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Assessing Gambler's Fallacy in Children Through Framing and Executive Functioning

Juliette H. Pope[1] & J. Mark Cleaveland[1]

[1] Department of Psychological Science, Vassar College, NY, USA

Correspondence: J. Mark Cleaveland, Department of Psychological Science, Box 298, 124 Raymond Ave, Poughkeepsie, NY 12604, USA. Tel.: 1-(845)-437-7375. E-mail: macleaveland@vassar.edu

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Abstract

There is a gap in the literature concerning how recency biases develop in younger cohorts, and their impact on mathematical reasoning. The gambler's fallacy is a negative recency bias that is defined as the false belief that for independent events, a streak of one outcome means that outcome is less likely to occur on a subsequent trial. In order to explore the developmental trajectory of this phenomenon, two groups of young children (4-5 years vs 7-8 years) participated in three tasks. All children first participated in a Flanker Inhibitory Control and Attention Test. The results of this test served to provide a measure of executive functioning for each participant. Next the children participated in two outcome prediction tasks. In one, each child observed a "friend" hiding behind one of two bushes over a sequence of trials, and then predicted their hiding location on a critical choice trial. In the other prediction task, participants observed an animation of a leaf falling from a tree and landing in one of two locations. In a critical choice trial, the participants predicted the landing spot of the leaf for the subsequent trial. Our data show 1) age differences in executive functioning scores, 2) an increase in negative recency bias as a function of executive functioning, and 3) the influence of framing effects on recency bias.

Keywords: executive functioning, framing, gambler's fallacy, hot hand fallacy, recency bias

1. Introduction

The interaction between the development of a child's executive functioning, their learned schemas, and their inferences about outcome frequencies remains an understudied set of phenomena. These phenomena have relevance for teachers because the assumptions and raw developmental capabilities that a child brings into a setting will greatly impact their interaction with pedagogical materials (Atherton & Nutbrown, 2016; Bada & Olusegun, 2015; Van Kesteren et al., 2014). In the following brief report, we present data showing an interaction between the framing of a sequence and a child's cognitive, executive functioning. We do so by measuring the predictions made by children of the relative frequency of a binary outcome. We place particular emphasis on "negative recency biases," as these have a considerable literature with adult subjects.

1.1 Existing Literature

The Gambler's Fallacy (GF) is a negative recency bias (e.g., Jarvik, 1951) that applies to outcomes with a fixed probability of occurrence. It is defined as the false belief that in such situations there in fact exists a negative correlation between outcome occurrence and outcome probability. In other words, following a consecutive series of a particular outcome, subjects behave as if that outcome will be less likely in the near future. The GF has been explored in great depth, with respect to many variables such as gestalt principles (Roney & Trick, 2003), contextual framing (Burns & Corpus, 2004; Ayton & Fischer, 2004), "reachability" (Bar-Hillel et al., 2014), chunking and memory capacity (Hahn & Warren, 2009) and loss (Mossbridge et al., 2017). However, these studies have been conducted almost exclusively with adults.

The few studies that have addressed recency biases from a developmental standpoint have presented conflicting results. For example, Chiesi and Primi (2009) found that the presence of a positive recency bias, the Hot Hand Fallacy (HHF), decreased with age, and that GF-type biases increased with age. Further research, however, has suggested that the tendency of young children to display HHF-type biases is limited. Sumner et al., for example, found a positive recency bias when young children were prompted with linguistic choices ("Does the bear like to eat apples or bananas"), but not when the same task was answered via pointing (Sumner et al., 2019). Fischbein &

Schnarch (1997) found no evidence of a positive recency bias in children and reported that negative recency biases decreased with age. Finally, Barash and colleagues (Barash et al., 2019) reported that young children tend to show both GF and HHF-type biases but purely as a function of utilizing outcome-based predictive strategies, i.e., win-stay, lose-switch and win-switch, lose-stay.

1.2 Present Study

We hypothesize that the conflicting results in the literature are likely due to differences in the assumptions and cognitive demands of their underlying tasks. Even in adults there is considerable research showing that framing and terminology greatly impact a subject's ability to assess frequencies. Generally, an outcome framed as the product of natural/random causes (e.g. spinning a roulette wheel) tends to bias subjects towards showing the GF bias. The same sequence framed as the product of human agency (e.g., shooting basketballs), instead biases subjects towards showing the HHF bias (Burns & Corpus, 2004; Ayton & Fischer, 2004; Fischer & Savranevski, 2015).

In order to account for age-appropriate stimulus presentations, we developed tasks that presented children with binary outcomes that were visually salient, and which were representative of real-world situations (see Figure 2). In one task a set of digital picture cards simulated a game of hide-and-seek in which a child was revealed to be hiding behind one of two bushes. In a second task children were presented with a digital animation of a tree losing leaves onto one of two circles on the ground. We believe that these scenarios are more accessible and familiar to young audiences. Further, these two scenarios allowed us to explore the effect of framing on a child's perception of randomness.

Finally, there is also literature to suggest that the gambler's fallacy has correlates with increased cognitive skills such as executive functioning (EF; e.g., Xue et al., 2012). Despite emerging during infancy, it is thought that EF improves most drastically during the preschool years and that, while improvements continue beyond this, the changes are more gradual into adolescence and early adulthood (Zelazo et al., 2003; Diamond, 2006; Weintraub et al., 2013). We hypothesized that this variable might also account for some of the variability observed in the development of recency biases in children. Analogical reasoning, for instance, has been shown to be a function of semantic competence (Goswami & Brown, 1990). Such reasoning has also been explicitly correlated with working memory in children 5 to 11 years old (Simms et al., 2018). As there is evidence for EF rapidly improving within the preschool years, we recruited participants within these years (4-5) as well as slightly after (7-8). All subjects were administered a Flanker Inhibitory Control and Attention Test (Simonds et al., 2007). Based on the literature above we predicted that we would observe a positive correlation between the GFF bias and our measure of executive functioning.

2. Method

2.1 Participants

Participants were recruited from the Wimpfheimer Nursery School, a laboratory nursery school on Vassar College campus, and via word of mouth. In the laboratory nursery school, teachers passed information about the study to all parents, and those who were interested signed consent forms. Other participants were recruited by spreading information about the study through faculty/staff at Vassar College, through psychology classes, and to other Vassar students via Facebook pages and personal communications. Any interested individuals were then contacted by the experimenter via email. Two age groups of participants were recruited, 43–71 months (M = 55.5 months) and 85-103 months (M = 94.7 months). We recruited 19 children for the younger age group and 16 for the older group. For each participant, informed consent was obtained from the parent/guardian and positive assent (either verbally or by way of a minor assent form) was obtained from the participants themselves.

2.2 Materials

Our experiment was conducted in the spring of 2021 during the COVID-19 pandemic, and therefore subjects were run remotely over the Zoom video conferencing platform. All materials were adapted to be electronic and accessible via computer. The experiment involved three tasks, each with its own set of materials.

2.2.1 Flanker Inhibitory Control and Attention Test

The Flanker Inhibitory Control and Attention Test is a test of cognitive flexibility and interference control, subfactors of executive functioning. In this test, a target object (a fish or an arrow, depending on participant age) was flanked on either side by two distractor objects (also fish or arrows). The target object was oriented either to the left or right, and participants were instructed to respond based on this orientation. Flanker objects were either oriented in the same direction as the target object (congruent trials) or in the opposite direction (incongruent trials).

The materials included 20 slides with the fish stimuli, including a mix of congruent and incongruent trials, and 20 slides with the arrow stimuli, including a mix of congruent and incongruent trials (see Figure 1). There were additionally four practice slides (two congruent, two incongruent) which preceded the test slides. Typically, participants respond in this task by pressing an arrow button that corresponds to the direction of the target object. However, due to the practical and technological constraints of the COVID-19 pandemic, participants were asked during the Zoom session to respond by pointing in the direction that the target object was facing. Response errors provided a score of Executive Functioning.

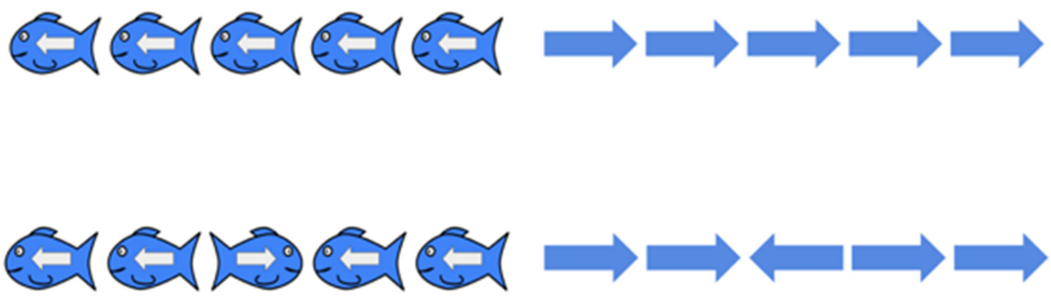

Figure 1. Flanker Materials

Note. Figure 1 depicts the materials used in the Flanker task. On the top are examples of the stimuli seen by participants during congruent trials; on the bottom are examples of the stimuli seen by participants during incongruent trials.

2.2.2 Human-Agent Recency Bias Task

In this task, participants played a "hide-and-seek" style game in which a "friend" named Sam was hiding behind one of two bushes. Subjects observed an image of two bushes, one red and one green, and were instructed that Sam was hiding behind one of the two bushes. In a subsequent slide, subjects were then shown an image of a figure crouching in front of one of the bushes, revealing where they had been hiding (see Figure 2A). The location of the person hiding followed one of two predetermined sequences (RGRGGG or GRGRRR). As both of these sequences were run for each participant (counterbalancing order) there were 14 trials (28 total slides): six for the first sequence, followed by the critical trial, then six for the second sequence, followed again by the critical trial. There were also two practice trials preceding the test trials (an additional four slides). The direction of participants' responses (GF-like or HHF-like) on critical trials following a run were recorded.

2.2.3 Non-Human-Agent Recency Bias Task

In this task, participants were shown an animation of a tree losing its leaves. The leaves fell into one of two circles, either yellow or blue, on the ground beneath the tree. Materials included two animations, one in which the leaf fell into the yellow circle and one in which the leaf fell into the blue circle (see Figure 2B). The animations were embedded in a slideshow presentation in which the order of where the leaves fell followed one of two predetermined sequences (YBYBBB or BYBYYY). Trials were run identically as described for the "Human Agency" task, above.

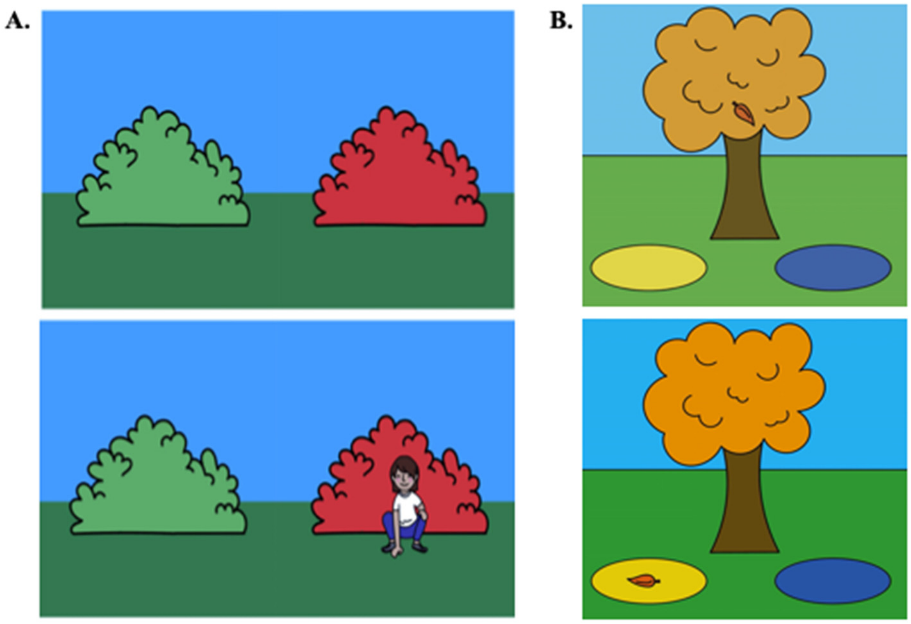

Figure 2. Recency Bias Task Materials

Note. A) The figure depicts the materials used in the human agent framing condition of the recency bias task. On the top left is an example of the stimuli seen by participants when asked to guess the hiding place of “Sam”; the bottom left image is an example of stimuli seen by participants when the hiding place of “Sam” is revealed. B) These two images depict the materials used in the non-human agent framing condition of the recency bias task. On the top right is a single frame of the animated sequence seen by participants at the start of the animation; on the bottom right is an example of a single frame of the stimuli seen by participants at the end of the animation with the leaf having landed on yellow.

2.2.4 Follow-up Questions

A series of follow-up questions were asked of the participants after they completed the recency bias tasks. The questions were intended to target familiarity with the situation and the effectiveness of the framing manipulation, and included some open-ended questions intended to highlight cognitive processes during the activities.

1. Have you played hide-and-seek before?
2. Have you ever seen trees lose their leaves when it’s fall?
3. When we were playing hide-and-seek, did you think your friend was choosing where to hide?
4. Why did your friend hide where they did?
5. When the tree was losing its leaves, did you think the tree got to pick where its leaves fell?
6. Why did the leaves fall where they did?

2.3 Procedure

As mentioned above, given the complications arising from the global COVID-19 pandemic, all procedures were conducted remotely and virtually, and care was taken to ensure the methodology was as flexible as possible given the uncertainty of these times. All correspondence with schools and guardians was carried out via email, and all experimental sessions were conducted over Zoom.

Children for whom genuine informed consent had been obtained from their parents or legal guardians were invited to play three games. Children who then provided positive assent (either verbally for those aged under 7 or via an assent form for those aged 7+) were presented with each of the following three tasks.

One of these tasks was a Flanker Inhibitory Control and Attention Test. Children received brief instructions detailing the rules of the activity and were then guided through four practice trials: two congruent (all stimuli facing the same direction) and two incongruent (target stimuli facing the opposite direction than the flankers).

Each trial was on a different slide of a slideshow presentation (PowerPoint or similar). The experimenter controlled the presentation from their computer and shared their screen with the participants. If the participant answered correctly (pointed in the same direction as the target stimulus was facing) in at least three out of four practice trials, 20 test trials then occurred with a random mix of congruent and incongruent trials. The number of congruent and incongruent trials was set to be equal (10 of each). The number of incorrect responses was recorded for each participant.

Another task was the Human-Agent condition of the recency bias task. Participants were told that they would be playing a variation of hide-and-seek and that their friend Sam would be hiding behind one of the two bushes on the slide. The children were prompted to recount the rules of hide-and-seek or were informed of the basic premise, to ensure familiarity. Participants were then guided through two practice trials, in which Sam was hiding behind each bush (red and green) before test trials commenced. During each trial, the child was prompted to guess behind which bush Sam was hiding by verbally indicating either "red" or "green." Sam's location was then revealed (by clicking onto the next slide in the presentation). The order of Sam's hiding places was predetermined (RGRGGG or GRGRRR), and participants' responses on each trial were recorded. The response on the trial immediately following a run of three identical outcomes was recorded as the critical trial. On the critical trial, Sam's hiding place was not revealed. This set of six trials and one critical trial was repeated twice (each of the aforementioned sequences was presented once, counterbalancing for order).

The third task was the Non-Human-Agent condition of the recency bias task. Participants received instruction that this game involved an animation of a tree with its leaves falling. They were told that the leaves would fall into one of the two circles on the ground beneath the tree (yellow or blue). Participants were guided through two practice trials, in which the leaf fell on each circle once, before beginning the test trials. In each trial, the participant was asked to guess where they thought the leaf would fall, by verbally stating either "yellow" or "blue," and then the animation was played (shared from the experimenter's computer screen in the same manner as above) to reveal into which circle the leaf fell. The order of where the leaves fell was predetermined (YBYBBB or BYBYYY) and the participant's response to the trial following the run of three identical outcomes was recorded as the critical trial. This set of six trials and one critical trial was repeated twice (each of the aforementioned sequences was presented once, counterbalancing for order).

The order in which the Human- and Non-Human-Agent tasks were presented was counterbalanced, so approximately 50% of children completed the Human-Agent condition first, while the other 50% completed the Non-Human-Agent condition first. Both physical pointing and oral responding were coded live by the experimenter, and there were no instances of ambiguity in responding. During practice trials, children were instructed on how to point in a visible and clear way and were reminded throughout the procedure.

In some cases, either a parent or teacher was present in the room during the experiment. The parent/teacher was asked not to help the child during the tasks and sat out of view of the child while they completed the tasks. In one instance, a child repeatedly looked back at the parent during the tasks, despite being reminded to face forward while playing the games. Following the completion of all three activities, participants were asked a set of follow-up questions (listed above) about the nature of the games. Following this, children were thanked for participating in the activities and asked if they had any questions about the games played.

3. Results

3.1 Executive Functioning

First, a two-sided t-test was conducted on the results of the Flanker task. Our results showed that younger participants ($n = 19$, $M = 3.05$, $SD = 2.59$) made significantly more errors on the Flanker task ($p = 0.02$) than older participants ($n = 16$, $M = 1.31$, $SD = 2.50$). These results confirm that the Flanker task worked as intended and that scores reflect differing EF abilities (e.g., Simonds et al., 2007).

3.2 Executive Functioning and Gambler's Fallacy Use

Next, we conducted a correlational analysis in order to assess our hypothesized relationship between EF and increasing negative recency bias (GF-like behavior). The measure for EF was the number of incorrect responses on the Flanker task, which had a potential range of 0 (participant gave all correct responses) to 20 (participant gave all incorrect responses). Our data ranged from 0 to 10 and had a mean of $M = 2.26$. The measure for GF was the number of GF-like responses across all four critical trials of the recency bias tasks, which had a potential range of 0 (participant gave only HHF-like responses) to 4 (participant gave only GF-like responses). Our data ranged from 0 to 4 and had a mean of $M = 2.29$.

Figure 3 plots the relation between GF-like responding and EF. As expected, the data showed a moderate negative correlation between errors on the Flanker task and amount of GF-like responses, $r(33) = -.35$, $p = .033$, indicating that individuals who performed better on a test of EF also demonstrated more GF-like responding.

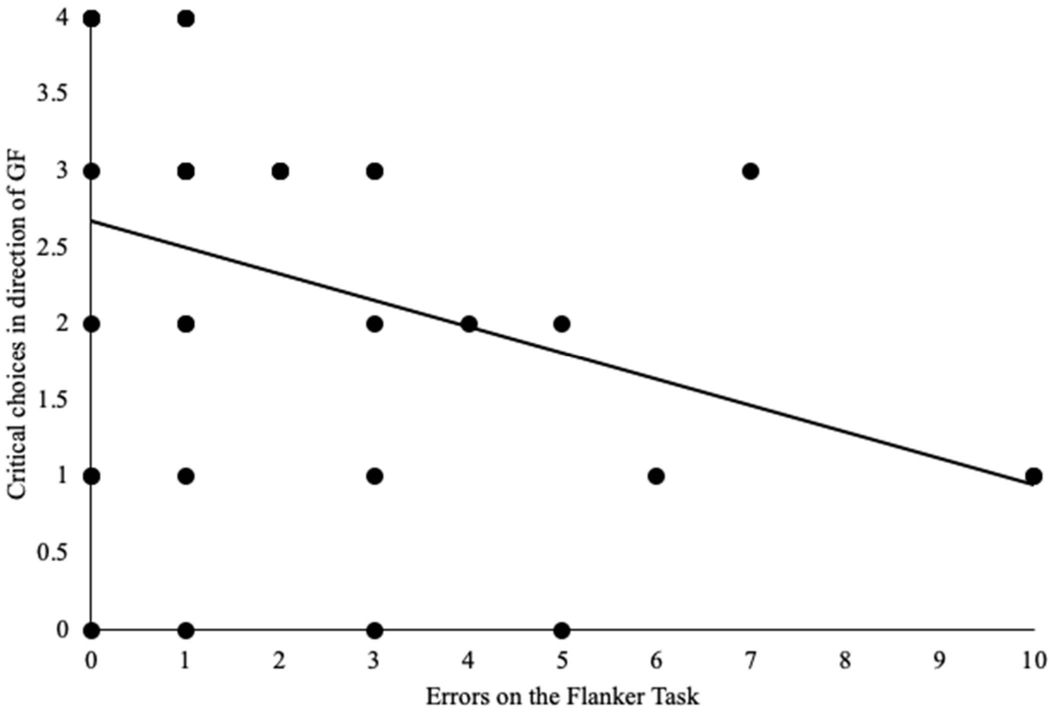

Figure 3. Executive Functioning and Gambler's Fallacy Correlation

Note. Figure 3 shows participants plotted by number of errors made on the Flanker task on the x-axis and number of responses made in the direction of the Gambler's Fallacy across both framing conditions on the y-axis. Solid line is a linear trend line. A moderate negative correlation between errors on the Flanker task, i.e., a decreasing Executive Function score, and number of Gambler's-Fallacy-like responses, is observed, $r(33) = -.35$, $p = .033$.

We broke this down further, conducting correlational analyses for Flanker Errors vs. GF-like responding for each of the two framing conditions separately. For the Non-Human-Agent framing condition, the data showed a moderate negative correlation between errors on the Flanker task and amount of GF-like responses, $r(33) = -.39$, $p = .016$. For the Human-Agent framing condition, however, the data showed only a weak negative correlation, which was not significant at the 0.05 level, $r(33) = -.21$, $p = .21$.

3.3 Effects of Age, Framing, and Executive Function

We then used a logistic regression to analyze the relationship between age, score on the Flanker task, and framing on the probability of demonstrating GF-like responding. Holding age and Flanker score constant, we found that the amount of GF-like responding was decreased by 72% (95% CI [.13, .58]) in response to the Human framing condition compared to the Non-Human framing condition. Holding age and framing constant, we found that the amount of GF-like responding decreased by 18% (95% CI [.70, .96]) for each additional error made on the Flanker task. Age did not significantly predict GF-like responding when framing and Flanker scores were held constant.

These findings confirm that children reacted to the framing of tasks in a similar manner to adults, demonstrating less GF-like responding in response to a human agent than to a random or natural cause. These findings further suggest that children with greater EF skills, who made fewer errors on the Flanker task, were more likely to respond in a GF-like manner to tasks regardless of framing.

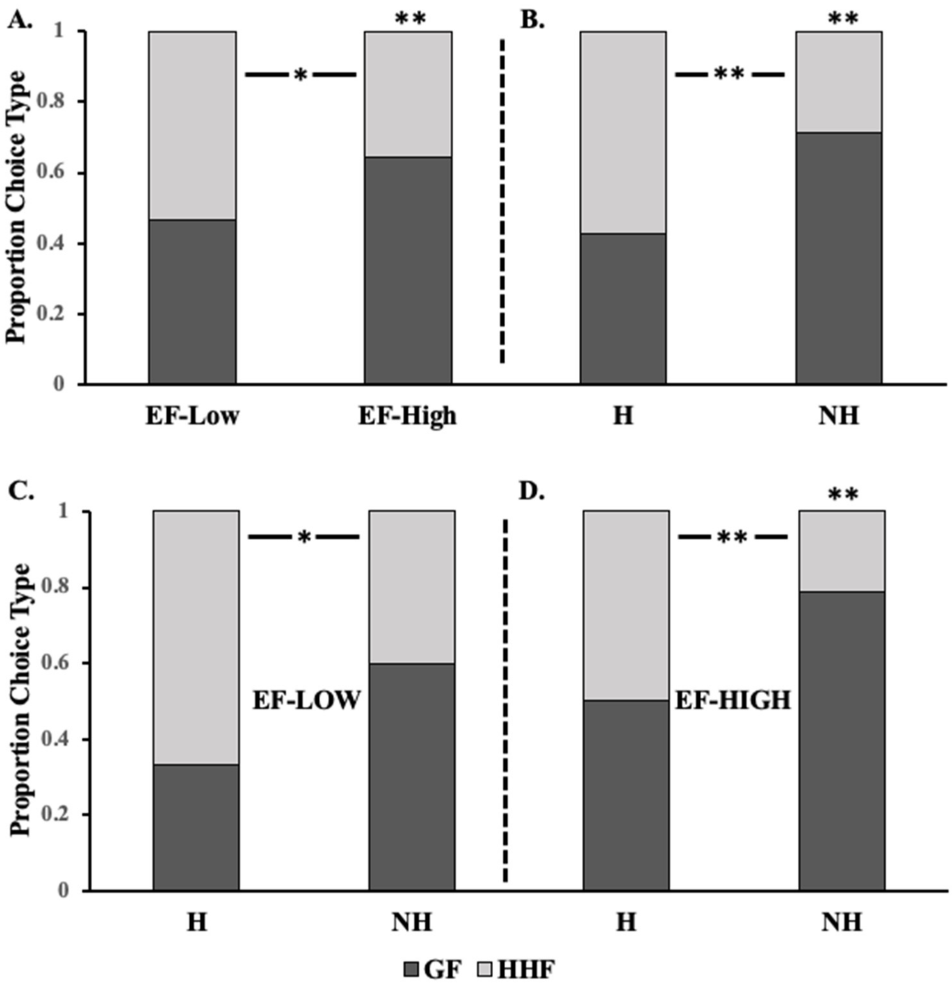

Figure 4. Proportion of Responses in Critical Choice Trials

Note. Proportion of responses during critical choice trials in which the subject displayed either a Gambler's Fallacy-like bias (GF, black) or a Hot Hand Fallacy-like bias (HHF, grey). EF-Low refers to subjects who made two or more errors on the Flanker Task. EF-High refers to subjects who made less than two errors on the Flanker Task. A) Proportions obtained across all critical choice trials for two groups: EF-Low vs. EF-High. B) Proportions obtained for all subjects in either the human agent condition (H) or the non-human agent condition (NH). C) Proportions broken out for just the EF-Low group when making choices in either the "human agent" condition or the "non-human agent" condition. D) Proportions broken out for just the EF-High group when making choices in either the human agent condition or the non-human agent condition. Note that asterisks indicate significance, either between groups, or from a 0.5 proportion within a group. $*p<.05$. $**p<.01$.

3.4 Qualitative Data

In addition to the quantitative data above, additional data was collected from six follow-up questions. Data collected from the follow-up questions is qualitative and should be treated somewhat anecdotally, however it provides interesting insight into the effectiveness of the framing manipulations as well as how children were interacting with and conceptualizing the activities.

3.4.1 Familiarity

In response to the questions "Have you ever seen trees lose their leaves when it's fall?" and "Have you played hide-and-seek before?", all participants answered affirmatively, confirming that the two scenarios were familiar to children across the two age groups. Many children, when asked about hide-and-seek, responded with anecdotes about their experience playing the game, and when asked about trees losing their leaves, provided lengthy (occasionally very scientific) descriptions of the seasonal cycle of trees, indicating that not only are these situations familiar to children but they are also very salient.

3.4.2 Agency

Two questions concerning perceptions of agency were included as manipulation checks to see if the different framing tasks achieved their purpose of invoking a sense of agency in the actor of the hide-and-seek task and randomness in the tree task. Participants were asked if the person was choosing where to hide in the Human-Agent condition and if the tree was choosing where its leaves fell in the Non-Human-Agent condition. While responding on the Human-Agent condition was relatively consistent across groups, there was a notable difference between the EF groups in response to the Non-Human-Agent condition (see Table 1). Only 20% of children in the EF-High group indicated that the tree was choosing where its leaves fell, compared to 60% of children in the EF-Low group.

Table 1. Perceptions of Agency by Condition and EF level

	Human Agent			Non-Human-Agent		
	Yes	No	Unsure	Yes	No	Unsure
EF-Low (*N* = 15)	10	2	3	9	6	0
EF-High (*N* = 20)	16	4	0	4	16	0

Note. Frequency of subjects categorized as low or high executive functioning that perceived agency on the part of the hide-and-seek (human agent) or tree (non-human agent) condition.

3.4.3 Why Did Your Friend Hide Where They Did?

This question and the following one are open-ended and were designed to shed light on how children were conceptualizing the scenarios. While all of the answers were different, there were some recurring themes that we identified. One such theme that was particularly prevalent was that the person hid per the rules of hide-and-seek, namely to try and stay hidden from the person attempting to find them. A sample response of this kind is, “Cause that was the sneakiest place he knew.” A second common category of responding was to identify that there was a pattern of some sort. A sample response of this kind is, “Because it’s like a pattern. Green, red, green, red, green, red.” A third common category of responding was to indicate that they didn’t know why the person chose to hide where they did, for example, “It’s a mystery.”

Some participants also gave long, narrative responses to this question. An example of this is:

His mother said, ‘Give her the pattern. Do the pattern for her.’ Then he got away with it and he could do whatever he wanted. And he got away with it. Maybe because he wanted to try to hide good and try to trick me because I was thinking oh it’s one pattern. He might have heard that and he was like maybe I should try to trick her that way.

Interesting to note that of the participants who indicated in the previous questions that their friend did not get to choose where they were hiding, several gave responses to the open-ended questions that suggested a sense of agency. One example is, “Because he was trying to hide somewhere.”

3.4.4 Why Did the Leaves Fall Where They Did?

Similar to the previous question, while responses to the open-ended questions were all different, there were some recurring themes we noticed. One such theme was that the wind was responsible for the leaves falling in different locations. A sample response of this nature is, “I think they fell where they did because um the wind blew that way then it’ll float down and fall that way.” Another theme in responding to this question was to express a sense of it being random and not due to any cause in particular. An example of a response within this theme is, “Because like it could be in either one but like sometimes it was just on that side and sometimes it was on the other side.” And finally, much like in the previous question, another theme of responding was to identify a pattern, for example, “Because they were a pattern, and it was cause it was easy and then it got harder and harder and harder.”

Again, interesting to note is that among participants who indicated that the tree did get to pick where its leaves fell, many gave responses to this open-ended question that suggested a contradictory lack of agency on the part of the tree. For example, “Because in fall leaves fall and they fall in different places.” These answers suggest a sense of randomness that does not hold as consistent with the assertion of the tree’s agency.

4. Discussion

Our study shows that recency biases, such as the gambler's fallacy (a negative recency bias) and the hot hand fallacy (a positive recency bias), can be readily studied in young children. We made two predictions at the outset of our experiment: 1) that GF-like responding would show a positive correlation with EF; and 2) that as EF increases, children would show framing effects that begin to resemble those seen in adults. In adults, GF-like responding is more likely when assessing outputs of natural systems, while HHF-like responding is more likely when assessing outputs related to human agents (Ayton & Fischer, 2004; Burns & Corpus, 2004; Fischer & Savranevski, 2015). Therefore, we predicted that recency biases would show sensitivity to framing effects in our 7 to 8-year-old subjects – children who on average score higher on EF – but not our 4 to 5-year-old subjects. On the whole, our data match these predictions.

First, we found that performance in the Flanker Task produced a significant difference in our age groups. Using this performance as a proxy for EF skills, we can state that our younger cohort possessed more rudimentary EF than our older cohort. Second, we found that when grouped by EF – EF-High vs. EF-Low – EF-High subjects were more likely to respond to binary outcome sequences with a GF-like bias. That is, a negative recency bias increased with EFs, as measured by our Flanker Task (Figures 3 and 4A). Finally, EF also corresponded to a sensitivity to framing effects. Children in the EF-High group showed increased GF-like responding that differed from chance in the "natural," non-human condition**,** but not the human agent condition (Figure 4D). Children in the EF-Low group did not show biased responding that differed from chance in either condition (Figure 4C).

Although our study found that GF-like responding increased along with EFs, it also found that this GF-like responding was limited to the framing effects of our "natural," non-human outcomes (i.e., leaves dropping from a tree). Both age groups (and EF groups) made choices at chance level when outcomes were framed as the result of a human agent. How can we explain this discrepancy? We favor an explanation in which world-knowledge domains interact with increasing EF (Fischer & Savranevski, 2015; Simms et al., 2018; Bobrowicza et al., 2022). That is, when a subject is presented with an outcome sequence and needs to make a subsequent prediction, we hypothesize that they make analogical inferences in order to inform these predictions. Natural systems, for example, often follow rules of "replenishment" in which appearance is followed by momentary decreases in frequency. Within such systems, predictions that follow GF-like behavior make sense (see Militana et al., 2010). We would suggest that younger children gain world knowledge about such systems more quickly than they do with relation to human agents, and therefore, such knowledge is available for analogical inferences, which in turn are influenced by EF.

Before turning to the limitations of our study, we should point out that another study has found similar results, albeit embedded in their reported data and relating to the increase in GF-like responding with age. In their study, Barash et al. (2019) tested students across five grade buckets in order to assess Bayesian updating. The grade buckets consisted of K – 2nd, 3rd – 5th, 6th – 8th, 9th – 11th, and college students. In their data, the authors present the relative prevalence of several outcome biases, one of which they label "Reverse." According to the authors, "Reverse is the strategy of a subject who draws inferences from all information but falls prey of the gambler's fallacy." (p. 312). Of interest is that the frequency of "Reverse" shows a substantial increase between the K – 2nd grade and the 3rd – 5th grade cohorts. In other words, Barash et al.'s data resembles our own in that GF-like responding shows a developmentally anchored increase between the ages of 4 and 8. We should note, though, that in the reported study, Barash et al. (2019) only report on the outcomes of a "natural," non-human system. What the developmental progression looks like for the positive recency biases observed in human-agent frames requires further study.

4.1 Limitations

In terms of limitations, our study has several. One noteworthy limitation of this study was that, due to the COVID-19 pandemic, all experimental procedures were conducted virtually using Zoom, Google Slides, and other electronic tools. This has implications for the present research both on an overarching level and for specific measures. First, for young children who had not experienced remote schooling or other comparable exposure to virtual spaces, the sense of novelty that may be present in these experimental situations could interfere with normal responding. Additionally, the Flanker Inhibitory Control and Attention Task is normally conducted in person on a touch screen device visible to both participant and experimenter. This was not possible due to current circumstances, so materials had to be adapted to use virtually, and participants were asked to respond by pointing in the direction of the target object rather than tapping an arrow. Further, the Flanker Inhibitory Control and Attention Task often incorporates response time as a variable in addition to the number of incorrect responses, however, this was not possible given technological and situational limitations. This likely introduced a ceiling effect on the score for the older participants, many of whom had zero incorrect responses on the Flanker Task.

In addition to limitations due to the global situation, there are also some potential confounds introduced by the experimental design itself. Firstly, the order of outcomes in the two recency bias tasks was taken from Roney and Trick (2003). This sequence of six outcomes followed by a critical trial was repeated twice for each of the two framing conditions, and several participants noted in follow-up questions that they had observed a pattern, some noting only that the outcomes briefly alternated before breaking from the pattern, and others noting that the breaks in the alternating pattern were consistent across activities. This may have influenced some participants to respond as a result of pattern recognition.

A final potential limitation of the research design is that the efficacy of the framing manipulations relied on participants interpreting the hide-and-seek condition as being the product of human agency and the tree condition as being the product of random, natural occurrences. In follow-up questions most participants indicated that this interpretation was achieved. However, others, especially in the younger cohort, indicated otherwise. One potential explanation of this is that prior research has shown that young children tend to anthropomorphize and attribute agency to non-human agents (Eddy et al., 1993; Barrett et al., 2001). One study conducted by Barrett et al. (2001) showed that children aged 3 to 4 attributed similar degrees of agency to people, non-human animals, and some plants such as flowers and trees. To address this potential confound, future research should consider differentiating the two conditions more thoroughly (e.g. have the non-human agent task involve an inanimate object rather than a living one).

4.2 Conclusion and Future Directions

Despite the limitations just mentioned, our study makes a significant contribution to understanding the development of positive and negative recency biases. It demonstrated first that Gambler's Fallacy-like responding showed an increase across development, in tandem with increasing Executive Functioning skills. The study further demonstrated that this increase in biased responding is only seen in the context of a "natural" or non-human event. These results mirror findings in adult literature, which suggest an impact of event framing on participant responding. More broadly, the results have implications for pedagogical practices, as changing cognitive assumptions and capabilities in early childhood may affect the way children interact with educational materials.

The introduction of this paper emphasized the lack of research on the developmental trajectory of response fallacies that are observed in adults: the gambler's fallacy and the hot hand fallacy are prime examples. This remains true. While this study aims to fill some of the gaps in this research, it is not sufficient. The findings in the present study suggest that there is a notable increase in the use of cognitive fallacies such as the GF across the preschool and early school years which future research should attempt to explore further.

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The authors declare that there are no competing or potential conflicts of interest.

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