a real-world reinforcement could be argued to be a “real” reinforcement and could have a more weighted effect on decision making. However, the results of a study by Dickhaut and colleagues (2013), suggests that these arguments may not be as valid as they may seem. Participants were presented with a decision making game in which the stakes became either lower with a greater chance of receiving a lesser reward or higher with a lesser chance of receiving a greater reward as they continued to play. Hypothetical points were used as reinforcement. The data of the study was compared to the results of another study that used the same procedure, but reinforced participants with real money (Holt and Laury, 2002). They found that preferences between real world money or points in a decision making task was revealed to be statistically indistinguishable. Hypothetical points were revealed to be just as salient as real money as a reinforcement. The results of this study also revealed a trend in risk aversion as the stakes increased (2010).

**Future Directions**

Though the manipulations in this study were not an effective representation of cost, future researchers should make an effort towards introducing cost in future studies testing The Energy Budget Rule. Our manipulation of response duration was an indirect manipulation of cost; we recommend a direct manipulation in future studies. For example, a direct manipulation of cost could be that initiating each choice subtracts a certain number of units from the power bar that participants tried to fill. Alternatively, if one were to keep the current study's manipulation of response duration (by altering avatar speed), the introduction of a timer could more effectively represent cost. In this case, the introduction of a Cost State in the second stage could reduce the time that the participant had left to complete the task - particularly in High Cost Conditions.

The study conducted by Dickhaut and colleagues (2013) speaks to the validity of the use of hypothetical high stakes situations in low stakes environments. Further modifications to the study, however, could be used to increase the stakes in the "real-world" low stake environment. An individual gambling at a casino will likely see or hear other people win. Arguably, the effect of observing someone else succeed in

**Conclusions**

A common assumption is that individuals with expendable resources are more likely to gamble than individuals with few expendable resources. Barnes found that individuals with expendable income reported lower levels of gambling (i.e., purchasing lottery tickets) than individuals with few expendable resources (2011). The results of this study, however, propose an alternative account of behavior. The main effect of phases in this study implies that as participants experienced the task, they quickly became sensitive to risk. No participants in this study preferred the high-risk alternative, but participants experiencing a positive budget condition were more prone to engage in high-risk choosing. The budget conditions in this study may have modulated the frequency of high-risk choosing in participants.

These implications can be extended to real life gambling situations. The Energy Budget Rule provides a real-world example to support its account of behavior. The account of behavior suggested by the results of the current study can also be extended into a real-world scenario. Take, for example, two individuals experiencing either a positive or negative budget condition (in terms of expendable resources for the night) gambling in a casino. These individuals decide that they will either play roulette (high-stakes) or slot machines (low stakes) through the night. According to the implications from the results of the current study, the individual with fewer expendable gambling resources will be more sensitive to losses when playing roulette than the other individual. They are likely to decide to switch from roulette to the slot machines sooner after losing at the roulette table than the individual with more expendable gambling resources who experiences the same number of losses.

The implications of the current study’s results can be further extended into an even simpler scenario. If given two individuals experiencing either a positive or negative budget condition in terms of the expendable resources they have after payday. If both of these individuals place weekly bets on a competition and experience losses, the individual with fewer expendable resources would be expected to modulate their behavior sooner than the other individual. On the next payday, they may choose to modulate their behavior by engaging in low-risk gambling like the lottery or scratch-offs. They may choose not to gamble at all. While both individuals are sensitive to losses when engaging in high-risk behavior, the individual experiencing a negative budget will be more risk averse than an individual experiencing a positive budget.

In conclusion, the task created for the current study was intended to be a risk-sensitive analogue that tested The Energy Budget Rule. It attempted to introduce cost (energy expenditure) into the task, an aspect of The Energy Budget Model that had not been considered in previous human analogues of the rule. The results of present study conflicted with the predictions of The Energy Budget Rule, aligning instead with the common-sense notion that having expendable resources leads to a relatively greater propensity for high-risk choice.

# REFERENCES

Abreu, F. B. E., & Kacelnik, A. (1999). Energy budgets and risk-sensitive foraging in starlings. Behavioral Ecology, 10(3), 338–345. doi: 10.1093/beheco/10.3.338

Barnes, G.M, Welte, J.W. Tidwell, M.C. & Hoffman, J.H. (2011). Gambling on the Lottery: Sociodemographic Correlates Across the Lifespan. Journal of Gambling Studies, 27, 4, 575-86.

Caraco, T., Martindale, S., & Whittam, T. S. (1980). An empirical demonstration of risk-sensitive foraging preferences. Animal Behaviour, 28(3), 820-830.

Dickhaut, J., Houser, D., Aimone, J. A., Tila, D., & Johnson, C. (2013). High stakes behavior with low payoffs: Inducing preferences with Holt–Laury gambles. Journal of Economic Behavior & Organization, 94, 183–189. doi: 10.1016/j.jebo.2013.03.036

Hertwig, R., Barron, G., Weber, E. U., & Erev, I. (2005). Decisions from experience and the effect of rare events in risky choice. Psychological Science, 15, 534–539.

Holt, C.A., Laury, S.K., 2002. Risk aversion and incentive effects. The American Economic Review 92 (5), 1644–1655.

Laude, Jennifer & Pattison, Kristina & Zentall, Thomas. (2012). Hungry pigeons make suboptimal choices, less hungry pigeons do not. Psychonomic bulletin & review. 19. 884-91. 10.3758/s13423-012-0282-2.

Lim, I. S., Wittek, P., & Parkinson, J. (2015). On the origin of risk sensitivity: the energy budget rule revisited. Animal Behaviour, 110, 69–77. doi: 10.1016/j.anbehav.2015.09.007

Lindeijer, T. Tiled Map Editor [Computer software]. (2008). Retrieved from https://www.mapeditor.org/

MacArthur, R., & Pianka, E. (1966). On Optimal Use of a Patchy Environment. The American Naturalist, 100(916), 603-609. Retrieved from http://www.jstor.org/stable/2459298

McDevitt, A. M., Pisklak, J. M., Spetch, M., Dunn, R. (2018). The influence of outcome delay on suboptimal choice, Behavioural Processes, Volume 157, Pages 279-285

Mishra, Sandeep & Lalumière, Martin. (2010). You can’t always get what you want: The motivational effect of need on risk-sensitive decision making. Journal of Experimental Social Psychology. 46. 605-611. 10.1016/j.jesp.2009.12.009.

Molet, M. Miller, H. C., Laude, J. R., Kirk, C., Manning, B. & Zentall, T. R. (2012). Decision making by humans in a behavioral task: Do humans, like pigeons, show suboptimal choice? Learning and Behavior, 40, 4, 438-447.

Pietras, C. J, Searcy, G. D., Huitema, B. E., Brandt, A. E. (2008) Effects of monetary reserves and rate of gain on human risky choice under budget constraints. Behavioural Processes, 78, 358-373

Searcy, G. D., Pietras, C. J., (2011). Optimal risky choice in humans: Effects of amount of variability, Behavioural Processes, Volume 87, Issue 1, Pages 88-99

Spetch, M. L., Belke, T. W., Barnet, R. C., Dunn, R., & Pierce, W. D. (1990). Suboptimal choice in a percentage-reinforcement procedure: Effects of signal condition and terminal link length. Journal of the Experimental Analysis of Behavior, 53, 219-234.

Stagner, J. P., & Zentall, T. R. (2010). Suboptimal choice behavior by pigeons. Psychonomic Bulletin & Review, 17,3, 412-416.

Stephens, D. W (1981). The logic of risk-sensitive foraging preferences. Animal Behaviour, 29, 2, 628-629

Van Rossum, G., & Drake Jr, F. L. (1995). Python reference manual. Centrum voor Wiskunde en Informatica Amsterdam.

Zentall, T. R. & Stagner, J. P. (2011). Maladaptive choice behaviour by pigeons: an animal analogue and possible mechanism for gambling (sub-optimal human decision making behaviour). Proceedings of the Royal Society B, 278, 1203-1208.

Zentall, T. R. (2017). An Animal Model of Human Gambling Based on Pigeon Suboptimal Choice. Research & Reviews: Neuroscience.

APPENDIX 1

## Energy Budget Task Script

Thank you for agreeing to participate in our study. In this game, you are a robot at an electricity plant in the year 4019. After an unexpected explosion, the main power grid has shut down and needs repairing. The electricity plant has gone into lockdown mode and you are locked inside the building - only you can fix the grid from the inside and free yourself from the building!

Use the arrow keys to control your player. The LEFT and RIGHT arrow keys are used to rotate or aim; the UP and DOWN arrow keys are used to move forward or backwards. There are rows of wooden boxes that have experimental 'battery boxes' inside of them - you can use them to get the grid back online! Press 'ENTER' to shoot a laser and break one of the wooden boxes - you can only break one wooden box at a time. After you break a wooden box, you will be instantly awarded a battery box and told where you can deposit it. A battery box may go in the generator on the left side of the screen, the right side of the screen, or you'll be instructed to choose the side that you think will work best. You must break a wooden box before you are able to deposit a battery box into a generator. Use 'SPACEBAR' to throw the battery box into a generator.

Your goal is to win the game by filling the power bar at the top of the screen three times before running out of wooden boxes. The battery bar must be completely filled three times to bring all systems back online. If you fail to completely fill the power bar three times, you will lose the game. Upon the end of the task, notify the researcher and they will debrief you. You will be given credit for your participation. Do you have any questions?