Correlation Between Executive Function & Risk-Taking in Children

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Cognitive Science Honors Program 2024

University of California, San Diego

Data Availability: **honors thesis coding**

Abstract

This study aims to investigate the association between children's executive function (EF) and risk-taking behaviors from 6-8 years old, and contribute to the understanding of their decision-making processes. We measure EF by scoring their accuracy at a game that requires them to act the opposite of given verbal commands. For measuring risk-taking, we give them coins to play with and present two boxes, high-risk and low-risk, and they will choose which one to put their coins in. The high-risk box outputs a loss and a high gain. The low-risk box outputs no loss but has small gains. They can exchange their coins for stickers at the end of the game. We want to know if children are more risk-averse or risk-seeking individuals. In addition, this study explores whether their decisions have to do with understanding the probability of events that are involved in risk-taking. The answers from this study can help us learn about children's cognitive development and show how they will react to situations where they face risks as adults. The first hypothesis is that higher executive function subjects will self-regulate more and show risk-averse behavior to guarantee more stickers. The second hypothesis is that subjects with lower executive function will have less self-regulation and show risk-seeking behavior, which might not guarantee more stickers. We also predict that children will score higher on the EF task with age, showing more self-regulation as they get older. In contradiction to the first two hypotheses, the preliminary results reveal trends of higher executive function scores making high-risk choices and lower executive function scores making low-risk choices. Moreover, the data shows that older subjects score higher on executive function, so the older kids are the ones making more risky choices. Therefore, the last hypothesis, which was having more self-regulation to make safe choices as a child gets older, was not found.

1. Introduction

The field of cognitive science includes a vast range of disciplines, including studying human development. Children learn and grow in many settings and gain different cognitive abilities that aid them in everyday life. One such ability is called executive function, which allows practicing self-regulation and being aware of oneself and one's actions. EF is known to be involved in attention for being goal-oriented, inhibition control for controlling our impulses against inappropriate actions or behaviors, and cognitive flexibility for thinking about multiple things simultaneously and adapting to changing circumstances (Diamond, A. 2013). We use these abilities to facilitate decision-making in everyday life and want to know if this decision-making facilitator specifically impacts children's decisions regarding risky behavior. Risk-taking is a behavioral outcome of decision-making and involves a situation of uncertainty in which the probability of each outcome, whether positive or negative, is known to the individual (Brand et al., 2007). In the context of decision-making with EF abilities, risk-taking may involve attention to keep track of the means for gains and losses, inhibiting impulses to non-beneficial behaviors, and cognitive flexibility to think about all the possible outcomes of the risk at hand. In order to address whether this correlation exists developmentally, this study tests 6-8-year-olds on executive function levels and risk-taking behaviors. For this project, the context of their risk-taking will be in an economic setting.

In order to build an economic framework for this study design, we must first orient ourselves to theories that explain how we think rationally. According to Utility theory, a rational being acts based on maximizing expected utility. Simply put, a rational human being will make a decision that gives them maximum payoff in a scenario that might give them the most satisfaction. However, not all human beings are rational. Prospect Theory considers our biases, showing us that humans place more weight on perceived losses than perceived gains (Sebora, T. C., & Cornwall, J. R. 1995). For example, this might mean losing $1 makes one feel worse off than a $1 gain because the loss feels bigger than the gain feels good. Because of this emphasis on loss, an individual may avoid risk-taking, even if it could give more payoff. Therefore, people are generally "loss averse" or avoidant to taking risks. These are frameworks that economists use to make sense of adult behavior, but we want to know how children fit into these.

2. Literature Review

We know from prospect theory that thinking rationally can be complex. In a risk-taking situation, rational thinking involves understanding probability, assessing risk, and assessing payoff. Can children reasonably be expected to be able to do these things? According to previous studies, children can reason probabilistically depending on the paradigm of their given task. An example of a simple task is when they draw chips from a box that are black, white, circular, and square at random. They are given information about the outcomes to know what all the chips look like (**Fig. 1**).

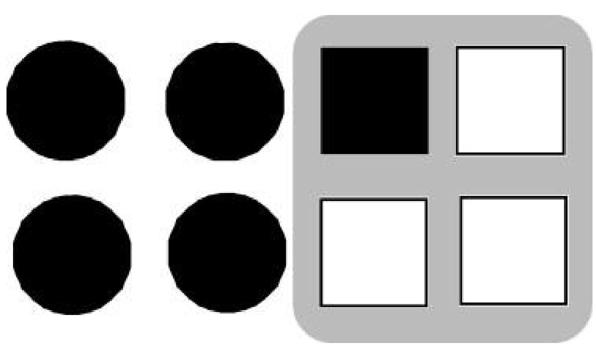


Fig. 1 Gritto, V. & Gonzalez, M. (2008)

The results of the study revealed that 5 to 10-year-olds are able to use the given information to successfully predict probabilities. For instance, as shown in Fig. 1, if the experimenter says they have a square chip, the child should predict that it is white because there are more white squares compared to black ones. However, when the task paradigm becomes more complex, children may struggle to reason probabilistically. In a different task, they are presented with the probability of 3 animals being right or wrong at predicting what's behind two doors, a positive and negative outcome respectively. The child then makes their own prediction to find the positive outcome. They are cued by the validity of the animals, where high validity means more accuracy and low validity means less accuracy (**Fig. 2**). The results showed that 6-year-olds fully and 9-year-olds partly neglected stated probabilistic information in their choices. They are not able to understand that following the animal with the highest validity might mean a higher probability of finding the treasure. This task is more complex because the child is determining the validity of cues on their own, and inferring probabilities through a social agent. Therefore, there is mixed literature about children understanding probability, and it relies on paradigm style.

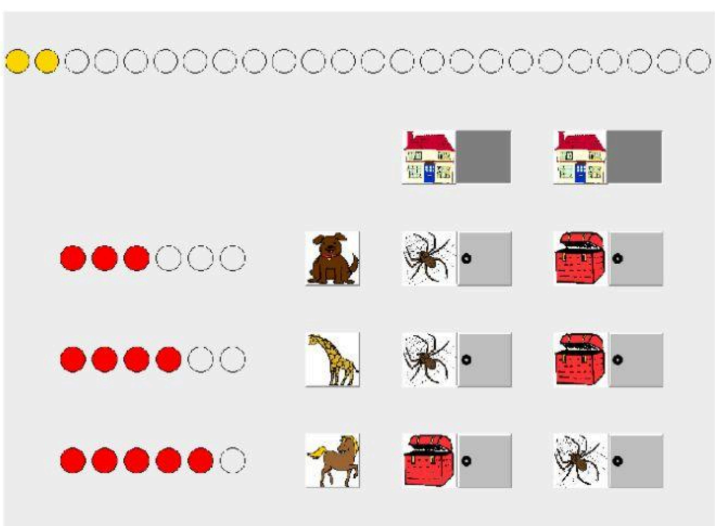


Fig. 2 Lang. A & Betsch, T. (2018)

There is also mixed literature about how children partake in risk-taking behavior. In the Bubble Gum Analogue Risk Task for Children (BART-C), K-8th graders control puffs to blow up the bubble and accumulate points, but it can explode at any point, and all the earned points can be lost. They get 30 actions, which they choose how to use. They spend the actions to either inflate the bubble and accumulate points or use the actions to save their current score and have a fallback if the bubble pops (**Fig. 3**). To mitigate the risk of ending up with nothing, they should save their points to add to towards total score. The results showed just this, as younger kids are loss-averse and save more to avoid that potential loss. According to this study, risk tolerance does not peak until adolescence. However, other studies show that risk tolerance starts much earlier, and children start risk-seeking at much younger ages.

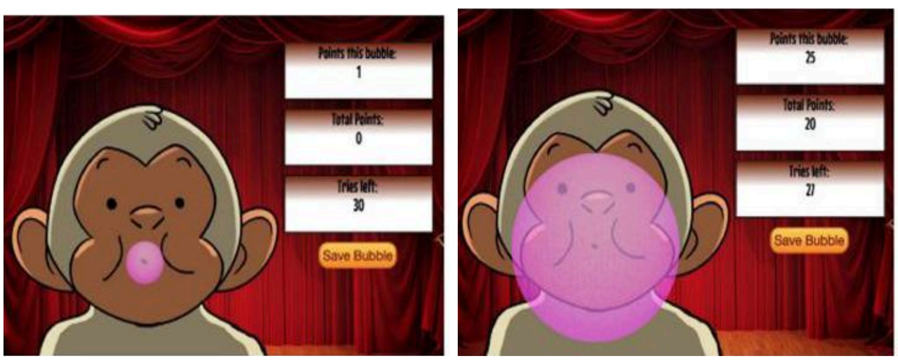
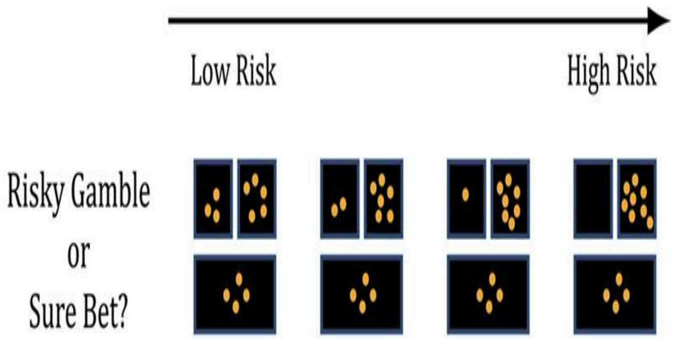


Fig. 3 Bell et. al (2019)

In a task that more closely resembles an economic decision-making situation, children are asked to choose between a risky gamble and a sure bet of 4 coins, knowing they can exchange their coins for a toy at the end. They operationalize risk as the chance that one gets less than four coins or the size of the loss when compared to the sure bet. According to **Fig. 4**, in the low risk, they only lose one coin; in the high risk, it means losing everything. The results of this complex task showed that 6-7-year-olds make the risky choice even when the risk level increases because they want the jackpot.



. **Fig. 4** Paulen et. al. 2011

Therefore, along with the literature on probability with kids, the literature about risk-averse and risk-seeing kids is also mixed. We want to understand what in development is driving these changes in children's risk-taking behaviors and see if executive function (if it, in fact, facilitates decision-making) is possibly correlated with the distinct findings.

3. Methods

Because this is a correlational study, we must measure executive function and risk-taking behavior. Since risk-taking itself is such a broad topic, the study is designed to measure it through an economic game. This way, we test risk levels in a specific context.

3.1 Participants

The subjects were male and female, 6-8 years old, and voluntarily tested at Fleet Science Center, San Diego, CA. These ages were chosen because the previous literature covers 5-12-year-olds, and 6-8-year-olds are a small developmental subset in that range. Data has been collected on 16 participants across this demographic, and it is recorded through parent-consented videos. They all receive five stickers at the end as a reward for the last task.

3.2 Measure Executive Function

First, to measure executive function, we implemented the Head Toes Knees Shoulders (HTKS) task (Ponitz, C. et al. 2008). This task was chosen because it has been widely used in previous research as a measure of executive function in children. The task requires children to follow the experimenter's verbal command and then instruct them to touch body parts different from the verbal commands. There are two parts to the task before the Final Test; in both parts, the child receives training (helping them if they get it wrong) and practice. Note that only Part 1 has a test of its own, and the child is not tested again until the Final Test. The following are the instructions that the child gets:

Part 1: Training, Practice, Test

"If I say touch your head, you touch your toes.

If I say touch your toes, you touch your head

Are you ready? Let's try it."

Part 2: Training, Practice (no test here)

"If I say touch your knees, you touch your shoulders.

If I say touch your shoulder, you touch your knees

Are you ready? Let's try it."

Final Test: test Part 1 and Part 2 together

"Now that you know all the parts, we're going to put them together."

The score is created from a total of 52 points created from one training round (with head and toes), one practice test (with head and toes), the first part test (with head and toes), and the final Test (with head, toes, knees, and shoulders). If they immediately get it correct, they get scored "2". If they show any sign of self-correction, even with the slight movement of going towards the wrong motion at first, they get scored "1". If they get the body part wrong altogether, they get scored "0". According to the authors of the task, the reason this task measures executive function is because it asks children to do a rule-switch in their heads, which is a function of cognitive flexibility, as children adapt to given circumstances and multiple pieces of information in their heads. It is also a measure of inhibitory control because they must act against their impulse and attention focusing because they must focus attention on the instructions being presented. The higher their score, the higher the executive function level a child has.

3.3 Measure Risk-Taking

Now, to measure risk-taking behavior, we created a coin box game. As seen in **Fig. 5**, the child is given three coins to play with, and they are told to get as many coins as they can to exchange each for stickers at the end:

“The more coins you have, the more stickers you can get at the end. Try to get as many as you can! Does that sound good?”

They are then shown all the possible outputs of a Low-Risk box and a High-Risk box. The Low-Risk box outputs 4, 6, and 5 coins, while the High-Risk box outputs 1, 9, and 5 coins. It is important to note that this is the order they come out in every time. On average, they have the same expected return, but the High-Risk box has a chance you end up with fewer coins than you put in, while the low-risk box guarantees a gain. This is a novel task in the sense that the high risk is not “all-or-nothing” like the previous literature, meaning not everything is at stake, and we’ll see if that makes a difference in their behavior.

The experimenter shows the distribution of coins shown in **Fig. 5** by presenting each output one at a time through the mechanisms of the boxes. The presenter has three coins, just like the child, and inserts them at the top of the box and uses their other hand to push a pouch with the coin output (**see Fig. 6**). When the pouch comes out of the box, they open it and count how many coins came out. The experimenter has the inputs and outputs ready to demonstrate from their perspective (**see Fig. 7**)

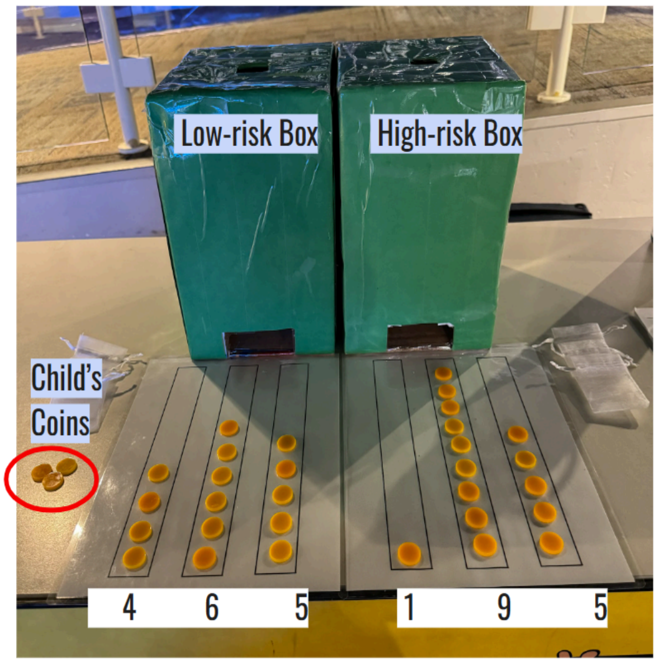


Fig. 5 What the distribution looks like

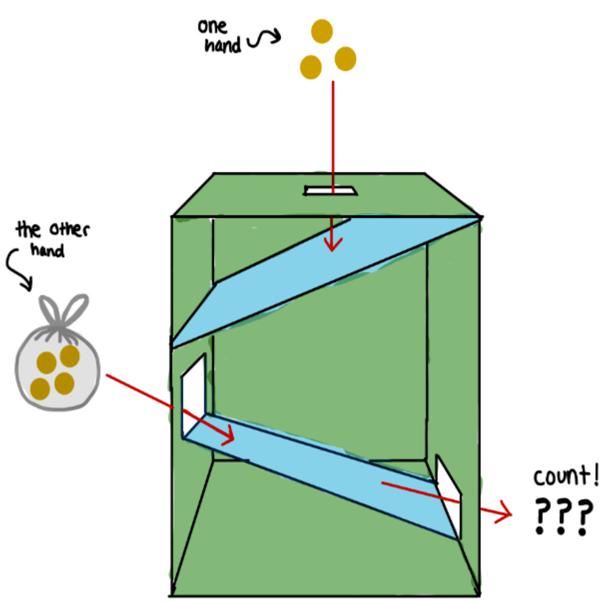


Fig. 6 How the box works

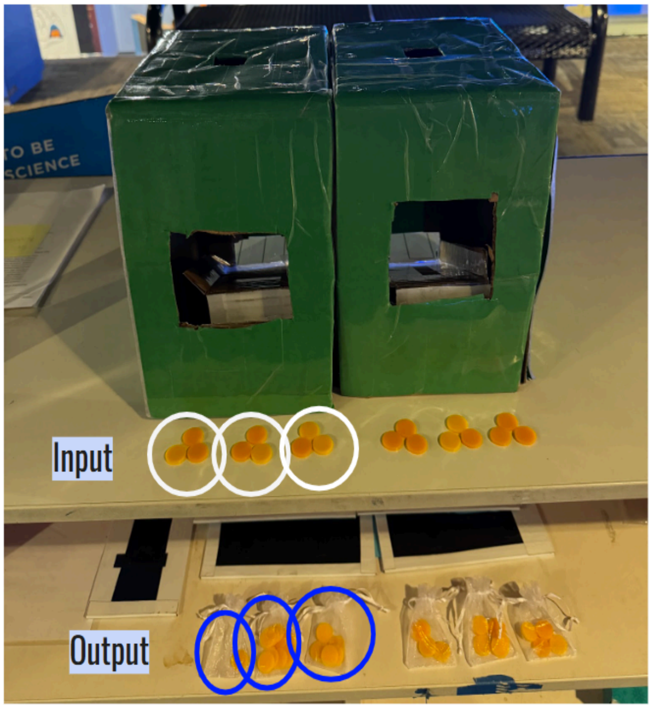


Fig. 7 The experimenter's perspective

3.4 Engagement

Throughout the task, the experimenter's role is to facilitate the child's understanding of the task and ensure their full engagement without influencing the child's decision-making process. Here's an example of the experimenter's dialogue as they assist the child in tracking the coins after each pouch:

High-Risk Box (first pouch):

Here are MY 3 gold coins. I am going to put it in the green box to use it.

place tokens and output bag with 1 token

So [Child's Name], how many coins did the box give out?

Did I get more coins or lose coins?

"lost" --> By how many coins? (2)

Incorrect --> Actually, the box lost 2 coins.

So there were 3 coins before and 1 coin after, so I lost 2 coins.

3.5 Measured Variables

Assuming they understand probability, we get to see if children are risk-averse or risk-seeking individuals and see where they fit into the literature because they get to choose a box to put their 3 coins in or choose not to play at all. We labeled their behavior as follows: 0 - chose not to play, 1 - chose low-risk box, 2- chose high-risk box. As an attempt to see if they understand the probability involved in the task, we also record their justification of the box chosen by asking them some debrief questions:

1. *Why did you choose that box to play with?*
2. *What do you think would happen if you had played with the other box?*

3.5 Counterbalancing

The children see that three coins go in the box, and different amounts come out, but it the order of the boxes changes per participant. The counterbalancing is the following: high-risk box presented first on the left (HR-LR Left), low-risk box presented first on the left (LR-HR Left), high-risk box presented first on the right (HR-LR Right), low-risk box presented first on the right (LR-HR Right). This should account for order and left-right biases, such as being likely to choose a box solely because it was presented first. The pilot data collection was distributed equally across these counterbalances (**see Fig. 8**). There are 7 six-year-olds, 7 seven-year-olds, and 2 eight-year-olds distributed across the four conditions (n=16). After the pilot stages of the study, we will fill each counterbalance with the same amount of participants across ages and gender.

Condition	Gender	Age
Low-High Left	Female	6
Low-High Left	Female	6
Low-High Left	Male	6
Low-High Left	Male	6

Condition	Gender	Age
High-Low Right	Male	6
High-Low Right	Female	6
High-Low Right	Female	7
High-Low Right	Female	7

Condition	Gender	Age
Low-High Right	Male	7
Low-High Right	Female	7
Low-High Right	Female	7
Low-High Right	Female	8

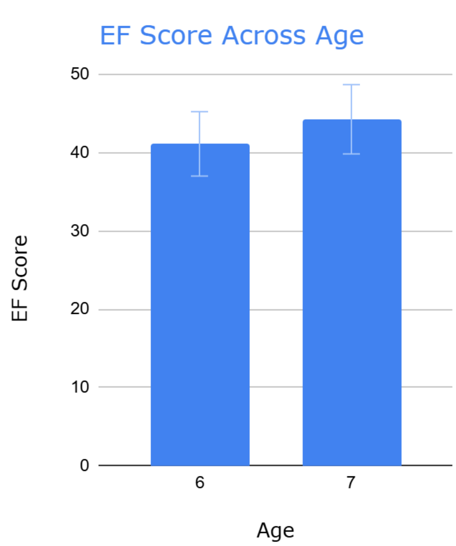
Condition	Gender	Age
High-Low Left	Male	6
High-Low Left	Male	7
High-Low Left	Female	7
High-Low Left	Male	8

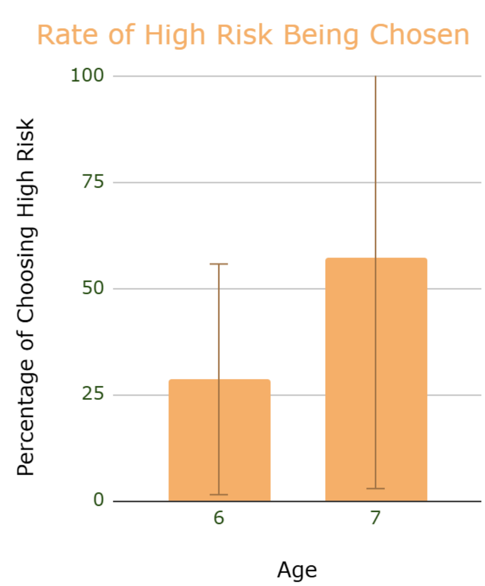
Fig. 8 The counterbalances

3.6 Hypothesis

Our hypothesis suggests that lower-level EF scores are likely to take more risk because they are distracted by extreme output. They are projected to be risk-seeking and choose the high-risk box. Conversely, higher-level EF scores are likely to take low risk because they have more self-regulation to be sure to receive gains. They are projected to be risk-averse, so they chose the low-risk box. A lower age should mean a lower EF level. Therefore, age should make you better at the task (Zelazo et al.; S. M., 2020).

4. Preliminary Results



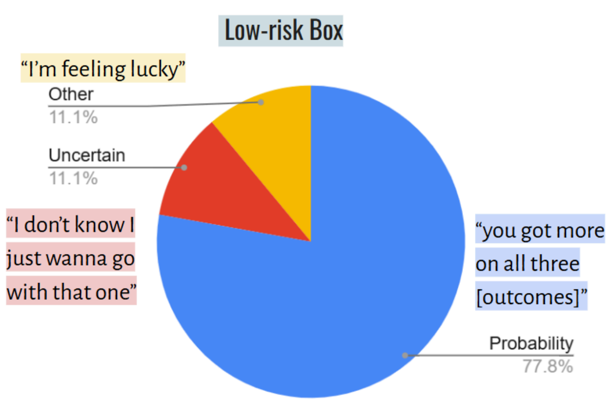


The 8-year-olds are excluded in this analysis for lack of participants in that age (n=14). Thus far, we have created graphs from the pilot data. On the left graph with blue bars, we compared the EF score to different ages. Among the 14 participants, older kids scored higher on the EF task, which follows the hypothesis. However, on the graph with orange bars, we checked them to see what percent of them chose the high-risk box. We saw more older kids making riskier choices, even though higher EF was predicted to be risk-averse.

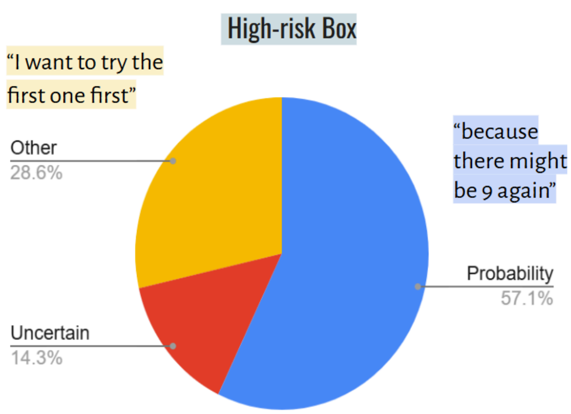
On the graph with green bars above, we compared the executive function scores to the risk level chosen (1-high, 0-low). Varying EF scores do not seem to show a difference in low/high-risk behaviors. We ran a statistical analysis on EF score using age and gender as controls, and we did not find a significant effect. So far, we have low statistical power because of the small sample size, so we can only present the current trends. The aim is to learn more about the correlation between executive function and risk-taking behavior in children by adding statistical power and increasing the sample size through more testing.

4.1 Qualitative Data

Based on their justifications for the box they chose, maybe we can learn something about where the children fit into the mixed literature results of understanding probability. From their verbal responses to the debrief questions (see section **3.5**), the children are split into three categories. First is the “Uncertain” group, that did not understand why they chose a box and might say "I don't know". The second group is the “Probability” group, that used probabilistic reasoning in their answer. For example, in the low-risk box, they might say, "You got more on all 3 outcomes," showing that they know the low-risk box is more likely to guarantee gains. In the high-risk box, the kids might say they chose this box because "there might be 9 again". The last category is the “other” group that did not use probability in their answers and instead might reason that “I want to try the first one first” or 'I'm feeling lucky". The following charts graph their responses:



In risk-averse children, 77.8% use probabilistic reasoning in their decisions.



In the risk-seeking children, 57.1% use probabilistic reasoning in their decision.

These are not causal accounts of their behavior or decisions, but it's interesting to see how they justified their choices because it can show if they were invoking Probabilistic Reasoning or using probabilistic terms. This goes for both box decisions. Overall, according to the charts, the kids use probabilistic language to justify their decisions more often than not.

5. Conclusion

From this project, further research is needed to see if executive function facilitates how people behave in decision-making about risks. Each decision they make can positively or negatively impact a life, whether that be in everyday life, entrepreneurship, drug abuse, or unhealthy addictions. Risk-taking is relevant when children face real-world situations involving uncertainty, and therefore, learning what influences taking risks can shape an individual and the next generation of children. Therefore, studying how these two might work hand in hand can really impact child development.

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