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Children's Reasoning About Possible Outcomes of Events in the Present and the Future

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When making decisions, we often must consider multiple alternative outcomes of events that will happen in the future, or of events that have already happened but the outcome is unknown. How do children navigate uncertainty across different points in time? Here, we tested several developmental hypotheses for children's ability to reason about possibilities in the present and in the future. In two experiments ($n = 192$, U.S. 3- and 4-year-olds), children were asked to prepare for two mutually exclusive possible outcomes of an event that either will occur in the future (Future condition) or had already occurred but the outcome was currently unknown (Present condition). In Experiment 1 ($n = 96$), children were asked to reason about the possible location of an object in an event. In Experiment 2 ($n = 96$), children were asked to reason about the possible identity of an object in an event. In both experiments, we replicated previous patterns of success with future possibility reasoning, and found no differences in children's ability to reason about possible outcomes in the present versus the future. Our results suggest that the ability to navigate uncertainty across different time points may emerge together in early development.

Public Significance Statement
This study shows that 3- and 4-year-old children can reason about and plan for events with uncertain outcomes, regardless of whether those events have already happened or whether they will happen in the future. This helps us understand the developmental roots of our ability to make decisions under uncertainty.

Keywords: future-oriented thinking, planning, possibility, epistemic uncertainty, cognitive development

In daily life, we often encounter situations that require us to consider multiple alternative outcomes of an event. Sometimes, an event has not yet occurred but *could* happen in the future. For example, when planning to attend an upcoming outdoor event, one might consider the possibility that the weather could be *either* dry *or* rainy and plan accordingly (e.g., by packing both sunscreen and an umbrella to cover both possibilities). Thinking about this scenario requires one to consider multiple, mutually exclusive outcomes that are purely hypothetical possibilities. However, sometimes, an event has already occurred, but the specific outcome of the event is unknown. For example, a student who receives an envelope from a college to which they applied might consider the possibility that the letter contains news of *either* an acceptance *or* a rejection and may mentally prepare themselves for both possibilities. Thinking about this scenario requires one to consider multiple, mutually exclusive possibilities for the outcome of an event that has already happened (the college has made their decision), but for which the present outcome must be represented with some uncertainty. Both modes of reasoning are fundamental to human cognition, enabling us to navigate uncertainty and make decisions across a range of different scenarios and across a variety of different points in time.

While a significant body of work has examined the emergence and development of children's ability to think about multiple, mutually exclusive possibilities, the majority of this work has focused on children's reasoning about possibilities *in the future*. Some of this work has looked at children's ability to reason about the

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possible future location of an object (e.g., Beck et al., 2006; Leahy, 2024; Leahy et al., 2022; Mody & Carey, 2016; Redshaw & Suddendorf, 2016; Robinson et al., 2006; Turan-Küçük & Kibbe, 2024). For example, Redshaw and Suddendorf (2016) asked children to anticipate the future possible location of an object dropped into the top of an inverted Y-shaped tube, such that the ball could emerge from either the right or the left exit. They found that, by age 4 years, children reliably placed their hands under both exits to catch the falling object, suggesting that they considered both possible future outcomes of the event and prepared accordingly, while children aged 3 years or younger often placed their hands under only one of the exits, suggesting that they had more difficulty considering both possible future outcomes in this scenario. Other studies have examined children's ability to reason about the possible identity of an object that will be selected in the future (e.g., Alderete & Xu, 2023; Robinson et al., 2006; Turan-Küçük & Kibbe, 2025). For example, Turan-Küçük and Kibbe (2025) asked 3- and 4-year-old children to prepare the favorite snack for one of two animals that would slide down a playground slide. When children were told the identity of the animal, they selected only the relevant snack, but when children were not told which animal would emerge, they selected both animals' favorite snacks, preparing for both possible future identities of the animal. Together, this work suggests that the ability to reason about and act on possibilities in the future emerges in the early preschool years.

Less is known about children's ability to reason about the possible outcomes of events that have already occurred. Both modes of reasoning—about things that have not yet happened and about things that have already happened but with unknown outcomes—require the reasoner to simultaneously represent multiple, often mutually exclusive possible outcomes for an event and to represent those outcomes as *merely possible* and not actual. However, theorists have hypothesized that there may be important differences in the cognitive architecture that supports reasoning about the possible outcomes of an event that has not yet happened (i.e., in the future) and reasoning about an event that has already occurred but the outcome of which is unknown (i.e., in the past or present), and these hypotheses lead to different developmental predictions.

One hypothesis is that reasoning about outcomes of events in the future may be more challenging than reasoning about outcomes that have already occurred but are unknown. This is because thinking about possibilities in the future requires future-oriented thinking and planning (Turan-Küçük & Kibbe, 2024). Children's ability to think about and plan for events that have not yet happened undergoes protracted development between the ages of 3 and 10 years (e.g., Atance, 2015; Atance & Mahy, 2016; Atance & O'Neill, 2001; Blankenship & Kibbe, 2019, 2022; Pham et al., 2024; Prabhakar & Hudson, 2014; Suddendorf & Corballis, 1997), and children's talk about the past or present emerges earlier than their talk about the future (e.g., Atance & O'Neill, 2005; Fivush et al., 1987). If developmental increases in future-oriented thinking and planning abilities support children's ability to think about possibilities in the future, this leads to the developmental prediction that reasoning about possible outcomes of an event that has not yet happened may emerge *later* than reasoning about possible outcomes of an event that has already occurred.

An alternative hypothesis is that reasoning about possibilities in the future may in fact be *less* challenging than reasoning about possibilities that have already occurred but are unknown. This is because the possibilities in an unknowable future are anchored in the physical world (e.g., an object could emerge from Exit A or Exit B), while the possibilities in an unknown present are anchored in the mind (Phillips & Kratzer, 2024; Robinson et al., 2006; see also Chow & Sarin, 2002; Heath & Tversky, 1991; Kahneman & Tversky, 1982). That is, when an event has already occurred, the world state is fixed, so reasoning about the possible outcomes of this event requires representing uncertainty of one's own epistemic state rather than uncertainty about the state of the world. Representing one's own epistemic state with some uncertainty would therefore make demands on metacognitive monitoring processes, which are undergoing significant development during the early childhood years (Ghetti et al., 2013), whereas representing possibilities anchored in the world would not require such processes. This hypothesis leads to the developmental prediction that reasoning about possibility in the future may emerge *earlier* in development than reasoning about possibility in the past or present.

Still a third hypothesis is that reasoning about possible outcomes of an event may be supported by the same cognitive processes, regardless of whether the reasoning is carried out over events that have not yet happened or events that have already occurred. In adults, mental time travel to the past and future is supported by the same neural architecture (e.g., Addis et al., 2007; see also Addis, 2020), and these processes are behaviorally related in adults and children (e.g., Busby & Suddendorf, 2005; Goulding et al., 2022). This hypothesis leads to the developmental prediction that reasoning about possibility in the future and in the past/present may emerge together.

Some recent evidence suggests that limitations on future-oriented thinking and planning may drive some of the developmental change observed in previous work on children's reasoning about possibilities in the future. Turan-Küçük and Kibbe (2024) found that 3-year-old children are more likely to take the correct action in the inverted Y-shaped tube task (covering both exits) if they were first shown the possible actions that can be taken on the Y-shaped tube, suggesting that reducing the planning requirements of the task revealed greater competence with representing possibility in younger children. And 2- and 3-year-old children can select between a sure thing and a merely possible future outcome in tasks that do not require actively planning an action for one of these outcomes (Alderete & Xu, 2023; Goddu et al., 2021; Stahl & Feigenson, 2024). Further, even 4-year-old children struggle when they are tasked with anticipating the future trajectories and locations of two objects (Leahy, 2024), suggesting that more complex coordination of future thinking and action planning may reduce older children's apparent competence with reasoning about possibilities in the future (although none of these tasks required children to reason about possible events that have already occurred).

There is one study that found some support for the second hypothesis that representing future possibilities may emerge *earlier* than representing the unknown present outcome of an event that has already occurred. Robinson et al. (2006) directly compared children's reasoning about possible outcomes of an event that has not yet occurred to children's reasoning about possible outcomes of an event that has already occurred. They showed 4- to 6-year-old children an apparatus with three doors marked with different colors (orange, green, and black) and asked the children to catch a toy block that could emerge from one of the doors by placing a tray or trays beneath one or more of the doors. Children were told that the experimenter would select a colored block from one of two opaque bags, one containing both orange and green blocks and one containing only black blocks, and the block they selected would emerge from the door matching its color. Relevant to our discussion here are the trials in which the experimenter selected a block from the orange/green bag. In some trials, children were asked to prepare the trays to catch the blocks *before* the block was selected from the bag. On these trials, children had to reason about the possible *future* identity of one of the blocks (it could be either orange or green). In other trials, the experimenter selected the object and placed it (out of children's view) on a ledge behind the set of doors and then asked children to prepare the trays to catch the blocks. On these trials, children had to reason about the possible *present* identity of one of the blocks; that is, they had to reason about an object that has a fixed identity in the world but whose identity is unknown to the child. In both trial types, the "correct" response is to place two trays, one under the orange door and one under the green door, accounting for both possibilities. Robinson et al. (2006) found that children were more successful on trials that required reasoning about a *future* possible identity of an object compared to trials that required reasoning about the *present* possible identity of an object. In subsequent experiments, children only began performing well at present-possibility reasoning around age 7 years. These results suggest that reasoning about possibility in the future may emerge earlier than reasoning about possibility in the present.

However, there are several reasons why further study may be needed. First, Robinson et al.'s (2006) study used a within-participants design, in which children were tasked with preparing for certain outcomes of events, uncertain outcomes of future events, and uncertain outcomes of events that already occurred. The within-participants design may have prompted children to contrast these different conditions or to suspect that the task may require them to respond differently in the different conditions. Second, Robinson et al.'s (2006) task required children to reason both about possible identities of an object (which object would be selected from the bag) and about possible locations of an object (which window[s] the object could emerge from) and to select among a number of possible decisions about the number of trays to select and the placement of those trays under one or more windows. The complexity of this task may have posed performance challenges for children (see, e.g., Leahy, 2024; Turan-Küçük & Kibbe, 2024, 2025); when faced with a complex scenario, when children knew that the object was sitting on a ledge behind the set of doors, children may have defaulted to "guessing" which door the object would come out of, rather than thinking about what possible identities the object could have. Third, and relatedly, although children's initial spontaneous responses suggested that they more readily represented possible future outcomes compared to possible present outcomes, children's performance improved with a simple prompt. In Robinson et al.'s (2006) study, children who placed only one tray were then asked, "Could it [the block] go anywhere else?" Many of these children subsequently placed the second tray in the appropriate location, suggesting that perhaps children's initial failure was due to other task demands rather than a failure to represent possible identities in the present.

Here, we report the results of two experiments in which we compared young children's reasoning about possibility when an event has not yet happened and when an event has already happened but its outcome is unknown. We adapted two pared-down tasks that have previously been used to examine 3- and 4-year-olds' representations of possible future outcomes of an event: a *possible locations* task (the inverted Y-shaped tube task; adapted from Redshaw & Suddendorf, 2016) and a *possible identities* task (the playground task; adapted from Turan-Küçük & Kibbe, 2025). We chose these tasks because they are doable by young children and because they tap two types of possibility reasoning—reasoning about possible locations of an object and reasoning about possible identities of an object (for discussion, see Turan-Küçük & Kibbe, 2025)—allowing us to examine future versus present reasoning across different domains. For each experiment, we used a between-participants design to contrast children's performance in a Future condition, in which children had to reason about possibilities for an event that would happen in the future (replicating the methods used previously), with children's performance in a Present condition, in which children had to reason about possibilities for an event that had already occurred but the outcome of which was unknown. We tested 3- and 4-year-olds because previous work using these methods showed that success in future-oriented possibility reasoning emerges in this age range. We could, therefore, examine whether and to what extent future- versus present-reasoning contexts impact children's performance in a developmentally relevant time period for possibility reasoning.

In Experiment 1, 3- and 4-year-olds ($n = 96$) were tasked with catching a ball that was dropped into an inverted Y-shaped tube, such that it could emerge from one of its two exits. We modified the apparatus by attaching small opaque boxes over each exit of the inverted Y. In the Future condition, these boxes were open at the bottom, such that a ball dropped into the top of the inverted Y would immediately emerge from one of the exits (as in Redshaw & Suddendorf, 2016). Children in this condition were asked to prepare to catch the ball *before* it was dropped into the tube, requiring them to represent the possible future locations of the ball. In the Present condition, the box bottoms were covered with sliding lids that were placed in a closed position at the outset, such that a ball dropped into the Y would fall into one of the opaque boxes (and could be released only by the experimenter sliding the box bottoms open). Children in this condition were asked to prepare to catch the ball *after* it was dropped into the tube, requiring them to represent the possible *present* location of the ball. We measured whether children placed their hands under both exits (covering both possibilities) or under only one exit (covering only one possible location).

In Experiment 2, 3- and 4-year-olds ($n = 96$) were shown a model playground slide, two different animals (e.g., bunny and monkey), and their favorite snacks (e.g., carrots and bananas) and were tasked with preparing "snack" for the animal that slid down the slide. We modified the apparatus by attaching a small opaque box to the bottom of the slide. In the Future condition, the box at the base of the slide was open, and we asked children to "get snack ready" *before* one of the animals was released into the slide (as in Turan-Küçük & Kibbe, 2025), requiring them to represent the possible future identity of the animal. In the Present condition, the box at the base of the slide was enclosed by a sliding door, such that an animal released into the slide would emerge in the closed box. Children in this condition were asked to "get snack ready" *after* the animal was released into the slide (such that the identity of the animal inside the box was unknown), requiring them to represent the possible *present* identity of the animal. We measured whether children chose both snacks (covering both possible identities) or only one snack (covering only one possible identity).

Since both of these methods were previously used to examine children's reasoning about possibilities in the future, we expected our Future conditions to replicate previous results (Redshaw & Suddendorf, 2016; Turan-Küçük & Kibbe, 2025). Of particular interest is children's performance in the Present conditions relative to the Future conditions. We outline specific predictions within each experiment.

Experiment 1: Possible Locations

Method

Participants

Ninety-six 3- and 4-year-old children were tested at the Museum of Science, Boston. Forty-eight children participated in the Future condition (24 3-year-olds, M_{age} = 42.4 months; 10 girls, 14 boys; and 24 4-year-olds, M_{age} = 52.8 months; nine girls, 13 boys, two unknown), and 48 children participated in the Present condition (24 3-year-olds, M_{age} = 41.5 months; 13 girls, 11 boys; and 24 4-year-olds, M_{age} = 54 months; seven girls, 17 boys). Some participants' caregivers opted to complete the optional demographics form. Participants were identified by their caregivers as White (66), Asian (10), Black or African American (3), or other (3), and 14 chose not to disclose. Caregivers identified their children as Hispanic (7) or not Hispanic (67), and 22 preferred not to disclose. Of the children's primary caregivers, 40 reported having a college degree or higher, 31 reported a high school degree or some college, and 25 chose not to disclose.

An additional 42 participants were excluded due to parental interference (6), declining to complete the study procedures (24; 11 in the Future condition, 13 in the Present condition), experimenter error (3), or equipment malfunction (9).

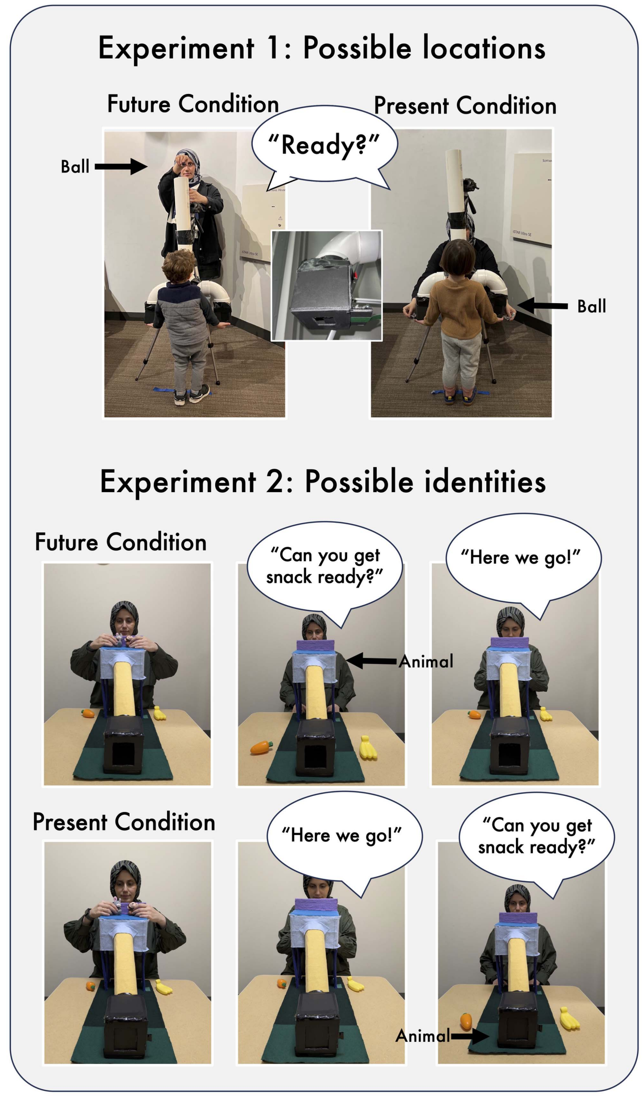
We first collected the sample for the Present condition and then proceeded to collect the sample for the Future condition. We chose the sample size to be comparable with previous studies that examined differences in performance across age groups and/or conditions and observed large effect sizes (e.g., Redshaw & Suddendorf, 2016; Turan-Küçük & Kibbe, 2024). We received approval from the institutional review boards of Boston University Charles River Campus and the Museum of Science, Boston, for this study. This experiment was not preregistered.

Apparatus

We built a modified version of the inverted Y-shaped tube apparatus described by Redshaw and Suddendorf (2016; see Figure 1). The apparatus was constructed from 9 cm diameter polyvinyl chloride pipe. The straight portion of the tube measured approximately 50 cm from the top opening to the point of bifurcation into two separate exits at the bottom, with the distance between the two exits being about 20 cm. A cardboard lever mechanism was installed inside the straight portion of the tube (not visible to children), which the experimenter could use to surreptitiously block one of the Y branches, making the ball go down the other path.

In our modified version of the Y-shaped tube apparatus, an opaque box (10 × 10 × 10 cm; constructed from black foam core board) was attached to each exit. Each box had an opening at the bottom that could be covered with a sliding lid (see Figure 1, inset). In the Future condition, the lid was absent, so the bottom of the box was open, enabling a ball dropped into the opening of the tube to fall straight to the ground. In the Present condition, the lid was intact; when the ball was dropped into the opening of the tube, it fell into one of the boxes, where it remained until the experimenter slid the lids open.

Figure 1
Apparatus and Example Test Trials From Experiments 1 and 2



Note. The top panel shows the apparatus and a Test trial snapshot from Experiment 1. The inset photo shows a close-up of one of the boxes placed over the tube exits. In the Future condition, the box lids were removed completely (such that the boxes functioned as open exits). In the Present condition, the box lids remained closed until the experimenter removed the lids. The bottom panel shows the apparatus and a sequence from a Test trial from Experiment 2. In the Future condition, the box door was removed completely. In the Present condition, the box door remained closed until the child made a response. Photos used with permission. See the online article for the color version of this figure.

We constructed a small, lightweight black ball (made of layered black duct tape), approximately 2 cm in diameter, which the experimenter could drop into the top entrance of the tube. Each box was lined with multiple layers of soft felt fabric. The lightness of the ball and the soft lining of the boxes ensured that children were not able to use the sound of the ball hitting the bottom of the box as a cue to the ball's location in the Present condition.

The Y-shaped tube was attached to a tripod using black duct tape. The tripod was positioned in such a way that the two openings of the Y-shaped tube were at a height that allowed children to place their hands on them comfortably without needing to bend down (see Figure 1).

Procedure

Future Condition.

Familiarization. First, the experimenter stood behind the apparatus while holding the ball over the top of the tube and said, "I want to show you a game. This is a ball game. I will drop a ball into the tube up here [the experimenter pointed the top opening of the inverted Y-shaped tube] and you get to catch it, okay?" During the familiarization trials, we marked an X on the floor (about 35 cm away from the apparatus) on which children were asked to stand to watch the ball's fall. The experimenter said, "First, let's watch how the ball comes out of the tube. Can you stand here on the X?" Then, the experimenter said, "I will put the ball into the top, and then look what happens." While holding the ball over the top opening of the Y-shaped tube, the experimenter said, "Ready?" She then released the ball into the tube opening while gently tapping the rear of the tube with her other hand to mask any unintentional sounds of the ball hitting one of the boxes. After the experimenter dropped the ball, it rolled to the floor, and the experimenter asked the children, "Did you see it?" Then, the experimenter picked up the ball from the floor and held the ball above the tube entrance again and said, "Let's do that again." In total, children watched four Familiarization trials, with the exit that the ball emerged from counterbalanced across trials and across children (either right, left, left, right or left, right, right, left). The entire four-trial familiarization sequence took about 80 s to complete.

Test Trials. In each of the two Test trials, the experimenter gave the following instruction: "Okay, now you get to try to catch the ball. Can you stand on this line?" The experimenter gestured to a tape line directly in front of the apparatus, close enough to allow children to place their hands under the exits (see Figure 1). Then, the experimenter said, "Remember, I will put the ball into the top and you get to catch the ball." Then, the experimenter held the ball over the entrance to the tube and said, "Ready?" The experimenter then waited until children placed their hand/s either under one or both box exits. Once children had positioned their hands, the experimenter said, "Here we go!" and dropped the ball into the tube (while gently tapping the back of the tube, consistent with the Familiarization trials). The experimenter then said, "Alright!" and retrieved the ball from the child (or the floor). She then proceeded to the second trial, saying "Let's play again!"

If the child was reluctant to place their hands under the box exits, the experimenter said, "Are you ready?" (repeating three times if needed). If the child was still hesitant, the experimenter said, "How do you catch the ball?" If the child's hand/s were out, but not underneath the tube apparatus, the experimenter said, "Can you put it/them underneath?" Finally, if needed, the experimenter said, "You should catch the ball before it hits the floor." If children failed to place one or both hands under the apparatus, the experimenter said, "Alright!" and did not continue the experiment.

The experimenter recorded children's hand positions after each trial in a Qualtrics form on a laptop computer. We counterbalanced the exit from which the ball emerged across the two Test trials and across children (either right, left or left, right).

Present Condition.

Familiarization. Familiarization trials proceeded similarly to the Future condition, except that the lids to the exit boxes were closed when the experimenter dropped the ball into the entrance of the tube. First, the experimenter dropped the ball into the tube entrance (while tapping the tube to mask any sounds) so that the ball fell into one of the boxes. The experimenter then grasped each box lid and said, "Ready?" and then opened both box lids simultaneously so that the ball fell out of one of the boxes and onto the floor. The experimenter then said, "Did you see it?" For each subsequent Familiarization trial, the experimenter replaced the lids, picked up the ball from the floor, held the ball above the tube entrance, and said, "Let's do that again!" Trials were counterbalanced as in the Future condition.

Test Trials. The two Test trials proceeded similarly to the Future condition, except that children placed their hand(s) under the exit(s) *after* the ball was dropped. In the first trial, the experimenter said, "Remember, I will put the ball into the top and you get to catch the ball. Here we go!" The experimenter then released the ball (while tapping the back of the tube) so that it fell into one of the boxes. The experimenter then grasped the box lids and said, "Ready?" The experimenter then waited until children placed their hands under either one or both exits. Once children had positioned their hand/s, the experimenter opened both lids simultaneously, releasing the ball. She then proceeded to the next trial, saying "Let's play again!" The counterbalancing was the same as in the Future condition Test trials.

Predictions

Previous research that has used the inverted Y-shaped tube task observed that 4-year-olds were more likely than 3-year-olds to place their hands under both tube exits. We expected to replicate that developmental pattern in our Future condition. Regarding children's performance in the Present condition, there were several possibilities. If future-oriented thinking and planning limit children's performance in the task (Turan-Küçük & Kibbe, 2024), then we expected children in the Present condition to outperform children in the Future condition and that this difference would be especially evident in the 3-year-olds, for whom future-oriented thinking and planning can be more challenging. However, if representing possibilities in the *present* is more challenging because it requires metacognitive awareness of one's own epistemic uncertainty (Phillips & Kratzer, 2024; Robinson et al., 2006), children in the Present condition should perform worse than children in the Future condition, and this difference will be especially evident in the 4-year-olds, who perform fairly well on the future-oriented version of the task. Finally, if reasoning about possibilities in the future and the present relies on similar cognitive machinery, we should observe no significant differences across the Future and Present conditions.

Transparency and Openness

Data for Experiments 1 and 2 can be obtained at https://osf.io/tgx9h/.

Results

We ran a generalized linear mixed model on children's responses (placing hands under both exits or placing hands under one exit), with age group (3-year-olds or 4-year-olds), condition (Future or Present), and trial number (Trial 1 or Trial 2) as fixed effects and participant ID included as a random effect to account for repeated measures. We used the lme4 R package (Bates et al., 2015). The model assumed a binomial distribution with a logit link function. The results are summarized in Table 1. There was no main effect of trial number and no interactions. We did observe a significant main effect of age group, with 4-year-olds outperforming 3-year-olds (consistent with previous research; Redshaw & Suddendorf, 2016; Turan-Küçük & Kibbe, 2024), but with no main effect of condition, suggesting that children used similar strategies regardless of whether they were assigned to the Future condition or the Present condition. We followed this up with a Bayes factor analysis for independent samples conducted on children's summed responses across the two trials, which yielded support for the null hypothesis that children's responses were similar in the future and Present conditions ($BF_{01} = 6.38$).

Children's responses are visualized in Figure 2. In the Future condition, in the first trial, 37.5% of the 3-year-olds (9/24) and 58% of the 4-year-olds (14/24) placed their hands under both exits of the Y-shaped tube. In the second trial, 21% of the 3-year-olds (5/24) and 66% of the 4-year-olds (16/24) placed their hands under both exits. In the Present condition, in the first trial, 25% of the 3-year-olds (6/24) and 62.5% of the 4-year-olds (15/24) placed their hands under both exits of the tube. In the second trial, 33% of the 3-year-olds (8/24) and 62.5% of the 4-year-olds (15/24) placed their hands under both exits.

Discussion

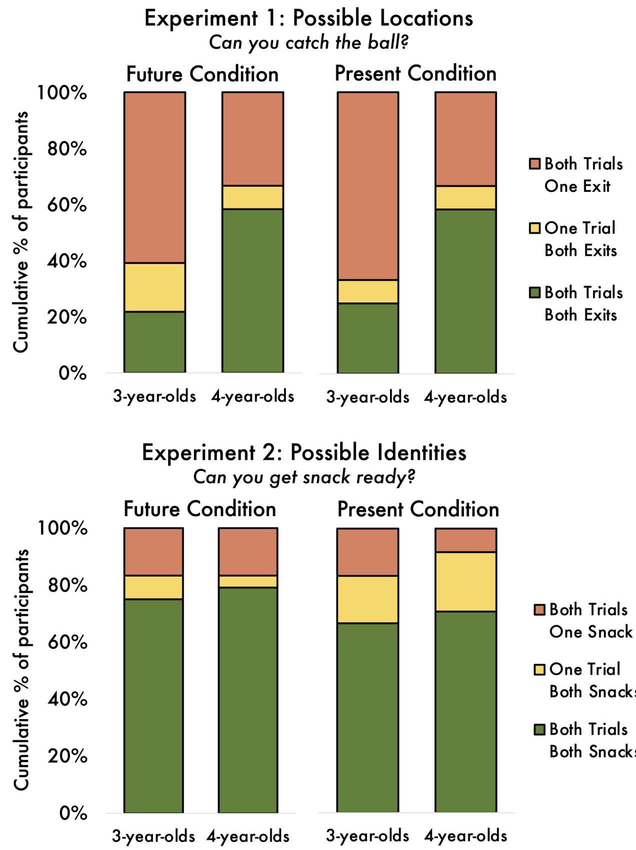
In Experiment 1, in a between-participants design, we contrasted children's reasoning about the possible outcomes of an event that has not yet occurred (Future condition) with children's reasoning about the possible outcomes of an event that has already occurred (Present condition) using a modified version of the inverted Y-shaped tube task of Redshaw and Suddendorf (2016). In our Future condition, we replicated the developmental pattern previously observed in the inverted Y-shaped tube task (Redshaw & Suddendorf, 2016; Redshaw et al., 2019; Turan-Küçük & Kibbe, 2024): 4-year-olds placed their hands under both exits more often than 3-year-olds. In our Present condition, in which children had to prepare for multiple, mutually exclusive possible outcomes of an event that had *already occurred*, we observed a similar pattern of results. Contra the future-planning-limited hypothesis and contra the metacognitive monitoring of epistemic uncertainty hypothesis, the results of Experiment 1 suggest that children may be deploying similar reasoning when representing uncertain outcomes of events that have not yet happened and events that have already happened.

Table 1
Generalized Linear Mixed Model Results for Experiment 1: Possible Locations

Fixed effect	*B*	*SE*	*Z*	*p*
Step 1: Main effects				
Intercept	−8.7148	1.9218	−4.535	<.001
Age (4-year-olds vs. 3-year-olds)	17.5697	3.0234	5.811	<.001
Condition (Future vs. Present)	−0.8747	2.5103	−.348	.728
Trial 2 versus Trial 1	−3.6132	2.4124	−1.492	.136
Step 2: Interaction effects				
Age × Condition	.2722	3.3278	.082	.935
Age × Trial	3.8380	2.6956	1.424	.155
Condition × Trial	3.8794	2.7303	1.421	.155

Note. *SE* = standard error.

Figure 2
Cumulative Percentage of Children's Responses Across Both Test Trials in Experiments 1 and 2



Note. In Experiment 1, children could place their hands under one or both exits of the inverted Y-shaped tube. In Experiment 2, children could choose one snack or both snacks for the animal in the slide. See the online article for the color version of this figure.

The results of Experiment 1 contrast with the results obtained by Robinson et al. (2006). While their study also required preparing to catch an object that could emerge from one of several locations (like our Experiment 1), children in their study were tasked with representing the uncertain *identity* of an object that either had not yet been chosen or had been chosen but whose identity was unknown. They found that 4- to 6-year-old children more readily represented the possible future identities of the object compared to the uncertain current identity of an object that had already been chosen. Perhaps representing uncertain identities results in an asymmetry that is not present when representing uncertain locations. Even though children had to represent their own uncertainty about the real-world location of an object in the Present condition of Experiment 1, the possibilities themselves were marked by physical locations in the world (i.e., the box on the left or the box on the right), which may have reduced demands on metacognitive monitoring of children's own epistemic uncertainty. By contrast, children in Robinson et al. (2006) had to represent the unknown identity of an object that was hidden from view, without the benefit of real-world physical markers for its possible identities. The demands of representing the unknown (but knowable) identity of an object without the benefit of perceptual markers of the space of possibilities may have resulted in the difference in performance observed in Robinson et al.'s (2006) study.

In Experiment 2, we examined children's reasoning about possible identities of an object in the future and in the present using the possible identities task of Turan-Küçük and Kibbe (2025). Their task required children to represent the uncertain identity of an object that would emerge from a playground slide *in the future* (e.g., either a bunny or a monkey would slide down the slide, but children did not yet know which one), and they found that both 3- and 4-year-olds could do so. In our modified version of their task, we included a replication of their task (Future condition) and also asked children to reason about the uncertain identity of an animal that had *already slid down the slide* into an opaque box (Present condition). Thus, in the Present condition, the identity of the animal was fixed in the real world, but its identity was unknown to children and needed to be represented with uncertainty. As in Experiment 1, we compared children's responses in the Future condition to children's responses in the Present condition (between-participants design).

Experiment 2: Possible Identities

Method

Participants

Ninety-six 3- and 4-year-old children were tested at the Museum of Science, Boston. Forty-eight children participated in the Future condition (24 3-year-olds, $M_{\text{age}} = 42.2$ months; 11 girls, 10 boys, three unknown; and 24 4-year-olds, $M_{\text{age}} = 52.4$ months; 10 girls, 13 boys, one unknown), and 48 children participated in the Present condition (24 3-year-olds, $M_{\text{age}} = 41.7$ months; eight girls, 14 boys, two unknown; and 24 4-year-olds, $M_{\text{age}} = 53.5$ months; 12 girls, 10 boys, two unknown). Some participants' caregivers opted to complete the optional demographics form. Participants were identified by their caregivers as White (43), Asian (12), Asian and White (2), other: not specified (8), other: Indian (2), Black or African American (1), Native Hawaiian or Pacific Islander (1), or Black or African American and White (1), and 26 chose not to share racial information. Caregivers reported their children as Hispanic (5) or not Hispanic (56), and 35 participants preferred not to disclose their child's ethnicity. Of children's primary caregivers, 72 reported having earned a college degree or higher, six reported having a high school diploma or some college, and 18 preferred not to disclose.

An additional 14 children participated but were excluded from analysis due to parental/sibling interference (4), experimenter error (7), the child not speaking English (1), or equipment malfunction (2).

Similar to Experiment 1, we first collected the sample for the Present condition, followed by the Future condition. Sample size was determined as in Experiment 1. All study procedures were approved by the institutional review boards of Boston University Charles River Campus and the Museum of Science, Boston. This experiment was not preregistered.

Apparatus

The apparatus consisted of a model playground tube slide on a green felt base (measuring 50 cm in height and 25 cm in width). The playground slide was constructed using a cardboard tube covered with yellow fabric (6 cm diameter, 30 cm in length). The top of the slide was enclosed by a 20 × 10 × 10 cm opaque black foam core box that was open in the back to allow the experimenter to reach inside. The exit of the slide was enclosed by an opaque black box made of foam core board (10 × 10 × 10 cm cube). The front of the box was fitted with a sliding door that could be opened, closed, or removed by the experimenter, allowing us to manipulate children's visual access to the exit at the bottom of the slide. We also used a set of stuffed fabric animal toys (monkey, bunny, piggy, cow, dog, and panda, each approximately 4 cm in height) and small plastic food items (banana, carrot, tomato, corn, muffin, and strawberry, each approximately 4 cm × 4 cm). Figure 1 shows photos of the apparatus.

Procedure

Future Condition.

Familiarization. Children were seated in a chair at a table across from the experimenter. First, the experimenter said, this is my slide game! In this game, animals love to slide down this slide [the experimenter pointed to slide]! And as soon as they get to the bottom of the slide, the animals always want to have a snack [the experimenter pointed to the box at the slide's exit]!

The experimenter then placed the tiger on the top left side of the playground and said, "This is Tiger. Tiger's favorite snack is grapes." The experimenter placed the plastic grapes on a table next to the playground. The experimenter put the tiger inside the box at the top of the slide (so that the tiger was no longer visible to children) and said, "Tiger is going to slide down the slide into the box, and he wants to have snack right when he gets to the bottom of the slide." Then, the experimenter said, "Can you get snack ready, so Tiger can have snack?" and gently pushed the food forward to the child's reach. The experimenter did not release the animal figure until the child placed the snack in front of the bottom opening of the slide. Once the child placed the snack, the experimenter said, "Here we go!" and released the tiger into the slide. Crucially, in the Future condition, the door at the exit of the slide was removed for the entirety of the experiment, so children could see inside the box at all times—that is, they could see that the box was empty before the experimenter released the tiger and then that the tiger landed inside the box after the experimenter released it. When the tiger emerged, the experimenter said, "Good job! Now, Tiger can have snack!," removed the tiger from the box, and pretended to have the tiger eat the grapes. She then removed the tiger and the grapes from the table.

Test Trials. The experimenter said, "Okay, let's play again with two friends. Now, this is Bunny [the experimenter placed Bunny on top of playground, left side]. And this is Monkey [the experimenter placed Monkey on top of playground, right side]." The experimenter said, "Bunny's favorite snack is carrots" and placed the carrots on the base of the playground to the left of the slide. The experimenter then said, "Monkey's favorite snack is bananas" and placed the bananas on the base of the playground to the right of the slide. The experimenter then placed both bunny and monkey inside the box at the top of the slide so that children were not able to see the animals (see Figure 1). The experimenter said, bunny and Monkey both want to go down the slide, but they cannot go down the slide at the same time because they will not fit and they might get hurt! So, they have to take turns! One of them is going to go down the slide first, but I do not know which one: Bunny or Monkey.

The experimenter then asked, “Can you get snack ready?” and pushed both foods forward simultaneously so that they were within the child’s reach. The experimenter waited until the child placed their choice(s) in front of the slide exit and removed their hands from the food(s). Then, the experimenter said, “Here we go!” and released the animal into the slide. If children selected both snacks or the snack that matched the animal that slid down the slide, the experimenter said, “Good job! Now, [Bunny/Monkey] can have snack!” If children chose the wrong snack, the experimenter said, “Where is [Bunny/Monkey]’s snack? There it is! Good job, now [Bunny/Monkey] can have snack!” The experimenter then pretended to have the animal eat the snack, removed the animal and snacks from the table, and removed the other animal from the top of the playground.

The second Test trial proceeded similarly, except with two new animals (cow and piggy) and two new foods (tomatoes and corn). The Test trials always proceeded in a fixed order (bunny/money trial followed by cow/piggy trial). Which animal slid down the slide on each trial was counterbalanced across children.

Present Condition.

Familiarization. The familiarization in the Present condition proceeded similarly to the Future condition, except that the door to the box covering the exit of the slide was closed. The experimenter said, “Tiger is going to slide down the slide into the box and, and he wants to have snack right when he gets to the bottom of the slide. Here we go!” The experimenter then released the tiger into the slide so that it landed inside the closed box at the exit of the slide. Then, the experimenter said, “Can you get snack ready, so Tiger can have snack as soon as I open the box?” The experimenter pushed the plastic grapes forward into the children’s reach. Once the child had placed the grapes in front of the box, the experimenter said, “Ok, let’s open the box!” and opened the lid to reveal the animal inside. When the tiger emerged, the experimenter said, “Good job! Now, Tiger can have snack!”

Test Trials. The Test trials of the Present condition proceeded similarly to the Future condition, except that after telling children that the animals needed to slide down one at a time, the experimenter said, “Here we go!” and immediately released one of the animals so that it landed inside the closed box at the bottom of the slide. Then, the experimenter pushed both snacks forward into the children’s reach and said, “Can you get snack ready?” After children made their choice, the experimenter said, “Ok, let’s open the box and see who came down the slide!” and slid open the door to reveal the inside of the box. She then gave feedback as in the Future condition.

The second Test trial proceeded similarly (with cow and piggy). As in the Future condition, the Test trials proceeded in a fixed order (bunny/monkey, followed by cow/piggy). Which animal was selected to slide down the slide on each trial was counterbalanced across children.

Predictions

Turan-Küçük and Kibbe (2025) found that 3- and 4-year-old children selected both snacks significantly more often when the future identity of the animal was not yet known (across both of their experiments, ~60%–80% of children did so) compared to a condition in which children were explicitly told which animal would slide down the slide. In our Experiment 2, we contrasted a Future condition (replicating Turan-Küçük & Kibbe’s, 2025, not-yet-known-identity condition) with a Present condition, in which the identity of the object is fixed but is currently unknown to the child. If future-oriented planning limits children’s ability to reason about multiple, mutually exclusive outcomes of an event, we would expect children to perform better in the Present condition, and this improvement would be especially evident for 3-year-olds. If reasoning about possible identities in the *present* is more challenging because it requires metacognitive awareness of one’s own epistemic uncertainty, children should perform better in the Future condition than in the Present condition (similar to the results of Robinson et al., 2006). Finally, we may find a pattern consistent with the pattern observed in Experiment 1; children may perform similarly in both conditions, suggesting that similar cognitive machinery undergirds reasoning about possibility in the future and the present.

Results

Analyses for Experiment 2 were conducted as in Experiment 1. We ran a generalized linear mixed model analysis on children’s responses (both snacks or one snack) with age group (3-year-olds or 4-year-olds), condition (Future or Present), and trial (1 or 2) as fixed effects and participant ID as a random effect. The results are summarized in Table 2. We observed no significant main effects or interactions: 3- and 4-year-olds performed similarly, and children’s responses were similar across the two conditions. A Bayes factor analysis for independent samples, conducted on children’s summed responses across the two trials, revealed support for the null hypothesis (BF_{01} = 6.32).

Children’s responses in each trial are visualized in Figure 2. In the Future condition, children’s responses were similar to what was observed in Turan-Küçük and Kibbe (2025). In the first Test trial, 19/24 children in both age groups (79%) selected both snacks, and this pattern also was observed in the second Test trial (19/24 children in both age groups [79%] selected both snacks). Children’s responses in the Present condition were similar to the responses of children in the Future condition. In the first Present condition Test trial, 17/24 3-year-olds (70%) and 18/24 4-year-olds (75%) selected both snacks. In the second Test trial, 19/24 3-year-olds (79%) and 21/24 4-year-olds (87.5%) selected both snacks.

Table 2
Generalized Linear Mixed Model Results for Experiment 2: Possible Identities

Fixed effect	*B*	*SE*	*Z*	*p*
Step 1: Main effects				
Intercept	9.4707	2.2089	4.288	<.001
Age (4-year-olds vs. 3-year-olds)	−.5076	2.5845	−.196	.844
Condition (future vs. present)	−1.2926	2.4860	−.520	.603
Trial 2 versus Trial 1	−.4337	1.7320	−.250	.802
Step 2: Interaction effects				
Age × Condition	.8427	3.4015	.248	.804
Age × Trial	1.1498	2.3076	.498	.618
Condition × Trial	4.0440	2.4448	1.654	.098

Note. *SE* = standard error.

Discussion

In Experiment 2, in which children had to reason about the uncertain identity of an object that would either emerge from a slide in the future (Future condition) or that had emerged from the slide but its identity was still unknown (Present condition), we found no differences in children's performance; both 3- and 4-year-old children often selected both snacks to cover both possibilities in both the Future and Present conditions. In the General Discussion section, we discuss the implications of the findings from Experiments 1 and 2.

General Discussion

In two experiments, we examined 3- and 4-year-old children's ability to reason about the possible outcomes of events at different points in time. Specifically, we contrasted children's reasoning in two theoretically relevant temporal contexts. Half of the children were asked to reason about the possible outcomes of an event that would happen in the *future*, such that the set of possible outcomes was purely hypothetical. The other half of the children were asked to reason about the possible outcomes of an event that had already occurred, such that its outcome was determinate in the *present* but unknown to the child. We used modified versions of two tasks that previously have been used to examine children's ability to reason about multiple, mutually exclusive possible outcomes of an event in the future: a *possible locations* task (after Redshaw & Suddendorf, 2016) and a *possible identities* task (after Turan-Küçük & Kibbe, 2025).

We outlined three potential developmental hypotheses for how children's performance in these tasks may be impacted by temporal context. One hypothesis suggests that future-oriented thinking and planning is a major limiting factor on children's ability to reason about possible outcomes of an event and predicts that reasoning about possibilities in the present may be easier or emerge earlier than reasoning about possibilities in the future (e.g., Atance, 2015; Atance & Mahy, 2016; Atance & O'Neill, 2001; Turan-Küçük & Kibbe, 2024). Another hypothesis suggests that reasoning about possible outcomes for events that have already occurred requires metacognitive monitoring of uncertainty in one's own mental states and therefore predicts that reasoning about possibilities in the present may be more challenging or emerge later than reasoning about possibilities in the future (e.g., Phillips & Kratzer, 2024; Robinson et al., 2006). A third hypothesis suggests that reasoning about possibilities across different points in time may be supported by the same cognitive architecture and therefore predicts that reasoning about possibilities in the present and the future may show similar emergence and development (e.g., Addis, 2020; Addis et al., 2007). Our results provide some support for this third hypothesis; across both experiments, we found that children responded similarly regardless of whether they were asked to reason about possible outcomes of an event in the present or in the future, and we did not observe any developmental differences in children's performance.

Our results contrast with previous results obtained by Robinson et al. (2006), who found that children struggled with reasoning about uncertain outcomes of events that had already occurred until around age 7 years. We find that, once children can successfully reason about possibility in the future (at ∼4 years for possible locations; at ∼3 years for possible identities), they appear able to also do so for possible outcomes in the present, and we observed no developmental differences in these different types of reasoning across the age range we tested (which is a period of substantial developmental change both in future-oriented cognition and in metacognitive monitoring; Atance, 2015; Lyons & Ghetti, 2010; Papaleontiou-Louca, 2019; Pham et al., 2024). This suggests that the ability to reason about events that have a determinate outcome in the world, but must be represented with some uncertainty in the mind, may emerge earlier than previously thought.

If children are using similar cognitive machinery to reason about uncertainty in both the present and the future, what cognitive processes are supporting this reasoning? Although physical uncertainty (about an event that has not yet happened) and epistemic uncertainty (about an event that has already occurred but the outcome of which is unknown) are distinct *in reality*, children may think about possibility similarly in both contexts. For example, children may be sensitive to differences in temporal context but may use the same representational format for representing possible outcomes in both contexts. This would mean that once children can *represent* uncertainty, they can use those representations to support both present- and future-based reasoning about uncertainty, even if they may deploy different cognitive processes to *reason* about uncertainty across different temporal contexts (e.g., future-oriented thinking in contexts involving future uncertainty but not in contexts involving past or present uncertainty). Another possibility is that children may approach both physical and epistemic uncertainty scenarios as if they both involve future uncertainty, since in both cases the uncertainty will be *resolved* in the future (from children's perspectives), and therefore, both cases could require children to plan for an action that they will take in the future in response to such uncertainty. Children may represent the possible outcomes of an event as *subjectively* possible from their own perspective (Redshaw & Suddendorf, 2020) regardless of whether the outcome has already occurred or will occur in the future and therefore deploy both metacognition and future-oriented thinking to represent, reason about, and plan for uncertainty across temporal contexts. For example, regardless of whether there is a possibility of rain *in the future* or whether the *current* weather is unknown (because one has not looked out the window yet), one might still deploy the same type of reasoning ("I should take an umbrella"). The design of our experiments does not allow us to distinguish between these possibilities, so future work is needed. Regardless, the fact that children respond similarly in the present and Future conditions in our experiments is suggestive of similar approaches to possibility across temporal contexts.

However, obtaining a null result is not necessarily definite evidence that similar cognitive processes are at play in reasoning about the present and the future. We used simplified tasks that were highly constrained in terms of the kinds of uncertainty that children had to consider (i.e., there were always only two possibilities, and the possibility space was known at the outset). We chose these tasks because they have previously been used successfully to measure future possibility reasoning in 3- and 4-year-olds. But it is possible that, in more complex scenarios or scenarios with greater uncertainty, one would observe an asymmetry in children's reasoning across different time points, as children's future-oriented cognition or metacognitive monitoring processes become more taxed. It is also possible that such asymmetries may emerge later in development, as children's reasoning abilities develop beyond thinking about more concrete possibilities (like the location or identity of an object) and to thinking more abstractly about possibility (Kushnir, 2023). Finally, it is possible that both future-oriented thinking *and* metacognitive monitoring were *both* limiting factors on children's performance and that we did not observe asymmetries because our different conditions successfully isolated each factor. Further work is needed to investigate these possibilities. Nevertheless, our results suggest that, at least during a developmentally relevant time period for reasoning about uncertainty, the time course for development of such reasoning in the future and the present proceeds similarly.

It is also important to consider other potential explanations for our null result. Specifically, what if we did not observe differences across the different conditions because children did not understand that these conditions *were* different? In both experiments, the event in the Present condition occurred out of children's view. If children ignored the fact that the event had occurred, they may view the Present condition as no different as the Future condition. We think this explanation is unlikely for several reasons. First, children were familiarized with the apparatus prior to the critical test trials. In Experiment 1, children first observed several familiarization trials in which the experimenter dropped the ball into the tube and then released the lids of the boxes so that the ball dropped out of one of the two boxes. In Experiment 2, children practiced getting a snack ready for a single animal; the experimenter told the children the animal was going to slide down into the box, released the animal into the slide, and then slid open the box lid to reveal the animal inside. Second, in both experiments, the experimenter's interactions with the apparatus during the test trials would not make sense if children thought that the event had not yet occurred. For example, in Experiment 1, the experimenter released the ball and then placed her hands on both of the box lids. If children thought that the ball had not yet dropped, they would need to represent the ball as hovering in midair. In Experiment 2, the experimenter told the children that an animal was going to slide down the slide *into the box* and that the children would need to get a snack ready so that the animal could have a snack as soon as the box was opened. After she released the animal into the slide, the experimenter's hands did not return to the top of the playground slide. If children thought the animal had not yet slid into the box, they would have to imagine that the animal could slide down on their own, without the assistance of the experimenter. While we cannot say definitively that children were not imagining such odd possibilities, we think that it is likely that children did understand the temporal dynamics of the task and acted accordingly. Future work could explore children's representations at different time points within a series of events to gain more precise insights into the representations that are supporting children's reasoning in these tasks.

Our results provide new insights into young children's ability to navigate uncertainty across different points in time. Children's pattern of responses across our two experiments suggests that the ability to reason about possible outcomes of events that have not yet happened and the ability to reason about possible outcomes of events that have already occurred may emerge and develop in tandem. Further, our results suggest that the ability to think about possibility in the present may emerge earlier than previously thought. Future work will investigate the specific mechanisms that support these abilities and their developmental trajectories across childhood.

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