The Development of Executive Function in Risky Decision Making among Preschoolers

BY

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Abstract

Risky decision making refers to making a decision that includes a choice with an uncertain outcome. Many skills such as executive function (EF) are important for effective decision making. EF refers to higher-order cognitive skills necessary for goal-directed behaviour. It is divided into two categories: hot executive function and cool executive function. Hot EF are used in a motivational context, whereas cool EF are used in a more abstract context. The present study assessed three- and four-year-olds' EF development in regard to risky decision making by utilizing various EF tasks and a Risky Decision Making task. Participants included 125 children from preschools across the greater Moncton area. Results revealed no significant difference in risk taking across a gain domain vs loss domain, that four-year-old children take more risk than three-year-old children in the Risky Decision Making task used, and that the delay of gratification task (DoGT), which assesses hot EF skills, is associated with proficient risk taking. In the future, research should evaluate the comprehension of the preschool-aged participants on the tasks at hand, exclude any distracting factors within the tasks, increase the age sensitivity of the Risky Decision Making task, and use a larger sample with a broader age range.

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The Development of Executive Function in Risky Decision Making among Preschoolers

Throughout a lifespan, each person faces multiple high-risk decisions. While deciding, it is common to weigh the pros and cons in pursuit of an expected value. Can you recall one of the first risky decisions you had to make? In comparison to a risky decision made in adulthood, as a child you may have had difficulty assessing your emotions and the facts available, resulting in a rash choice. Imagine it is June, and you begin to plan a trip to Florida for winter break. The plane tickets for a round trip currently total around $1380.00; however, the price is subject to change before then. Choosing when to buy your ticket becomes a risky decision, in which you must decide if you would like to pay the current and known price or choose to wait. Although the tickets may become cheaper, people who wait risk paying more or risk having no tickets available. While most adults are able to handle this type of decision-making, this type of decision-making would be beyond the abilities of young children. What changes over development to improve this type of decision-making? What abilities underlie this type of decision-making? The present thesis investigates these questions.

Executive Function

Despite the difficulty in establishing a concrete and consistent definition of executive function (EF) across research, the general consensus is that the term refers to mental processes used in self-regulation that is goal oriented (Zelazo & Müeller, 2010). Cognitive processes within executive functioning include regulating thoughts, emotions, and behaviours in an adaptive and goal-oriented manner (Garon et al., 2014). Furthermore, shifting, working memory, and inhibition are critical components of EF

(Garon et al. 2008). These skills are crucial for daily tasks such as risky decision making, concentration, planning, and time management. EF abilities are mediated via prefrontal networks, which research has indicated develop rapidly during early childhood (Hodel, 2018).

The decision-making process illustrates the complex nature of EF abilities. While some decision-making situations depend on one's ability to process emotional information, others do not. Cool EF is distinguished from hot EF by the need to regulate emotional content (Zelazo & Müller, 2010). Generally, cool EF refers to abstract problem-solving occurring in non-affective and neutral environments (Garon et al., 2014 In contrast, hot EF is emotionally and motivationally rooted. Both cool and hot EFs have been found to be significantly associated to naturally occurring day-to-day decision making (Garon et al., 2014). Cool EF has a hierarchical relation with hot EF as it entails the needed skills to resolve cognitive conflict that hot EF does not have. In other words, when a conflict does not entail motivational factors, individuals can rely on the abstract skills found in cool EF (Zelazo & Cunningham, 2007).

Cool Executive Function

Although hot and cool EF overlap in some processes, the two have distinct properties (Zelazo & Müller, 2010). Cool EF skills are primarily associated with networks in the dorsolateral prefrontal cortex (DL-PFC) (Zelazo & Müller, 2010). Most research regarding early EF skills has focused on cool executive functioning (Garon et al., 2008). To maintain a non-affective context, researchers assessing cool EF will often have an absence of rewards and punishments. The absence of motivational stimuli provides individuals with a neutral environment in which they will feel more inclined to

use more abstract reasoning skills. Abstract reasoning, along with working memory, long-term memory, shifting, and inhibition are all skills associated with cool EF (Garon et al. 2008). Research on cool EF indicates that the skills develop rapidly during preschool years but only reach peak capacity near the age of 20 (Zelazo et al., 2013). The following sections briefly review three main types of EF assessed during the preschool period.

Inhibition

Inhibition is a skill in executive functioning that requires children to regulate a behavioural response. An example of this skill would be to restrain oneself from engaging in certain behaviours despite temptation. Upon assessment of their desired dominant response, those engaging in inhibition will suppress and redirect their behaviour (Garon et al., 2008). One commonly used inhibition task is the Stroop task. As seen in Miyake et al.'s (2000) research, this task requires participants to state the colour of a stimulus in a high-speed setting; however, some trials included the presentation of a colour written out but displayed in a font colour that differs from the word (e.g., "PINK" presented in yellow). However, this task along with others demonstrates the complex nature of studying inhibition as it often requires participants to learn, hold and apply a rule. As a result, most inhibition tasks also assess working memory.

The Object retrieval task (Diamond, 1990) is commonly used to assess inhibition in young children. This inhibition task begins by placing an object (e.g., a toy), in a transparent box. The transparency of the box ensures that the toy remains visible to participants. The researcher asks the child to get the object for them. To attain the toy,

the child must reach around the box and through the opening. If the child reaches directly for the toy, they will be obstructed by the transparent barrier. This task assesses children's ability to inhibit their desire to directly reach for the toy and learn to reach around successfully.

Garon et al. (2014) present an adapted version of this object retrieval task entitled the Tricky and Silly Box tasks. The Tricky Box task presents children with a box with two transparent doors on the front and a lever on the left and right sides. A different toy is positioned behind each transparent door. The researcher then demonstrates to the child that the levers lift the transparent doors, enabling them to obtain the toy. After their demonstration, the researcher asks the child to get a specific toy. Researchers measure whether the child chooses the correct lever or reaches directly for the toy. If the child uses the incorrect lever, they can try again. Following this box task, the child is provided with a new box. The new box, entitled the silly box, is identical to the first, except the right lever now lifts the left door, and the left lever lifts the right. The researcher demonstrates to the child which lever lifts which door. Following the demonstration, they ask the child to get one of the two toys. The trials continue by alternating between the toys the researcher wants from the participant. This inhibition task measures participants' ability to inhibit their previous learning regarding which lever opens which door and their desire to directly reach for the toy.

Findings on this inhibition task suggest an age improvement during preschool. In other words, older children are better at inhibiting their desire to directly reach for the object and use the levers to lift the screen door for the object's retrieval. More specifically, Garon et al. (2014) found that during the simple inhibition task, in which

the lever opened the door on the corresponding sides, results demonstrated a continuous increase of performance, with an interruption of a deceleration period in the midst of preschool development. Additionally, age improvement was found on the more complex stage, the silly box task where children must inhibit the dominant response of using the same side knob to lift the door. Garon et al. (2014) found that performance in this task is relatively stable until about halfway through preschool development, in which children have a sharp increase in performance.

Working Memory

Working memory is another EF skill. This form of memory consists of short-term retention of information. Working memory is composed of two processes: simple and complex. Simple working memory refers to the skill of retaining learnt information in one's mind while complex involves manipulating the retained information for its application and use (Garon et al., 2008). Many tasks utilize working memory as participants must remember and apply rules learnt from the instructions provided. The Keep Track task is a commonly used task to assess working memory (Miyake et al., 2000). As seen in Miyake et al.'s (2000) research, this task instructs participants to memorize several list items. After the list presentations, participants write down all remembered items. The number of items remembered is an indication of the strength of one's simple working memory. This skill develops more gradually during the preschool period in comparison to other EF skills (Garon et al., 2014).

Shifting

A third executive function skill closely related to working memory and inhibition is shifting. As previously mentioned, working memory is significant in this

research as it enables children to hold rules in memory for short periods of time. However, shifting occurs when participants must adapt their thoughts, behaviours, and cognitions to new learning that contradicts the previously stored information. Shifting is directly related to inhibition as the participant must inhibit the old mental set in order to utilize a new mental set. The Dimensional Change Card Sort (DCCS) task is commonly used to assess shifting. This task, developed by Zelazo et al., (2006) has children sort presented cards by a certain dimension. For example, each card may display one of two shapes, e.g., circle and square. Additionally, the circle and squares alternate between two colours, e.g., yellow and blue. At first, the participant will be asked to sort each card by the presented shape. However, after several trials, the researcher will ask the child to begin to sort by colour. As a result, the relevant stimulus of shape then becomes an irrelevant stimulus and the colour which was irrelevant prior is now relevant. This assesses the child's ability to shift their attention from one dimension to another.

One measure of shifting during the preschool period is the Dimensional Change Card Shift (DCCS). This task, commonly conducted via online software, assesses shifting skills among children (Semnov & Zelazo, 2018). Initially developed by Zelazo et al., (2006), this task presents children with two boxes. One box displays the image of a green rabbit, while the other displays a purple pig. Researchers then have children sort a series of test cards with either the green pigs or purple rabbits into boxes with the corresponding colour on them. After sorting all purple rabbit cards to the purple pig box and green pig cards to the green rabbit box, the child is instructed to sort the following assortment of cards by their shape. The child's ability to switch the applied rule, retain the new one in mind, inhibit engagement of the old rule and sort by the new one is

measured. Across research, the colours and images presented for the DCCS task may differ, but the goal of measuring participants' ability to shift their learnings and correctly sort the presented cards remains. Findings indicate a rapid improvement on this task from 3 to 5 years of age (Garon et al., 2008).

Garon et al.'s (2014) study presents an adaptation of the DCCS task, in which preschool participants must find a hidden animal under one of two flaps in a flap book. In one dimension, the animal is under the same shape (e.g., a square), instead of a differently shaped presented flap. As the task progresses, the flaps begin to be coloured, adding irrelevant information that participants must ignore. However, in the second dimension, the previously irrelevant stimulus (the colour) becomes the clue as to where the animal is hidden. As a result, the child must begin to ignore the formerly relevant stimulus (the shape). This task assesses the child's ability to shift their learnings of relevant and irrelevant stimuli. In congruence with past research, Garon et al. (2014) found a significant age improvement on this task from 1.5 to 5 years of age.

Hot Executive Function

In contrast to cool EF, hot EF occurs in highly motivational environments. Research has indicated that hot EF skills are associated with the ventromedial prefrontal cortex (VMPFC) and the overlapping orbitofrontal cortex (Zelazo & Müller, 2010). In this thesis, the term VMPFC will be used to refer to the region including the ventromedial and orbitofrontal cortex. Hot EF research tasks must include affective challenges that require goal-directed behaviour. These tasks utilize rewards and punishments to create highly emotional contexts for participants. As a result, researchers

interested in assessing hot executive function assess emotionally driven behaviour produced by participants to achieve a particular goal.

Decision Making Under Risk

Each day, people make choices ranging from small to large; however, the context of these decisions differ. Although definitions of risky decision making have differed amongst researchers, it is clinically defined as behaviour or choices that can result in negative repercussions (Defoe et al., 2015). However, as stated by Defoe et al., (2015) what constitutes a negative outcome is subjective and therefore, difficult to define. As a result, in the current study, risky decision making will be defined as when the choice or action made includes an uncertain outcome or consequence. For example, say a child goes to the store with $4.00 to buy candy. There is a pack of 8 chocolate bars for $3.50 and a candy surprise bag for the same price. This child loves candy and wants to maximize the amount they get. The child must decide whether they want the eight chocolate bars or the uncertain choice of the surprise bag. The child does not know whether the unknown bag will provide them with more, less, or the same amount of candy, constituting the bag as the uncertain option. In contrast, the pack of chocolate bars is the certain option as it visibly comprises 8 chocolate bars which the child is aware of. The child must then decide whether they want to make a risky decision.

By defining risk by the presence of uncertainty, the concept becomes easily applicable to both gain and loss domains in research. In other words, a risky decision is when a choice in the decision has the possible probability of being less than 1/1. For instance, an option that has a ½ (.5) probability of resulting in a gain of two stickers is uncertain whereas an option that has a 1/1 probability of resulting in a gain of one

sticker is certain. Furthermore, this is also applicable in a loss domain where the certain option has a 1/1 probability of losing one sticker whereas the uncertain option provides the probability of ½ (.5) of the loss of two stickers or no stickers. Note that the expected outcome or value (EV) differs in each of these options. The expected value is obtained by multiplying the probability of an outcome by the value of the outcome.

In the literature on decision-making, a distinction is often made between decisions made under risk and decisions made under ambiguity (Brand et al., 2006). Decisions made under risk refer to tasks in which decisions are made in a context of known probabilities for each option. In contrast, decisions under ambiguity refer to tasks in which decisions are made in a context where information is not provided about each option. Rather individuals must learn the value of each option by making the choices and getting feedback.

The cups task, developed by Levin and Hart (2003), is a task used to assess decision-making under risk in children and adults. This task presents participants with four boxes on a table, two on the left and two on the right. Participants choose a box to find hidden prizes. Their choices consist of a safe and certain option or a risky uncertain option. Probabilities for the risky option are provided to participants. Participants' preferences for the risky or riskless options are assessed across two domains: the gain domain and the loss domain. Created to assess risky decision making in an affective context, researchers measure the number of risky decisions taken in loss domains vs gain domains and the impact of the expected value of the prize.

In the gain domain, participants are told which side of boxes will provide them with a single prize. In contrast, they are told that the other side of boxes is the uncertain

side, as the two boxes have different numbers of prizes. On the uncertain side, one box has a sum of two prizes, while the other has none. The value of the prizes differs across trials, but one of the uncertain boxes is consistently less than the certain option, and the other is always more. As a result, participants must choose if they want the known number of prizes or to make a risky decision and potentially gain double, more than double, or nothing.

In contrast to the gain domain, the loss domain begins by providing participants with ten prizes. Additionally, the task uses two boxes, one on the left and one on the right. Inside the boxes are faces used to indicate the number of prizes lost. The box on the certain side presents a frowning face with a "1" placed on the nose, indicating the loss of one prize. While inside the box of the uncertain side is two faces: a smiley face with no number and a frowning face with a "2". The “2” indicates the loss of two prizes, while the smiling faces indicates the loss of none.

Results in older children and adults indicate that there is a domain effect in risky choice whereby participants tend to make risky choices in the loss domain in comparison to the gain domain (Levin & Hart, 2003; Levin et al., 2007; Strough et al., 2011). For example, Levin and Hart (2003) found a strong preference for children’s risky choices when in the loss domain compared to the gain domain. This indicates that a preference for risk to avoid loss is present at the young age of 5 years old. This higher propensity to take risks in the loss domain as compared to the gain domain is called the framing effect. However, we do not know how preschoolers would perform on this task as the youngest age tested on this task was 5-year-olds.

Another finding in this area of research is a change in risk taking throughout childhood, adolescence, and adulthood (Weller et al., 2011). Typically, the finding is of a decrease in risky choices throughout a lifetime, particularly for the gain domain (Weller et al., 2011). Many researchers have adapted Levin and Hart's (2003) Risky-Decision Making to add to its findings. For example, some research has presented the task as a computerized task. As a result, the title of "Risky Cups Task" differs across studies as the procedure does not always incorporate cups. Additionally, depending on the study, the items gained in these tasks vary.

Finally, using this task, experimenters often provide different trial types to assess sensitivity to expected value (EV) of the risk. Individuals who take more risks when it is advantageous in comparison to when it is disadvantageous have a higher sensitivity to EV. Research in this area has indicated an increase in sensitivity to EV over a lifetime (Levin et al., 2014).

Decision Making Under Ambiguity

The most commonly used task for assessing decisions under ambiguity is the Iowa Gambling Task (IGT; Bechara, et al., 1994). This task consists of the presentation of four decks of cards. Participants strive to maximize their profits by randomly choosing one card from one of the decks. The card chosen may add to or deduct from the participant's profit. The participant then continues selecting a single card at a time from any of the four decks. However, each deck has a pattern, leading to either a positive or negative net worth. Each card in decks A and B provided participants with large rewards of money; however, many cards in these decks had significantly larger deductions than gains. In contrast, decks C and D provided small sums for gains but

even smaller losses. As a result, decks A and B led to a negative net gain while C and D led to a positive net gain. Primarily conducted on a computer, participants view the tallies of losses and gains provided by each deck. Participants continue to draw cards without knowing when the game will end. This task assesses hot EF since it produces a motivational context of attempting to maximize rewards and avoid punishments.

Results indicate that individuals without damage to their brain are typically able to learn the patterns of the deck and thus begin to choose decks C and D to maximize their profits (Bechara et al.,1994). However, research has demonstrated that individuals with damaged ventromedial prefrontal cortex (VM-PFC) are unable to learn to not choose the disadvantageous decks of A and B even if they identified that they were the less beneficial decks (Bechara et al.,1994). These findings are significant in the field of EF research as they indicate the key role of VM-PFC in the hot EF system as these individuals show poor performance on making beneficial goal-directed behaviour in a motivational context.

Based on Bechara et al.'s IGT (1994), Kerr and Zelazo (2004) developed the Children's Gambling Task (CGT), a simplified version used to assess decision-making under ambiguity in children. As opposed to the four in the IGT, the CGT consisted of two decks of cards. The cards present one or two smiling or frowning faces. The number of frowning faces indicate the number of candies lost, while the smiling faces indicate the number of candies gained. The CGT differs from the IGT, as it provides participants with an easily interpretable indication of whether they gained or lost their desired reward. A second notable difference is the change of reward from money to candy.

Despite these differences, both the IGT and CGT involve uncertainty. In both tasks, until participants learn the patterns regarding which deck is advantageous vs disadvantageous, both deck options are “uncertain”, as their outcome is unknown. Some researchers have identified this uncertainty as ambiguity to ensure its distinction from the uncertainty present in the probability of loss/win that is known vs unknown. As seen in Garon’s (2016) research, some studies ask children part-way through the task which deck is better and worse. This dimension of verbal communication ensures the opportunity for assessment of the child's learning of the deck patterns. Overall, the CGT's general procedure remains the same as the IGT, with few adaptations to be better understood and completed by a younger age range.

As seen in the IGT, one deck in Kerr and Zelazo’s (2004) research provides participants with small immediate rewards and smaller losses, while the other has large immediate rewards but larger losses. As a result, one deck is ultimately advantageous while the other is disadvantageous for the goal of maximizing the obtainment of candy. Findings suggest that the development of this type of hot EF skill is prominent throughout the preschool years of life since four-years-old have been found to perform significantly better than three-year-olds at identifying patterns and maximizing profits (Kerr & Zelazo, 2004). Additionally, this finding is significant as it indicates a rapid development of decision-making skills within affective contexts between the ages of three and four.

Temporal Decision Making

The two previous decision-making tasks (Cups Game and IGT) assess repeated decisions between two options that differ in terms of net gain and probabilities of win

and loss. Another type of decision-making task involves consideration of time and size of reward when making a decision. Temporal decision-making tasks involve the integration of time with reward size to calculate value. Note that these tasks overlap with decision under risk tasks (e.g., Cups task) and decisions under ambiguity (e.g., IGT) in different ways. They overlap with decisions under ambiguity because both involve consideration of reward size and time in making a decision. Furthermore, in both tasks, participants are provided with knowledge about each option before making the decision. The most well-known hot EF task that measure temporal decision making is the delay of gratification task (DoGT; Mischel & Ebbesen, 1970). One variation is the DoGT choice task; this typically involves the choice between a small, immediate reward and a larger, delayed reward. Research on this task indicates vast differences among participants' ability to wait for a larger reward (Mischel et al., 1989). These differences can be accounted for by many variables such as age, individual differences, the physical presence of the rewards, the differences between the immediate and delayed rewards, and the ability to engage in other activities while waiting (Mischel et al., 1989).

The second adaptation of this task is the DoGTwait (Steelandt et al., 2012). This task involves placing a reward (e.g., a marshmallow) in front of the child participant. Following the reward presentation, the researcher instructs the participant to wait for their return before taking the reward. If able to wait, the participant will receive a larger and more desirable reward. However, if they choose not to wait, the participant can ring a bell and eat the presented marshmallow. Results indicate that two-year-old children wait for shorter periods than older participants (Steelandt et al., 2012). Additionally, Steelandt et al. (2012) found that the time the three and four-year-olds waited increased

as the size of the delayed reward increased (Steelandt et al., 2012). DoGTwait findings are consistent with most findings on DoGTchoice, as they indicate a positive correlation between waiting and age.

Risky Decision Making Task and Executive Function

Research in adults has indicated that decision-making under risk (risky decision making) involves both hot (Brand et al., 2007; Weller et al., 2010) and cool EF abilities (Brand et al., 2014; Schiebener et al., 2011). For instance, Weller et al., (2010) found that individuals who passed the IGT had a significantly greater sensitivity to EV in the Cups Game compared to individuals who failed the IGT. Similarly, Brand et al. (2014) found that sensitivity to EV on a measure of risky decision making was associated with a cool EF factor composed of working memory, shifting and inhibition. In terms of the developmental literature, there is very limited evidence of decision making under risk and association with EF abilities. One study found an association between performance on a cool EF task and performance on a risky decision making task in children aged 8- to 17 years. Similarities and differences among the Cups Task, IGT, and DoGT can be seen as listed in Table 1.

Table 1

Comparison between the Cups Task, IGT, and DoGT

Ability	Example of Task	Reward Magnitude	Loss Magnitude	Probability	Time	Knowledge before choice	Conflict within each trial	Conflict over multiple trials
Decision-making under risk	Cups Game	✓	✓	✓		✓	Certain small reward vs uncertain large reward	Small certain immediate vs very small net/small net/medium net *
Decision-making under ambiguity	IGT, CGT	✓	✓	✓	✓		Certain large reward with uncertain large loss vs certain small reward with uncertain small loss	Large immediate reward with long term loss vs Small immediate reward with long term win
Temporal Decision-making	DoGT	✓			✓	✓	Immediate small reward vs delayed large reward	Similar to trial

Note. *For our task: disadvantageous = 4 vs 3 per 2 cards / neutral = 4 vs 4 per 2 cards/advantageous = 4 vs 6 per 2 cards

General Conclusion

Risky decision making is an inevitable experience across one's lifespan and making risky decisions may rely on the development of certain EFs (Bechara et al., 1994). As a result, determining when the executive skills necessary for risky decisions develop is essential. As previously stated, EF skills are used for goal-directed behaviour. More specifically, hot EF is of benefit in motivational contexts, while cool EF is used in non-affective contexts. Therefore, depending on the emotional level of an environment, both are necessary for producing goal-directed behaviour. It is likely that both cool and hot EF are involved in real-life decision making. While the evidence indicates that both hot and cool EF are involved in risky decision making for older children and adults, it is unclear whether this association holds true for younger children.

Research on EF in risky decision making among adults has determined that the prefrontal lobes play a critical role in such goal-directed behaviour (Bechara et al.,1994). Significant research has been conducted on EF in risky decision making with adult participants, however, less so on children. The research that has been conducted on children has indicated rapid development of decision-making skills within affective contexts between the ages of three and four (Kerr & Zelazo, 2004). Although some research has been done on children, the majority of it has solely assessed decision making under ambiguity (e.g., CGT) rather than decision making under risk (e.g., Cups Game). As a result, the main goal of the current study is to assess early development of decision making under risk in preschoolers. In this respect, various aspects of decision-making under risk will be investigated in young children including the framing effect, total risk taking, and sensitivity to EV. Another goal is to investigate how cool and hot

EF work together across development in risky decision making in preschool participants.

Rationale

This current study aims to add to the minimal research on how cool and hot EF collaborate in risky decision making across early development. To examine cool EF skills, an inhibition and shifting task will be conducted. In contrast, hot EFs will be assessed by the Preschool Gambling Task (PGT) and the Waiting Game (Delay of Gratification). Lastly, the Tricky Envelopes Game (a modification to the cups task) will assess children's risky decision making abilities. As found in past research on older children and adults, we hypothesized that younger children would make more risky decisions than older children. Furthermore, we hypothesized that children would make riskier decisions in the loss domain in comparison to the gain domain and that children's sensitivity to expected value (EV) will increase with age. Finally, we hypothesized that sensitivity to EV would be directly related to both hot and cool EF tasks.

Method

Participants

In this study, participants included 125 children between the ages of three and four. We had nearly an equal division of three-year-old participants (40%) to four-year-old participants (60%). Participants were recruited from preschools across the New Brunswick area. Parents signed a permission slip to permit their child's participation. Participants were incentivized throughout the procedure with toys and stickers.

Materials

Delay of Gratification Task

A clear plastic box with three divided sections was used in the delay of gratification task. On top of each sector of the box was a visual display of how long participants need to wait to receive the desired toy (e.g., two timers; see Appendix A). Additionally, a sand timer for 30 seconds was used. Presented rewards differed across each round. The first round used three bouncy balls, the second four capsules, the third four rings, and the last six erasers. The task demonstration included a sock puppet named Lambchop, and the reward of stickers. Lastly, researchers had a score sheet (see Appendix B).

Preschool Gambling Task

In the PGT, two flap books of cards with felt covers were used (see Appendix C). One flap book cover displayed a giraffe, while the other displayed a zebra. Besides the different cover animals, the flap books were generally identical. The flap books consisted of cards with monsters and bunnies. A magnetic board displayed a four-story house and a 40-step flight of stairs. A car magnet was used and placed on the staircase. Lastly, children were given multiple stickers as rewards and researchers will use a score sheet (see Appendix D).

Inhibition Task

The inhibition task included the presentation of two boxes. On the front of both boxes were two transparent doors, and on the left and right side of the box was their corresponding levers (see Appendix E). The boxes were distinguishable from each other by their different fabric patterns. Behind the doors of the tricky box was a blue and

yellow bear (see Appendix E), while the silly box had an orange and green bear (see Appendix F). Additionally, a score sheet was used (see Appendix G).

Shifting Task

In this task, a flap book was presented. For the first dimension, each page of the book presented a cat with its eyes either opened or close. In the majority of dimension one, a green square was situated on one side of the cat while a yellow square was on the other (see Appendix H). After the first six pages, the shapes on the two sides of the cat were no longer squares but a heart and star (see Appendix I). Behind each flap, an image of the cat smiling, or frowning was displayed. In the second dimension, an owl was presented in place of the cat (see Appendix J). Additionally, instead of beginning with the squares, the flaps displayed yellow or green stars and hearts throughout all ten pages. Identical to dimension one, a smiling or frowning owl was presented on the other side of the flap. A score sheet was used for both dimensions (see Appendix K).

Risky Envelope Task

The first dimension of the risky envelope task presented children with a flap book. On each page of the flap book, there were three envelopes (see Appendix L). On one side, was an envelope with a transparent cover displaying several stickers. The other side of the page had two envelopes, each with an opaque green covering. In between the two green envelopes were two images: one that displayed a higher number of stickers than the other side of the page and the other with an absence of stickers. Children were provided with stickers for this task.

In dimension two, the same flap book from dimension one was used, but the images instead displayed Sesame Street's Cookie Monster eating a number of their

stickers (see Appendix M). Additionally, children were provided with a sticker book. Lastly, a bin made from fabric that resembled Cookie Monster stored the lost stickers of participants. For both dimensions, a score sheet was presented to the researcher (see Appendix N).

Procedure

Delay of Gratification Task

The DoGT that was used in the current study combined aspects of the DoGTwait and DoGTchoice. This task began with a demonstration from a sock puppet named Lambchop. We presented Lambchop with a clear plastic box with three divisions. Each sector had one sticker inside of it. The researcher explained to Lambchop that they could take the immediate prize of one sticker, wait for one 30-second timer for two stickers, or wait for two 30-second timers for all three stickers. In the demonstration, Lambchop chose to wait for one timer to get two stickers. After this demonstration, to ensure the child's understanding, the researcher asked them task comprehension-based questions, e.g., “How long does Lambchop need to wait to get all three stickers?”. Afterwards, the child completed four trials of the same task. In the first trial, one bouncy ball was placed in each sector. In the second trial, one ring was in the first sector, one in the second, and two in the last. In the third trial, two capsules were positioned in the first sector, one in the second, and one in the third. In the final trial, two erasers were placed in each sector.

Preschool Gambling Task

In this study, we used an adapted version of the Children’s Gambling Task (CGT) developed by Garon and English (2021), entitled the Preschool Gambling Task (PGT). This task began with the magnetic car positioned at the center of a four-story

staircase displayed on a magnetized board. Researchers explained to the child that the game's goal is to get to the top of the stairs. They explained that the child would gain a sticker for each step climbed. Furthermore, this task utilized two flap books. On the cover of one of the flap books was the image of a zebra, and the other was a giraffe. The researcher explained to the participant that for each round, they had to choose a card from either flap book. Upon flipping the page, the card displayed bunnies, monsters, or both. The researchers explained that each monster leads to going down one step and losing one sticker, while each bunny leads to going up one step and getting a sticker. After the explanation, the researchers asked the child if they would like to play. If the child agreed to play, they first were asked which deck they would like to choose from, the giraffe or zebra. In each trial, the child's deck selection was recorded. After 30 trials, the child was asked which animal deck is the best and which is the worst. After this, the child completed another 10 trials. At the end of all 40 trials, the child was asked to distinguish which animal deck is the best and worst again.

Inhibition Task

The Tricky and Silly Box task was a two-dimensional task that assessed children's inhibition skills. The first dimension used the tricky box. To begin, researchers demonstrated to children that to retrieve a toy bear behind the transparent door, they pull the red levers on the side of the box. Upon using the levers, the transparent screen door lifted, enabling clear access to the object. More specifically, if one lever was pulled, the corresponding door lifted (e.g., pulling the right lever lifted the right screen door). Following this demonstration, the researcher asked the child to retrieve the blue or yellow bear. Children completed 10 rounds of the tricky box task. In

the first five rounds, they were tasked with retrieving the blue bear, which was continuously hidden behind the same side door. Afterwards, the child was asked to retrieve the yellow bear on the opposite side of the blue bear.

In the second phase, children were presented with the silly box. In contrast to the tricky box, the levers in this box opened the transparent door on the opposing side, e.g., the left screen door opens upon pulling the right lever. There was a green and orange bear behind the doors in this dimension. To begin, researchers pulled each lever separately, demonstrating to the child that the lever opens the opposite screen door. After this demonstration, children engaged in five trials. Throughout the five trials, the side the participant had to retrieve the bear from was alternated.

Shifting Task

The shifting task included two dimensions and a practice trial prior to each. The practice trial presented a cat with its eyes open and a cat with its eyes closed. The researcher flipped the yellow squared flap next to the cat with its eyes open and told the child, “The cat likes to be under here when awake. See they are smiling!”. Additionally, the researcher flipped the green flap over the cat with its eyes closed and said, “When that cat is sleepy, it likes to be under here!”. If the cat is awake, the reverse side of the yellow flap displayed the cat smiling, while on the reverse side of the green flap, the cat frowning. In contrast, behind the green flap in the sleepy cat presentation, the cat was smiling but behind the yellow flap, the cat was frowning. To ensure the child’s understanding, the researcher used the same page and asked the child to show them which flap the sleepy cat vs the awake cat likes to be under. After the practice trial, the child proceeded to six trials prior to the pre-shift phase of dimension one. In these trials,

the flap book randomly alternated between presenting the awake cat who wants to be under the yellow flap and the sleepy cat who wants to be under the green flap. However, for the pre-shift, the coloured flaps shifted from being in the shape of squares to being a heart and star (see Appendix I). Participants did not engage in a practice test for this shift despite the change in shape stimulus. They were expected to continue to sort the awake and sleepy cats underneath the flap of their desired colour.

If the participant got a minimum of six out of 10 correct, they moved on to dimension two. In this shift dimension, an owl was used in place of the cat. Similar to the pre-shift in the first dimension, the owl was presented between a star and a heart that is either yellow or green (see Appendix J). This task begins with a practice trial. To begin, the researcher demonstrated to the child that when the owl's eyes are open, it is happy under the heart and not under the star. However, when sleepy, the owl likes to be under the star and not the heart. Using the practice trial page, the child was asked which flap the sleepy owl likes to be under vs the awake owl. The child then proceeded to sort 10 presented owls underneath their preferred flap. Throughout these trials, the presentation of the sleepy vs awake owl differed in a randomized sequence.

Tricky Envelope Game

The tricky envelope game procedure included two dimensions: the lost set and the gain set. The researchers alternated between which set was presented first amongst participants. For this task, the child was presented with a flap book. Each page of the flap book had two sides, a risky side, and a safe side. The researcher explained to the child that they could choose the envelope presented on the safe side or one of the two envelopes presented on the risky side (see Appendix L). In the gain set, the safe side

presented a transparent envelope that displayed the number of stickers the child would gain if they chose it. In contrast, the risky side presented two green, opaque envelopes. Between both opaque envelopes were two images: one image displayed more stickers than the stickers on the safe side, while the other presented no stickers. In the first round, the researcher explained to the child that they could choose the safe and transparent side where they could see a gain of two stickers or one of the two envelopes from the risky side, in which they could see one envelope with a gain of three stickers and one envelope with nothing. Throughout the task, the number of stickers varied, but the risky side continuously had one envelope with more stickers than on the safe side and the other with no stickers. The child completed six trials of the gain frame. After each trial, the researcher stated how many stickers were won or not won to ensure task clarity.

In the loss domain, the child was presented with a booklet of stickers and a flap book. In contrast to the gain domain, the safe side of each page presented a transparent envelope in which a picture of the Cookie Monster eating a small sum of their stickers was displayed. However, on the risky side, there were two opaque envelopes. In between them were two images of the Cookie Monster: one of him eating a higher number of stickers than on the safe side and one of him eating none of their stickers. In the first round, the child viewed the first page of their sticker book. This page presented them with three stickers. With the use of the page of the flap book, the researcher explained to the child that they could either choose the safe side and thus, feed one of their three stickers to the Cookie Monster, or the risky side which may cause the monster to eat all or none of the stickers. The child continued this game for six trials.

After each trial, the researcher stated how many stickers the child lost or did not lose. Additionally, the lost stickers were stored in the mouth of the Cookie Monster.

Participants were randomly assigned to the first or second order. Order one was gain set, loss set, gain set, loss set while order two was the loss set, gain set, loss set, gain set. Both orders ensured the repetition of both domains.

Results

The average DoGT, PGT, Inhibition, and Shifting task total scores are presented in Table 2. As seen in this table, on average, the four-year-old age group scored higher than the three-year-old group for each task, but these differences were not significant.

Table 2

Means and Standard Deviations for Task Performances

	Three-year-old group	Four-year-old group	Total sample
DoGT total score	4.75 (2.61)	5.17 (2.77)	5.01 (2.71)
PGT cards from advantageous deck total	21.38 (.8.63)	24.04 (7.57)	22.96 (8.09)
Inhibition score	.74 (17)	.83 (.13)	.80 (.15)
Shifting score	.48 (18)	.54 (.25)	.51 (.23)

Note. Standard deviations presented in parentheses.

Similarly, the means and standard deviations of the Risky Decision Making task for each age group are presented in Table 3. As can be seen, the three-year-old group took fewer risks than the four-year-old group.

Table 3

Means and Standard Deviations for Risky Decision Making

	Three-year-old group	Four-year-old group	Total sample
Risk in Loss Domain	.55 (.28)	.65 (.29)	.60 (.29)
Risk in Gain Domain	.53 (.30)	.60 (.29)	.57 (.29)
Risk Total	.54 (.24)	.61 (.24)	.58 (.24)

Note. Standard deviations presented in parentheses.

The Effect of Age and Domain on Risky Choice

To investigate the effect of age and domain on risky choice, a mixed analysis of variance (ANOVA) was run with proportion of risky choice as the dependent variable. Order and Domain (Loss, Gain) were used as within-subject variables while age in years was used as a between-subject variables. The results revealed no significant main effect for order, $F(1, 125) = 0.85$, $p = .35$, $\eta_p^2 = .007$. In other words, there was no significant difference in risk taking for Order 1 compared to Order 2. There was no main effect for domain, $F(1, 125) = 0.94$, $p = .33$, $\eta_p^2 = .007$; children did not take more risks in the loss domain in comparison to the gain domain. Additionally, there were no significant interactions. Results did, however, reveal a marginal main effect of age, $F(1, 125) = 3.63$, $p = .06$, $\eta_p^2 = .028$ such that, four-year-old participants ($M = .62$, $SE = .03$) made more risky decisions than three-year-old participants ($M = .54$, $SE = .03$).

The Effect of Age and Trial Type on Risky Choice

Two mixed ANOVAs were conducted to evaluate the effects of age, order, and trial type on proportion of risky decisions for each domain (loss and gain). In the loss domain, results were corrected with the Greenhouse-Geisser estimate, as Mauchly's sphericity test was significant $\chi^2(2) = 6.38$, $p < .05$. The results for the loss domain

revealed a significant main effect for trial type, $F(1.9, 238.06) = 3.14$, $p < .05$, $\eta_p^2 = .024$. No other main effects were significant. There was a main interaction effect for Trial type X Order X Age, $F(1.9, 238.06) = 3.21$, $p < .05$, $\eta_p^2 = .025$. Since this interaction involved age, it was followed up by assessing effects within the individual age groups.

Within the three-year-old group, Mauchly's sphericity test was significant, indicating a violation of sphericity $\chi^2(2) = 10.74$, $p < .05$, which was corrected with the Greenhouse-Geisser method. There were no statistically significant main effects or interactions within this age group. The results for the four-year-old group revealed a main effect for trial type, $F(2, 148.95) = 4.98$, $p < .05$, $\eta_p^2 = .062$, such that the number of risky decisions made differed on whether the trial type was advantageous, disadvantageous or neutral. Additionally, order revealed a marginal main effect, $F(2, 148.95) = .063$, $p > .05$, $\eta_p^2 = .045$, such that more risky decision making occurred in Order 2 ($M = 0.70$) compared to Order 1 ($M = 0.58$).

For the loss domain, follow-up paired t-tests indicated a significant difference between the risk taking in disadvantageous trials and risk taking in the advantageous trials, $t(76) = -2.97$, $p = .001$. The other comparisons (disadvantageous vs neutral and advantageous vs neutral) were not significant (both *p's* > .05).

For the gain domain, there were no significant main effects or interaction effects. Estimated marginal means were calculated for order and trial type; however, no significant differences were found. As a result, no further tests were carried out.

Association of Risk Taking with Executive Functions

Pearson correlation coefficients were calculated to assess the relationship between EF and profitable risk taking as measured by the expected value variables. The total DoGT scores was significantly correlated with EV scores in the *gain domain* during the second block, $r = .217$, $p < .05$, such that those who waited longer in the DoGT had higher EV scores in the gain domain during the second block. Additionally, DoGT scores were positively correlated with EV total scores in the second block $r = .209$, $p < .05$, such that those who waited longer in the DoGT had a high total EV score in the second block. No other executive function scores significantly correlated with EV scores.

Exploratory Analysis: The Effect of Age on Consistency of Strategy

In order to explore whether younger children were choosing at random, consistency of strategy use within each trial and domain type was calculated. A consistent choice in strategy was calculated by counting the proportion of times each child used the same choice (i.e., safe, or risky) for consecutive trials of the same type (i.e., advantageous, neutral, disadvantageous). In other words, if a child chose the safe option for each of the four advantageous trials of the loss domain, they would receive a perfect score. Similarly, if they chose the risky option for each of these trial types, they received a perfect score. However, if they shifted from trial to trial (e.g., safe, risky, safe, risky), they would receive a score of "0". If children were choosing at random, they would receive a consistency proportion score of closer to .5 (there are four possible variations for each pair of trials: safe, risky; safe, safe; risky, risky; risky, safe, two of which are consistent). A mixed ANOVA using consistency scores as dependent was run. There was a significant Age X Trial interaction effect, $F(2, 244)=3.782$, $\eta_p^2= .03$, $p =$

.024 and a significant interaction of Domain X Trial, $F(2, 244)=6.720$, $\eta_p^2= .052$, $p = .001$. Follow up to the interaction of Age X Trial indicated a significant age effect for the advantageous trials, $t(122) = 2.93$, $p = .004$ where older children were significantly more consistent in the advantageous trials ($M =.743$, $SE = .025$) compared to younger children ($M = .627$, $SE = .027$). Follow up to the Domain X Trial interaction effect indicated a significant domain difference for disadvantageous trials, $t(124) = 3.859$, $p= .004$ whereby children were significantly more consistent for the loss domain ($M = .749$, $SE = .026$) compared to the gain domain ($M = .596$, $SE = .034$). The domain difference was not significant for the other trial types (all ps > .05).

Finally, consistency was compared to chance (50%) to assess whether children were choosing according to strategy or randomly. Table 4 provides a summary of the means and t-tests. With Bonferroni adjustment p-values for number of comparisons, 3-year-olds were found to use a consistent strategy for disadvantageous trials in the loss domain, $t(49) = 6.742$, $p < .001$, for the advantageous trials in the gain domain, $t(49) = 3.183$, $p = .018$, and for neutral trials in the gain domain, $t(49) = 5.111$, $p < .001$. In contrast, 4-year-olds were found to choose consistently when compared to chance for all trial types except disadvantageous trials in the gain domain (see Table 4).

In summary, older children were more consistent in their strategy use in the advantageous trials, irrespective of domain. Furthermore, children were more consistent in the loss domain in comparison to the gain domain. Finally, while younger children were using a consistent strategy in about half of the trial types, there was more evidence that the 4-year-olds were choosing in a consistent manner throughout the game.

Table 4

Means, Standard Deviations and One-Sample t-tests for Consistency of Strategy as a Function of Age, Domain, and Trial Type

	3-year-olds	
	Mean (SD)	One sample t-test
Loss Domain		
Disadvantageous	.607(.341)	$t(49)=6.742$, p <.001
Neutral	.630(.350)	$t(49)=2.623$, p =.072
Advantageous	.607(.341)	$t(49)=2.210$, p =.192
Gain Domain		
Disadvantageous	.597(.384)	$t(49)=1.780$, p =.492
Neutral	.727(.310)	$t(49)=5.110$, p <.001
Advantageous	.647(.326)	$t(49)=3.183$, p =.018
	4-year-olds	
	Mean (SD)	One sample t-test
Loss Domain		
Disadvantageous	.732(.285)	$t(73)=6.999$, p <.001
Neutral	.743(337)	$t(73)=6.210$, p <.001
Advantageous	.770(.302)	$t(73)=7.703$, p <.001
Domain		
Disadvantageous	.595(.360)	$t(73)=2.262$, p =.162
Neutral	.678(.340)	$t(73)=4.495$, p <.001
Advantageous	.716(.269)	$t(73)=6.927$, p <.001

Note. p-values are Bonferroni adjusted for multiple comparisons

Discussion

The current study aimed to assess both hot and cool executive functions concerning risky decision making across the preschool period. Executive function was assessed with an inhibition task, a shifting task, and two types of decision-making tasks (PGT and DoGT). Risky decision making was assessed with a task inspired by Levin

and Hart's (2003) cups task. Based on past findings in older children, it was hypothesized that younger children would take more risks than older children, that children would take more risks in the loss domain than in the gain domain, and that proficient risk taking (EV scores) would be associated with hot and cool EF task performances.

Despite being found in past research, the current results did not support the hypothesis that younger children would take more risks than older children. The hypothesis that children would take more risks in the loss domain compared to the gain domain was also not supported. However, the results indicate that 4-year-olds are more proficient risk takers in the loss domain than 3-year-olds. Lastly, the third hypothesis, regarding EV scores' relation to hot and cool EF task performance, was only partially supported. Each of these results will be discussed in turn.

Age and Domain Effects on Risky Decisions

The hypotheses that older children would take fewer risks than younger children and that children would take more risks in the loss domain than in the gain domain were not supported. Generally, in research conducted on adolescents and adults, a domain effect has been identified, such that participants take more risk to avoid a loss than to achieve a gain of the same magnitude (Levin & Hart, 2003; Levin et al., 2007; Strough et al., 2011). Similarly, past findings on children have indicated that although most of their choices are risky, there is a significant increase in risk taking in the loss domain (Levin & Hart, 2003). Although this risk preference has occurred in past studies with participants as young as five years old (Levin & Hart, 2003), this study did not replicate it within the preschool age group.

One potential explanation for these non-significant findings is that the children were too young to grasp the concept of the Risky Decision Making task. Prior to 2003, risky decision making was not assessed in children as the tasks were deemed too complex to be understood and completed appropriately. Respectively, Levin and Hart (2003) conducted the first Risky Decision Making task designed for children. They ensured the task comprehension of participants by having them repeat the task goals to the researchers. Although the current study was unable to replicate Levin and Hart's (2003) findings, their research comprised children five years of age and older. Additionally, they had measures in place to ensure the participants' understanding. The current research assessed children between the ages of three and four and did not check their task comprehension but did attempt to enhance it through a task demonstration. Subsequently, we are unable to confirm whether the task was properly understood by this young age group. Furthermore, it is significant to note that although the interaction was not significant, the means indicated that there was more risk taken in the loss domain than the gain domain. Since this pattern was identified, the lack of significance could be explained by a power issue.

The current study's findings may indicate that the three-year-old participants did not grasp the concept of the task and therefore chose envelopes at random. In contrast, the four-year-old participants better understood the task and, as a result, were able to implement a task strategy. This potential explanation is supported by the exploratory analysis. Findings from the analysis on consistency of strategy use indicated that older children were more consistent in their strategy use. Overall, older children likely better understood the task and consistently implemented their chosen strategy. In contrast,

there was less evidence that three-year-olds used a consistent strategy. Future research could recruit participants with a broader age range to assess if consistency of strategy improves throughout development.

Another potential issue with the Risky Decision Making Task was that some children showed great interest in the bin resembling the Cookie Monster. At times, it appeared that children were eager to interact with/feed it. To do this, they may have purposefully chosen the safe side option knowing that it would result in an interaction with the bin. This explanation is further supported by looking at the associations of the two phases of our inhibition task with the number of risky cards chosen. The first phase measures a type of impulsivity (direct reaching for something within sight) while the second phase measures a more complex form of behavioural inhibition, sometimes called effortful attention, that involves withholding a prepotent response while keeping a goal in mind (Garon et al., 2014).

These two types of inhibitions seemed to be associated with different choice tendencies for 3-year-olds. When an exploratory regression was run with age in months, phase 1 score, and phase 2 score as independent variables and total risks taken in the loss domain as the dependent, the overall regression was highly significant, $F(3, 45) = 5.22$, $p = .004$, $r^2 = .271$. Three-year-olds who had high impulse control (high phase 1) chose more from the risky side in the loss domain ($B = .592$, p .009) while children who were high on complex inhibition (high phase 2) chose more from the safe side ($B = -.422$, $p = .016$). In other words, children who were high on impulsivity tended to choose the safe side where they could see a card with the monster eating some of their stickers rather than the risky side where they could not see the cards (only small images of the

outcomes). This regression analysis was not significant for the 4-year-olds, $F(3, 67) = 1.931$, $p = .133$. The envelope's transparency may have motivated the impulsive 3-year-olds to choose the safe side in the loss domain as they were captivated by the Cookie Monster bin and knew that if they chose this, they would certainly have the opportunity to engage with it by feeding it a number of stickers. This may explain why there was no significant difference in the number of risks taken between domains. Although this game design ensured that the task was captivating for children, future studies should ensure that losing stickers is not a potentially positive experience for children. Unfortunately, the children's interest in the Cookie Monster bin may have motivated them to take more risk in the loss domain in comparison to past studies that did not have this variable in their task's procedure.

Age and Trial Type Effects on Risky Decisions

In 2014, Levin et al. found that children take more risks when the expected value is higher on the risky side (advantageous trial) than when it is lower than the safe side (disadvantageous trial). Although not found within our 3-year-old group, a main effect for the trial type was identified in the four-year-old group. This significant difference indicated that the four-year-old children took more risks when it was advantageous than disadvantageous. Those able to differentiate between disadvantageous and advantageous trials are more sensitive to EVs. Additionally, as seen in past studies, sensitivity to EV increases throughout development (Levin & Hart., 2003; Levin et al., 2014). This finding aligns with the current study as the three-year-old participants had no significant differences between trials, whereas the four-year-old participants took significantly more risk when it was advantageous (70% of the time) vs when it was disadvantageous

(57%) of the time. Overall, this indicates that the four-year-old children were better at differentiating between the disadvantageous and advantageous trial types.

The Association of Hot and Cool EF with Proficient Risk Taking

Research has addressed the role of hot and cool EF abilities amid risky decision making in adults. Concerning cool EF abilities, inhibition, shifting, and working memory were all identified as predictors for EV sensitivity (Brand et al., 2014). As a result, the current study hypothesized that this association would be present in young children. However, none of the cool EF tasks had significant associations with EV scores. Despite this, the hypothesis that EF is associated with proficient risk taking was partially supported. Findings indicated that those with high DoGT scores were also proficient risk takers in their second completion of the domains. In other words, the ability to wait during the DoGT significantly predicted the ability to gauge when it was proficient to take risks upon the second block of the task. This significant association did not occur during the first block, likely due to children needing the experience to learn and practice the task to understand its goal. This finding is significant as it indicates that the hot EF skills involved in waiting for a desired reward are associated with one's ability to gauge proficiency in taking risks. It also fits with the abilities involved in both tasks. Recall that the DoGT and the Risky Decision Making task both provide information on the choices whereas the PGT required children to learn about the choices through feedback (see Table 1). The significant association with the DoGT rather than with the PGT indicates that individual differences in performance on the Risky Decision Making task were driven more by how children reasoned about the choices once they were given information about the two options. Future research could

utilize other hot EF tasks to further assess the role of the cognitive skills underlying goal-directed behaviour in motivational contexts and its relation to proficient risk taking.

Limitations and Conclusions

A series of factors could have influenced the current findings. The first potential explanation is our sample size. Our study was constrained due to time, resources, and location. As a result, the research was only conducted with 125 participants. This small sample reduced our power to find small effects in our sample. For instance, the framing effect was in the expected direction (i.e., children took more risks in the loss domain), but the effect size was small ($\eta_p^2 = .007$). Increasing our sample size by even 25 children would have improved power to reliably detect a small effect. Secondly, we did not account for personality differences. As seen in Levin and Hart's (2003) study, personality and temperament predict risky decision making among young children. Moreover, shyness was found to be associated with choosing more from the risky side. In the current study, children who were shy were more reluctant to participate in our study. It is likely as a result that the current sample is more representative of children who are lower in shyness and potentially more likely to take risks.

The current study found that four-year-old children took more risks than three-year-old children, that domain had no significant impact on risk taking, and that proficient risk taking (EV scores) was associated with the DoGT. Although not all hypotheses were supported, these findings add pertinent information to the repertoire of EF development in risky decision making. A potential explanation for the older children taking more risks than those younger is that three-year-olds may have been too young to fully understand the options in the current task. As a result, future research may benefit

by simplifying the Risky Decision Making task further, ensuring no utilization of distracting variables, and checking task comprehension. These factors may have also influenced why children took more risks in the gain domain than in the loss domain despite past findings presenting the opposite. The current study also indicated that the four-year-old group took more risks in advantageous trials than in disadvantageous trials, thus indicating proficient risk taking. The hypothesis that EF skills would be associated with proficient risk taking was partially supported. The ability to wait in the DoGT was significantly associated with proficient risk taking. This finding indicates that the ability to gauge when risk taking is advantageous is related to one's hot EF development in early childhood.

In closing, the current study adds to the new repertoire of risky decision making in the development of children. As individuals become more independent, they are provided with more opportunities to take risk. As a result, assessing risk taking and its underlying cognitive skills in preschool-aged children is significant to understanding its role in human development. Findings indicate that four-year-old children took more risks during the risky decision making task than did three-year-old children. Additionally, the results indicate that children as young as four years of age can differentiate when risk taking is worthwhile and when it is not. The results suggest that hot EF is associated with proficient risk taking in preschool-aged children. Overall, children's cognitive skills improve and consequently, aid in certain tasks such as risk taking. We recommend that future studies continue to assess risky decision making in developing children, including three-year-olds, to identify the age at which these processes begin and the factors that may benefit risky decision making research methods

on preschool-aged children. Up to now, research has supported that children as young as five years old can comprehend and complete Risky Decision Making Tasks (Levin & Hart, 2003), the current findings indicate that children younger than five show some ability to understand and make risky decisions when it is advantageous.

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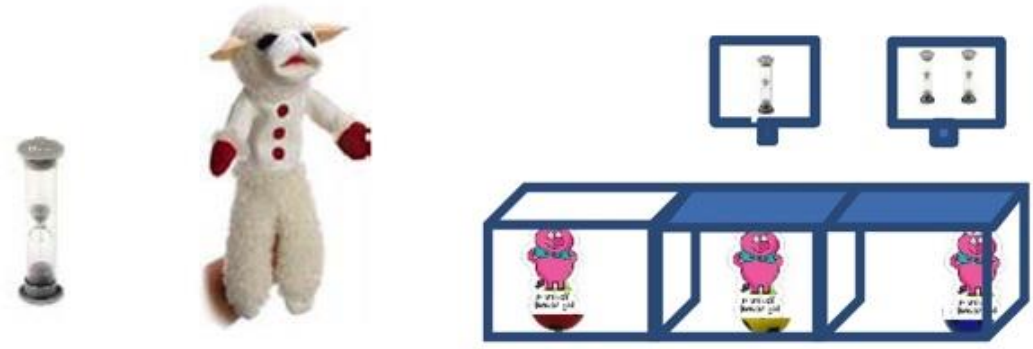
Appendix A

Delay of Gratification



Appendix A. *Hybrid wait-choice delay of gratification task set-up.*

Appendix B

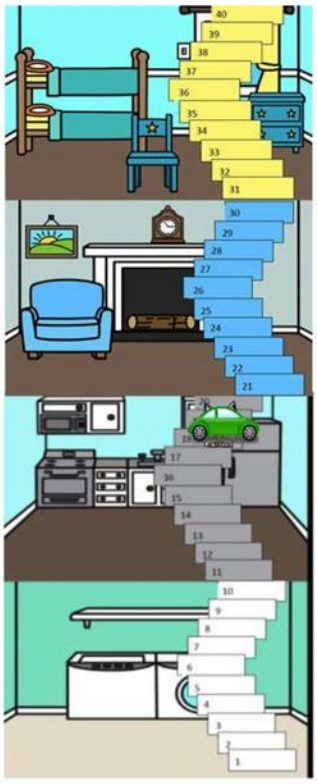
Delay of Gratification Scoresheet

3. Waiting Game			
Circle final choices Put X near choice if child started to wait but took available toy(s) before end of timer			
Immediate		1 sand timer turn	2 sand timer turns
Trial 1	1 ball	2 balls	3 balls
Trial 2	1 capsule	2 capsules	4 capsules
Trial 3	2 rings	3 rings	4 rings
Trial 4	2 erasers	4 erasers	6 erasers

Trial	Box 1	Box 2	Box 3
1			
2			
3			
4			

Appendix C

Preschool Gambling Task



******If the child has chosen from only 1 deck after 10 cards, encourage the child to choose from the other deck – it is necessary to get at least 2 cards from the other deck to have a valid assessment (i.e., need to experience win & loss from that deck)
Why don't we try [animal]?

Appendix C. Preschool Gambling Task materials.

Appendix D

Preschool Gambling Task Scoresheet

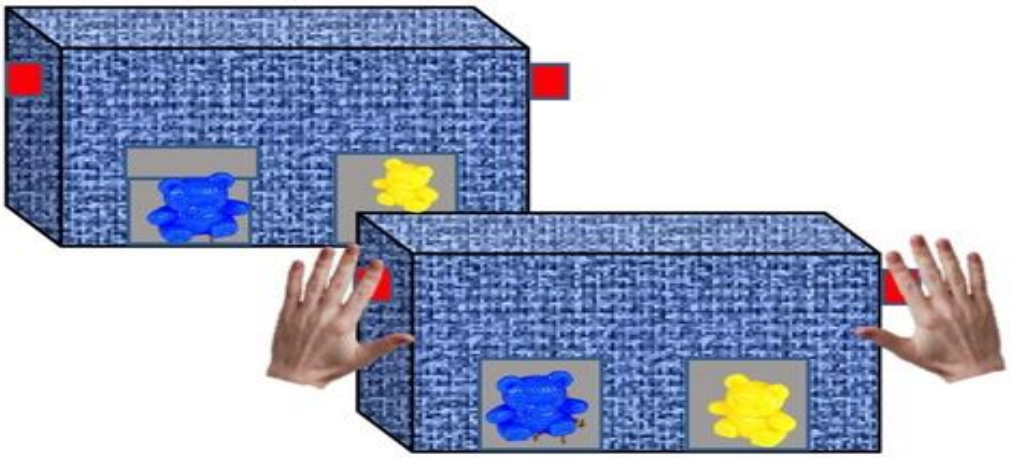
Card	Deck				Card				
1	Zebra		Giraffe		21	Zebra		Giraffe	
2	Zebra		Giraffe		22	Zebra		Giraffe	
3	Zebra		Giraffe		23	Zebra		Giraffe	
4	Zebra		Giraffe		24	Zebra		Giraffe	
5	Zebra		Giraffe		25	Zebra		Giraffe	
6	Zebra		Giraffe		26	Zebra		Giraffe	
7	Zebra		Giraffe		27	Zebra		Giraffe	
8	Zebra		Giraffe		28	Zebra		Giraffe	
9	Zebra		Giraffe		29	Zebra		Giraffe	
10	Zebra		Giraffe		30	Zebra		Giraffe	
11	Zebra		Giraffe		First Awareness test				
12	Zebra		Giraffe		31	Zebra		Giraffe	
13	Zebra		Giraffe		32	Zebra		Giraffe	
14	Zebra		Giraffe		33	Zebra		Giraffe	
15	Zebra		Giraffe		34	Zebra		Giraffe	
16	Zebra		Giraffe		35	Zebra		Giraffe	
17	Zebra		Giraffe		36	Zebra		Giraffe	
18	Zebra		Giraffe		37	Zebra		Giraffe	
19	Zebra		Giraffe		38	Zebra		Giraffe	
20	Zebra		Giraffe		39	Zebra		Giraffe	
					40	Zebra		Giraffe	
					Second Awareness test				

Awareness tests

1. Which is best? Zebra Giraffe	2. Which is best? Zebra Giraffe
Why is it best?	Why is it best?
Which is worse? Zebra Giraffe	Which is worse? Zebra Giraffe
Why is it worse?	Why is it worse?

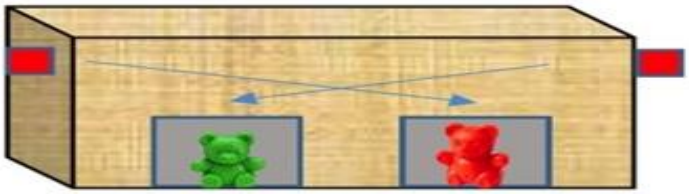
Appendix E

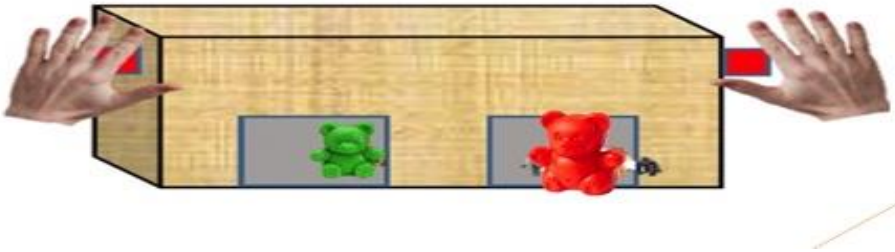
Tricky Box



Appendix F

Silly Box





Appendix G

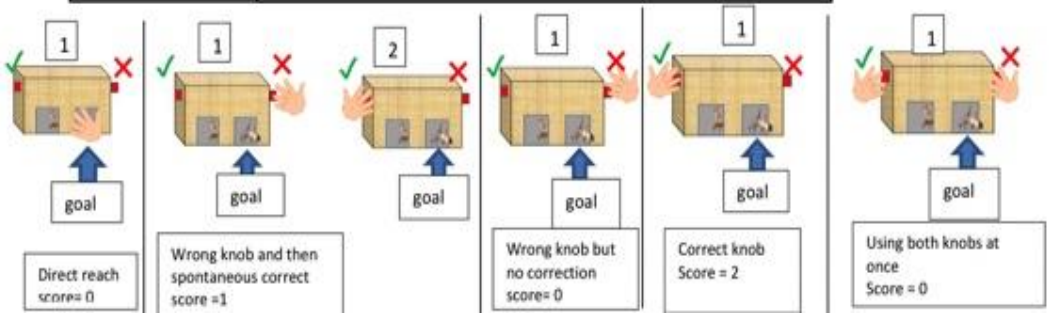
Tricky Box and Silly Box Scoresheet

Participant #____	Age 3 / 4 M/F Daycare_____
Tricky Box	Place checkmark next to action from child
trial 1	direct____knob_____
trial 2	direct____knob_____
trial 3	direct knob_____
trial 4	direct____knob_____
trial 5	direct____knob_____
Tricky Box Side 2	Place checkmark next to action from child
trial 1	Direct ____other side Correct_____
trial 2	Direct____other side____Correct_____
trial 3	Direct____other side____Correct_____
trial 4	Direct____other side____Correct_____
trial 5	Direct____other side____Correct_____
	6/10 on previous
Silly Box	Circle"1" if child initial uses wrong knob first but spontaneously switches to correct knob. Circle "2" if child uses the correct knob first. Direct reach and using both double knobs at once gets a "0". If child uses wrong knob and does not self-correct within 2-3 seconds, remind child of rule, but child gets a "0".
R trial 1	0---1----2 Direct reach____ Same_____ Double knobs_____
L trial 2	0---1----2 Direct reach____ Same_____ Double knobs_____
R trial 3	0---1----2 Direct reach____ Same_____ Double knobs_____
L trial 5	0---1----2 Direct reach____ Same_____ Double knobs_____
R trial 5	0---1----2 Direct reach____ Same_____ Double knobs_____

For Tricky Box
Stop rule = 3 consecutive correct – Go to next stage
- Child must get at least 6 correct on Stage 1 & 2 of Tricky box to do the Silly Box stage

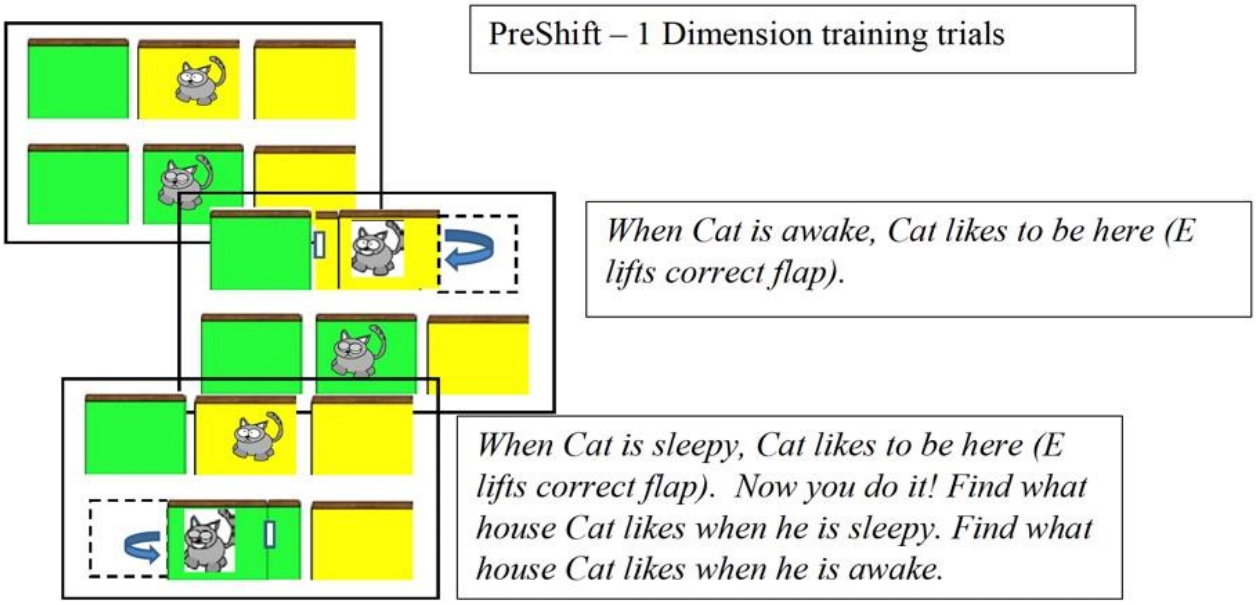
Do All 5 of the Silly Box

Alternate sides
Make sure to put hands on both knobs after hiding toy for Silly box.



Appendix H

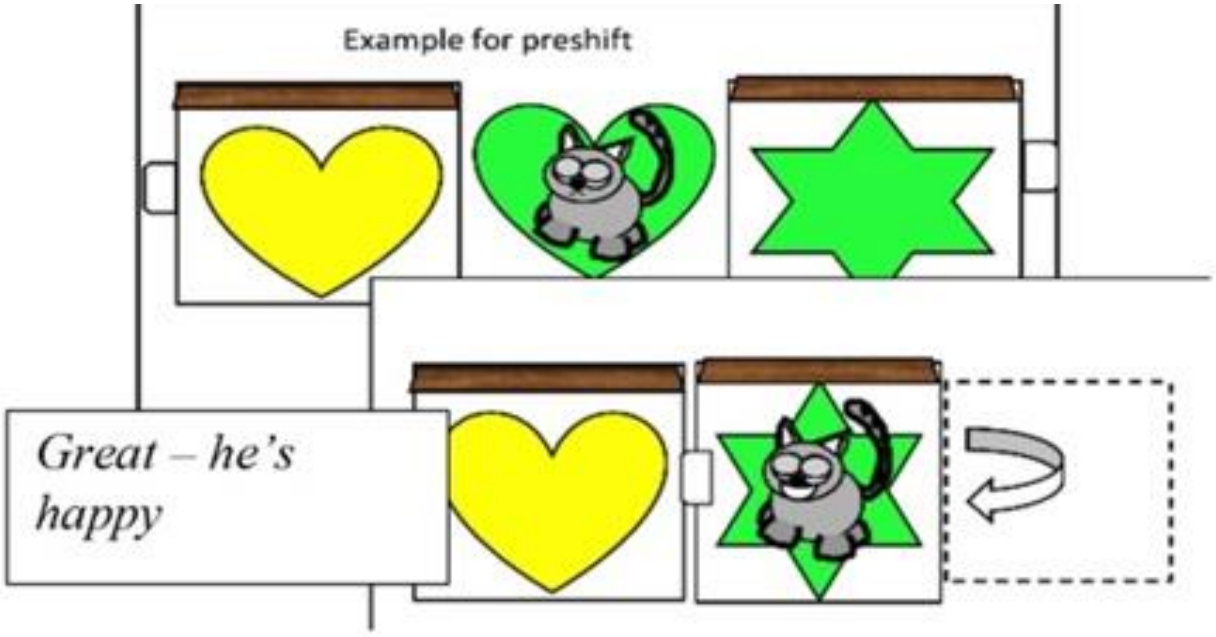
Shifting Task



Appendix H. *Shifting task dimension 1 illustration*

Appendix I

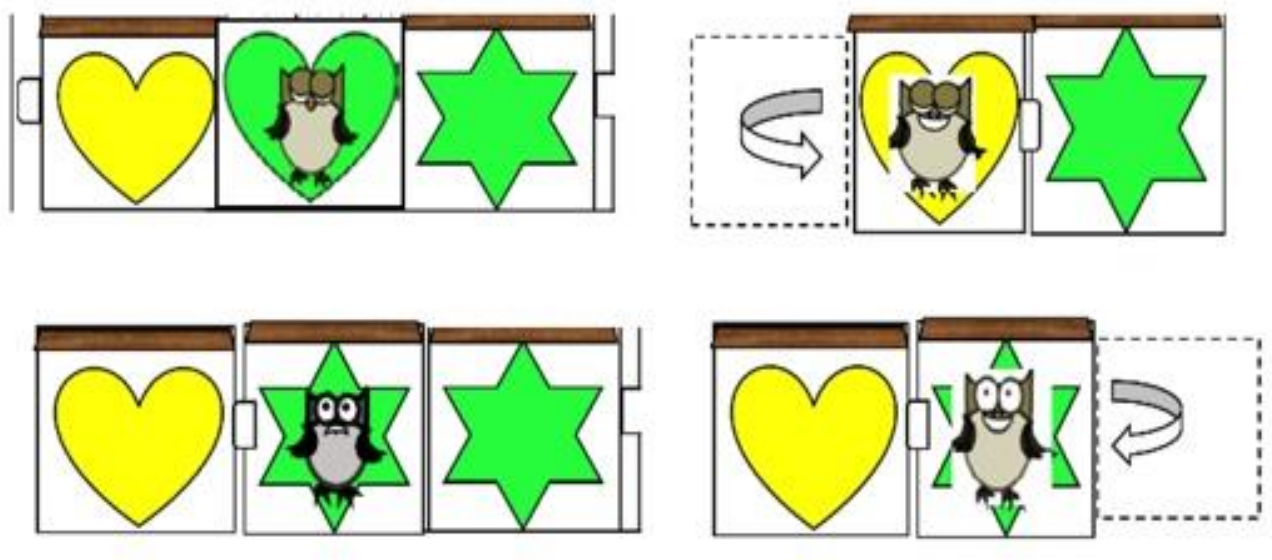
Shifting Task Pre-shift



Appendix I. *Shifting task dimension 1 pre-shift illustration*

Appendix J

Shifting Task



Appendix E. *Shifting task dimension 2 illustration*

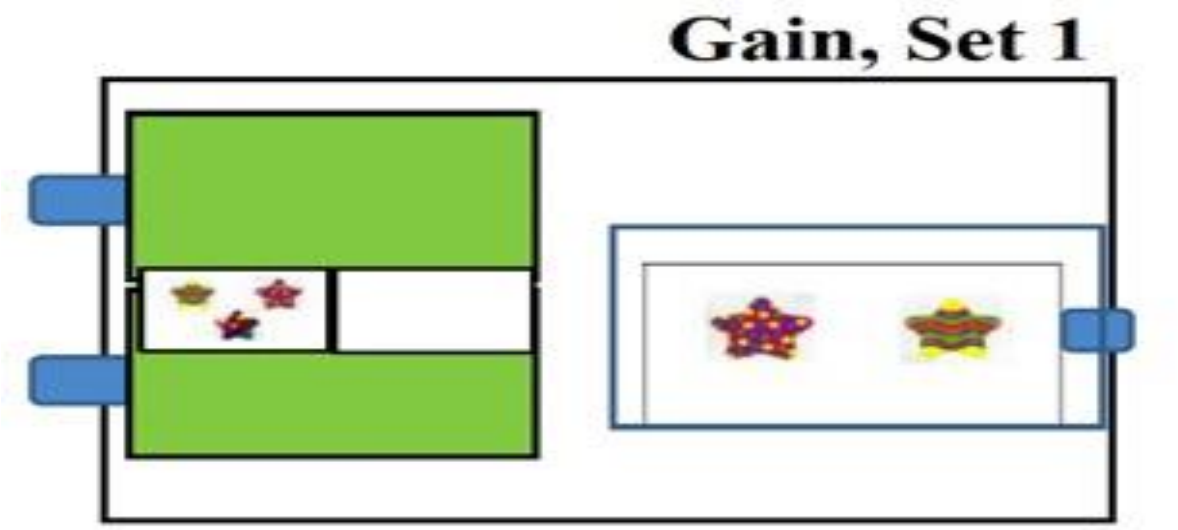
Appendix K

Shifting Task Score sheet

ID_____Gender_____Age_____Daycare _____			
Circle choice (either correct or incorrect column)			
Trial	Target	**Correct**	**Incorrect**
ND1	green	green	yellow
ND2	yellow	yellow	green
ND3	green	green	yellow
ND4	green	green	yellow
ND5	yellow	yellow	green
ND6	yellow	yellow	green
ID shift	target	**Correct**	**Incorrect**
Trial	colour		
PS1	yellow star	yellow heart	green star
PS2	yellow star	yellow heart	green star
PS3	green heart	green star	yellow heart
PS4	green heart	green star	yellow heart
PS5	yellow star	yellow heart	green star
PS6	green heart	green star	yellow heart
PS7	yellow star	yellow heart	green star
PS8	yellow star	yellow heart	green star
PS9	green heart	green star	yellow heart
PS10	green heart	green star	yellow heart
		pass ID shift	6 out 10
ED Shift	target	**Correct**	**Incorrect**
Trial	shape		
ED1	green heart	yellow heart	green star
ED2	green heart	yellow heart	green star
ED3	yellow star	green star	yellow heart
ED4	yellow star	green star	yellow heart
ED5	green heart	yellow heart	green star
ED6	yellow star	green star	yellow heart
ED7	yellow star	green star	yellow heart
ED8	green heart	yellow heart	green star
ED9	yellow star	green star	yellow heart
ED10	green heart	yellow heart	green star

Appendix L

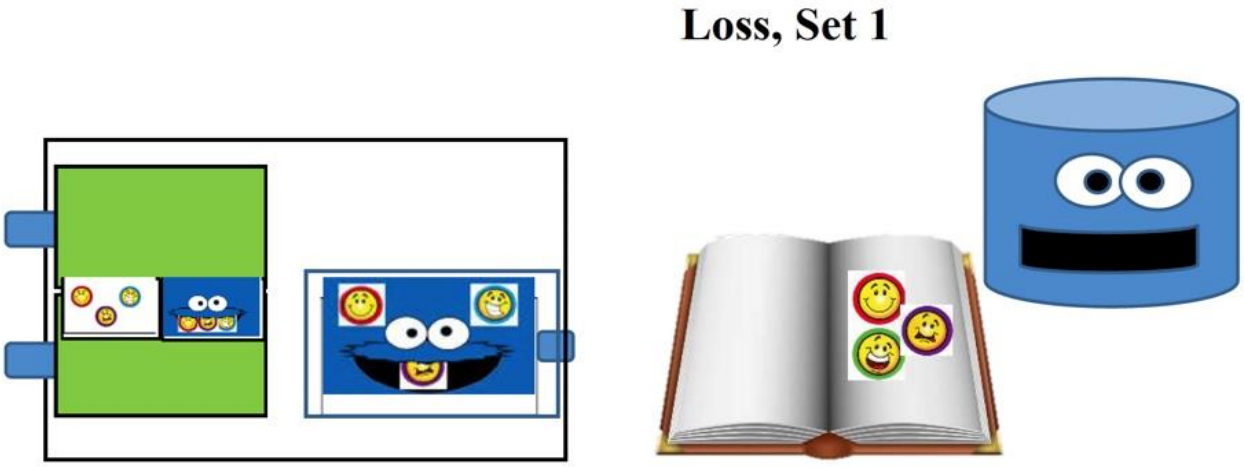
Risky Envelope Gain Domain



Appendix G. *Risky envelope gain set illustration*

Appendix M

Risky Envelope Loss Domain



Appendix G. *Risky envelope loss set illustration*

Appendix N

Risky Envelope Scoresheet

Order 1

Set 1

Gain trials	Gain Trials: Risky	Gain Trials: Safe
practice	win 0 | win 3	win 2
1	win 0 | win 4	win 2
2	win 0 | win 6	win 2
3	win 0 | win 3	win 2
4	win 0 | win 6	win 2
5	win 0 | win 3	win 2
6	win 0 | win 4	win 2

Loss trials	Loss Trials: Risky	Loss Trials: Safe
practice	lose 3 | keep 3	keep 2
1	lose 4 | keep 4	keep 2
2	lose 6 | keep 6	keep 2
3	lose 3 | keep 3	keep 2
4	lose 6 | keep 6	keep 2
5	lose 3 | keep 3	keep 2
6	lose 3 | keep 4	keep 2

Set 2

Gain trials	Gain Trials: Risky	Gain Trials: Safe
1	win 0 | win 4	win 2
2	win 0 | win 6	win 2
3	win 0 | win 3	win 2
4	win 0 | win 6	win 2
5	win 0 | win 3	win 2
6	win 0 | win 4	win 2

Loss trials	Loss Trials: Risky	Loss Trials: Safe
1	lose 4 | keep 4	keep 2
2	lose 6 | keep 6	keep 2
3	lose 3 | keep 3	keep 2
4	lose 6 | keep 6	keep 2
5	lose 3 | keep 3	keep 2
6	lose 3 | keep 4	keep 2

Order 2

Set 1

Loss trials	Loss Trials: Risky	Loss Trials: Safe
practice	lose 3 | keep 3	keep 2
1	lose 4 | keep 4	keep 2
2	lose 6 | keep 6	keep 2
3	lose 3 | keep 3	keep 2
4	lose 6 | keep 6	keep 2
5	lose 3 | keep 3	keep 2
6	lose 3 | keep 4	keep 2

Gain trials	Gain Trials: Risky	Gain Trials: Safe
practice	win 0 | win 3	win 2
1	win 0 | win 4	win 2
2	win 0 | win 6	win 2
3	win 0 | win 3	win 2
4	win 0 | win 6	win 2
5	win 0 | win 3	win 2
6	win 0 | win 4	win 2

Set 2

Loss trials	Loss Trials: Risky	Loss Trials: Safe
1	lose 4 | keep 4	keep 2
2	lose 6 | keep 6	keep 2
3	lose 3 | keep 3	keep 2
4	lose 6 | keep 6	keep 2
5	lose 3 | keep 3	keep 2
6	lose 3 | keep 4	keep 2

Gain trials	Gain Trials: Risky	Gain Trials: Safe
1	win 0 | win 4	win 2
2	win 0 | win 6	win 2
3	win 0 | win 3	win 2
4	win 0 | win 6	win 2
5	win 0 | win 3	win 2
6	win 0 | win 4	win 2