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Three- and four-year-old children represent mutually exclusive possible identities

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ABSTRACT

How do children think about and plan for possible outcomes of events that *could* happen in the future? Previous work that has investigated children's ability to think about mutually exclusive possibilities has largely focused on children's reasoning about one type of possibility—the possible locations of an object. Here, we investigated children's reasoning about another type of possibility—mutually exclusive possible identities. In two experiments (N = 201 U.S. 3- and 4-year-olds), children were told that two animal characters (e.g., a bunny and a monkey) were going to take turns sliding down a playground slide. Children were told that the animals wanted to eat their favorite foods (e.g., carrots and bananas, respectively) as soon as they got to the bottom of the slide. In an Unambiguous Identity condition, we told children the identity of the animal that would slide down. In an Ambiguous Identity condition, we told children that which animal would slide down first was unknown. To examine children's representations of possible identities, we asked children to "get snack ready." We found that children in the Unambiguous Identity condition selected only one of the snacks (i.e., the favorite snack of the animal they were told would slide down), whereas children in the Ambiguous Identity condition selected *both* snacks, suggesting that they were accounting for *both* possible identities. These results extend the literature on the development of modal reasoning to

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include reasoning about possible identities and suggest that this ability may be available to children as young as 3 years.

Introduction

Humans are adept at navigating the inherent uncertainties of daily life. From deciding whether to carry an umbrella on a cloudy day to planning emergency responses to potential natural disasters, we engage in decision making that requires us to think about multiple, often mutually exclusive, possible outcomes of events that have not yet happened but *could* happen. A growing body of literature examining the development of modal reasoning suggests that children's capacity to plan for such uncertainties is predicated on their ability to simultaneously represent multiple mutually exclusive outcomes of an event (e.g., Beck et al., 2006; Gautam et al., 2021; Leahy & Carey, 2020; Mody & Carey, 2016; Redshaw et al., 2018; Redshaw & Suddendorf, 2016; Robinson et al., 2006; Suddendorf et al., 2017; for theoretical reviews, see Harris, 2022; Leahy & Carey, 2020; Redshaw & Ganea, 2022).

Children's modal reasoning is usually assessed with tasks that require children to represent mutually exclusive possibilities while minimizing the need for extensive prior knowledge or the ability to understand complex instructions. For example, Redshaw and Suddendorf (2016) asked children to catch a marble dropped into the top of an inverted Y-shaped tube, such that the marble could exit from either the right branch of the Y *or* the left branch of the Y. To succeed in this task, children needed to represent the possible trajectories of the marble as it falls through the tube, reason that it may emerge from either the right exit *or* the left exit, and act accordingly, placing their hands under *both* exits to guarantee that they will catch the falling marble regardless of which exit it emerges from. Redshaw and Suddendorf (2016) found that around 4 years of age children reliably place their hands under the exits of both branches of the tube, covering both possible outcomes, suggesting that they are able to simultaneously represent mutually exclusive possibilities. By contrast, children under 4 years old are more likely to place their hands under only one tube exit, which has been taken as evidence that they are unable to represent mutually exclusive possibilities and may represent only one possibility at a time (for replications, see Suddendorf et al., 2017; Redshaw & Suddendorf, 2016; Suddendorf et al., 2017; and Turan-Küçük & Kibbe, 2024; see also Leahy, 2023, 2024, for converging results from a variation of this task that required children to track multiple object trajectories and contrast a guaranteed or impossible outcome and a merely possible outcome). Similar results were obtained in a task that required children to represent the possible locations of stickers that could be hidden (out of children's view) in a set of opaque containers (Leahy et al., 2022; Mody & Carey, 2016).

Together, these studies have converged on a developmental picture of children's modal representational capacities, one in which children typically begin to succeed at modal reasoning tasks around 4 years of age. Theorists have suggested that children younger than approximately 4 years are unable to simultaneously represent mutually exclusive possibilities (e.g., Carey et al., 2020; Harris, 2022; Leahy & Carey, 2020; Leahy et al., 2022; Redshaw & Suddendorf, 2016, 2020). Instead, theorists have argued that younger children may have a *minimal representation* of possibility (e.g., Leahy & Carey, 2020; Leahy et al., 2022); younger children know that there are multiple possible outcomes of an event, but instead of concurrently representing all possible outcomes as merely possible, they select one possible outcome and treat that outcome as certain.

However, the study of children's representations of multiple mutually exclusive possibilities has been largely limited to a specific type of reasoning—reasoning about an *object's possible location in physical space* (i.e., an object can be in one location or another location, but it cannot be in both locations at once). These tasks typically require children to simulate the possible trajectories of a moving object (e.g., an object dropped into a slide or tube, an object placed behind an occluder into one of several containers), determine the possible locations at which the object will arrive (e.g., branches of the

tube, containers behind the occluder), and take an action in response to those possible locations (e.g., position hands or cups to catch the falling object, select a container that might hold a sticker). Although the above tasks differ from each other on several dimensions, ultimately children are being asked to represent a similar type of possibility—the possible location of an object.

Because a large portion of the evidence regarding children's ability to represent mutually exclusive possibilities comes from tasks that tap similar physical reasoning processes, it can be difficult to draw more general conclusions about children's modal reasoning abilities, for several reasons. First, in children's everyday lives, they are faced with many different kinds of scenarios in which they must represent possibility. Children might know that they will get to play with only one of several possible desirable toys at choice time and may need to plan accordingly. Or they may be told that if it is not raining they will go to the playground, but if it is raining they will go to the museum. In these situations, children must represent multiple mutually exclusive possibilities in contexts that extend to domains other than physical reasoning about an object's location. Yet, less is known about whether children represent possibility in other contexts.

Second, the type of physical reasoning required for many modal reasoning tasks may be particularly challenging for younger children, who have been shown to have difficulty in reasoning about the trajectories of moving objects in situations that do not require representing possibility. For example, young children expect that an object dropped into a curved tube will fall straight down rather than follow the curve of the tube (a "gravity bias"; Hood, 1995, 1998), and even older children struggle when tasked with predicting the trajectories of two objects (Hood et al., 2006). This physical reasoning limitation could pose a challenge for children faced with predicting the possible trajectories and final locations of objects in many modal reasoning tasks. Indeed, previous work suggests that 4-year-olds have more difficulty in responding correctly in tasks that require them to represent the possible trajectories and final locations of two objects (Leahy, 2023, 2024) compared with tasks that require predicting only one object's possible trajectories and locations (e.g., Redshaw & Suddendorf, 2016; Turan-Küçük & Kibbe, 2024). Furthermore, 3-year-old children have more success with taking a correct action in modal reasoning tasks when they are given additional scaffolding, such as being shown the possible actions that can be taken in the Y-shaped tube task before they are required to take an action themselves (Turan-Küçük & Kibbe, 2024). And 3-year-olds can distinguish a guaranteed outcome from a merely possible outcome in a task that does not require them to reason physically about an object's potential trajectory or location (Alderete & Xu, 2023). It is possible that children's competence at modal reasoning tasks may be masked by physical reasoning demands that may be distinct from limitations imposed by a developing representation of possibility.

One study examining children's ability to represent possibilities did ask children to consider multiple possible identities of an object. Robinson et al. (2006) showed children an apparatus with three colored chutes, one for each of three different colored blocks. Children were tasked with placing trays under the exits of the chutes to catch a block placed in one of the chutes. In an *unknowable* condition, children were told that the experimenter would place a block into one of the chutes from a bag containing both orange and green blocks. Children were then given the opportunity to place one or more trays under the chute exits before the experimenter removed a block from the bag. To succeed, children needed to realize that the color of the block could be either orange or green and to place trays under both the orange and green chutes, covering both possibilities. The authors found that children under 5 years of age typically placed only a single tray, whereas 5- and 6-year-olds were more likely to place both trays. Furthermore, in an *unknown* condition, where the experimenter selected and placed the block inside the top of the chute (with its identity unknown to children), even older children struggled with the task, placing only one tray more often. Whereas this task required children to think about multiple possible identities, it also made significant demands on children's physical reasoning—because children needed to reason about both possible identities and multiple possible object trajectories and needed to make predictions about the future location of an object—making it unclear whether children's difficulty with the task was due to difficulty in representing mutually exclusive possible identities or to other task demands.

Here, in two experiments, we aimed to examine whether 3- and 4-year-old U.S. children can represent multiple mutually exclusive possible identities of an object. We designed a novel modal reasoning task for 3- and 4-year-olds that did not require extensive previous knowledge and also did not

require children to reason about possible physical trajectories or possible locations of objects. Instead, we asked children to represent two mutually exclusive possible characters that could be involved in an event. Our goals were twofold. First, we wanted to extend the study of children's representation of possibility to another domain of reasoning—reasoning about mutually exclusive identities. Second, we wanted to examine whether developmental patterns observed in the previous modal reasoning literature—in which 4-year-olds typically outperformed 3-year-olds—would again be observed in a task where children were asked to reason about possible identities rather than possible locations of an object.

In Experiment 1, 3- and 4-year-olds were shown a playground scenario in which animal characters could slide down a single playground slide and then eat "their favorite snack" as soon as they reached the bottom of the slide. We introduced children to two animal characters (e.g., Bunny and Monkey) and their favorite snacks (e.g., carrots and bananas, respectively) and told children that both animals wanted to go down the slide, but they could not both fit inside the slide, so they needed to take turns. In an Ambiguous Identity condition, we told children that which animal would slide down first was unknown. Children were then asked to "get snack ready." We measured whether children selected only one snack, preparing for only one of the two possible animal identities, or *both* snacks, covering both possible animal identities. We compared children's choices in the Ambiguous Identity condition with their choices in an Unambiguous Identity condition, where children were told which animal would slide down the slide. In Experiment 2, we replicated and extended Experiment 1 while ruling out a possible alternative explanation for the results of Experiment 1.

Across both experiments, we hypothesized that if children in the Ambiguous Identity condition could successfully represent that one *or* the other animal will emerge from the slide, then they should select both snacks—covering both possible identities—whereas children in the Unambiguous Identity condition should select only one snack. Such a result would suggest that children can represent mutually exclusive possible identities. We also hypothesized that reducing the physical reasoning demands of the task—by asking children to reason about possible identities rather than possible trajectories or locations—might make the task more doable by younger children. Therefore, we predicted that 3- and 4-year-olds may perform similarly in the task. Such a result would suggest that younger children may have more competence with modal reasoning than is evident from tasks that require children to reason about possible trajectories or locations of an object.

Experiment 1

Method

Participants

A total of 96 children participated in Experiment 1, with 48 in the Ambiguous Identity condition (n = 24 3-year-olds, mean age = 42.63 months, range = 36–47, 13 girls and 11 boys; n = 24 4-year-olds, mean age = 52.46 months, range = 48–58, 9 girls, 14 boys, and 1 unknown) and 48 in the Unambiguous Identity condition (n = 24 3-year-olds, mean age = 41.79 months, range = 36–47, 12 girls and 12 boys; n = 24 4-year-olds, mean age = 53.92 months, range = 48–59, 12 girls and 12 boys). Sample size was determined to be comparable to previous studies that examined age differences in children's responses in modal reasoning tasks. Children were tested in the Museum of Science, Boston. An additional 5 children participated but were excluded from analysis because of caregiver interference (n = 4) or experimenter error (n = 1). The study was approved by the institutional review boards of the Boston University Charles River Campus and the Museum of Science, Boston.

Apparatus and stimuli

Children interacted with a small model playground (measuring 50 cm in height and 25 cm in width) constructed using cardboard and felt fabric of various colors. The playground featured a cylindrical slide made from a cardboard tube covered with yellow felt (6 cm in diameter and 30 cm in length). The opening at the top of the slide was hidden by an enclosed cardboard box covered in blue felt, and the bottom of the slide sat on a green felt base and was open and visible to children. Stimuli

also included a set of fabric stuffed animal toys (a pig, a cow, a monkey, a rabbit, and a tiger, each measuring ~ 7 cm in height) and a set of small plastic food items (corn, tomato, banana, carrot, and grapes, all ~ 4–11 cm in height). Fig. 1 shows a schematic drawing of the apparatus (see Fig. S1 in the online supplementary material for a photo of the apparatus in the museum setting).

Procedure

Children were seated in a chair at a table across from the experimenter. All children completed a familiarization trial, followed by two condition-specific test trials.

Familiarization. First, the experimenter said (pointing to the apparatus), "This is my slide game! In this game, animals love to slide down this slide! And as soon as they get to the bottom of the slide, the

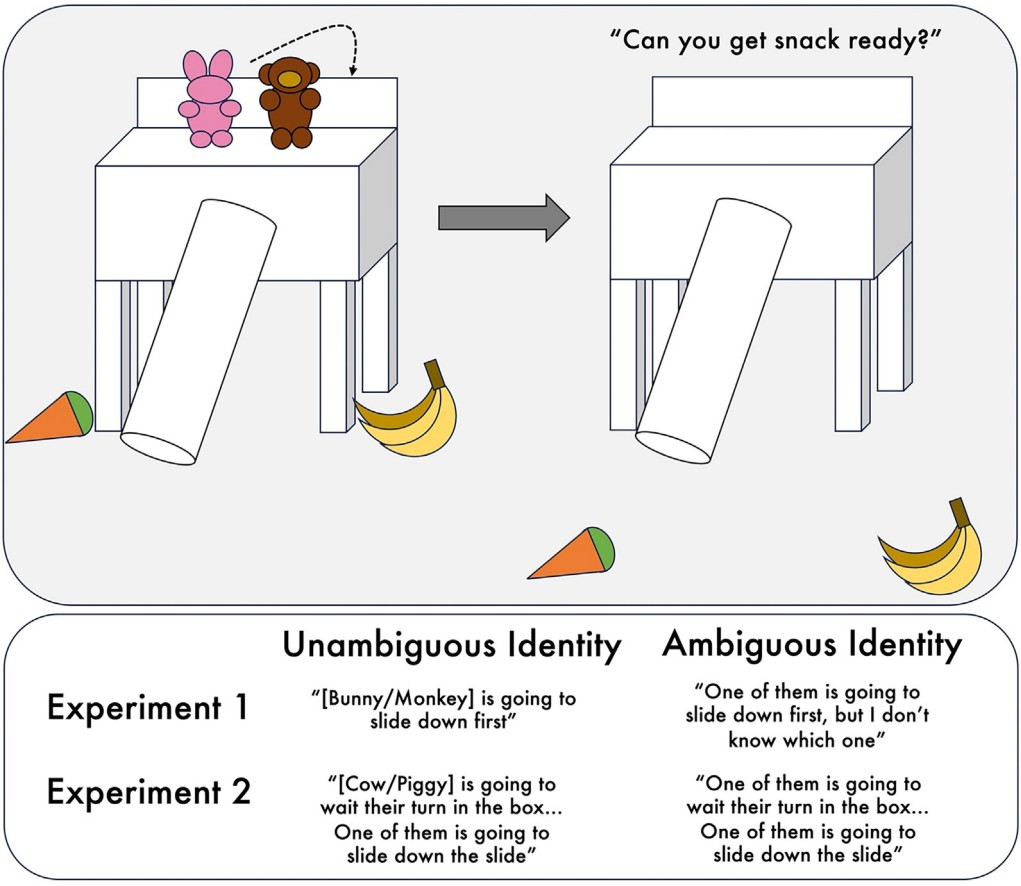

Fig. 1. Schematic of the apparatus and method for Experiments 1 and 2 (top panel) and relevant samples from the scripts for each experiment (bottom panel). In each test trial, the experimenter told children that two animals wanted to slide down the slide but that they were going to take turns. In Experiment 1, the experimenter placed the two animals inside the top of the slide. In the Unambiguous Identity condition the experimenter told children which animal would slide down first, whereas in the Ambiguous Identity condition the identity of the animal was unknown. In Experiment 2, after placing the animals inside the top of the slide, the experimenter told children that one of the animals was going to wait its turn in a separate opaque box (which was then placed to the side). In the Unambiguous Identity condition children were told which animal was waiting inside the box (and could use that information to infer which animal would slide down the slide), whereas in the Ambiguous Identity condition the identity of the animal inside the box (and the identity of the animal that would slide down) was unknown. In both experiments, children were asked to "get snack ready" before an animal slid down the slide.

animals always want to have a snack!" 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." She then placed the plastic grapes on a table next to the playground. The experimenter put Tiger inside the box at the top of the slide so that the tiger was no longer visible to children and explained, "Tiger is going to slide down the slide! And remember, he wants to have snack right when he gets to the bottom of the slide. Can you get snack ready so Tiger can have snack as soon as he slides down the slide [the experimenter pointed to the opening at the bottom of the slide]?" Then the experimenter gently pushed the plastic grapes forward into children's reach. All children retrieved the plastic grapes and placed them at the base of the slide (if children did not respond immediately, the experimenter again pointed to the opening at the base of the slide and repeated the instruction). Once the children had placed the grapes, the experimenter released the tiger into the top of the slide, retrieved the tiger from the opening at the bottom of the slide, and pretended to have the tiger eat the grapes. She then removed the tiger and the grapes from the table.

Ambiguous Identity condition. In the first test trial, the experimenter said, "Okay, let's play again with two friends. Now, this is Bunny [the experimenter placed the bunny on top of the slide box, to the left] and this is Monkey [the experimenter placed the monkey on top of the slide box, to the right]. Bunny's favorite snack is carrots [the experimenter placed the plastic carrots on the base of the playground on the left of the slide], and Monkey's favorite snack is bananas [the experimenter placed the plastic bananas on the base of the playground on 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 (Fig. 1) and said, "Bunny and Monkey both want to go down the slide, but they can't go down the slide at the same time because they won't 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 don't know which one: Bunny or Monkey. Can you get snack ready?" The experimenter then pushed both plastic foods forward so that they were in the children's reach. The experimenter waited until children placed the food(s) at the base of the slide and pulled their hands completely away from the foods. She then released an animal into the slide (the identity of the animal was counterbalanced across participants) and said, "Okay, let's see who goes down the slide!" When the animal reached the bottom of the slide, the experimenter said, "Who came down the slide?" If children placed both snacks or the correct snack, the experimenter said, "Good job! Now, [Bunny/Monkey] can have snack!" If children placed the incorrect snack, the experimenter said, "Where is [Bunny's/Monkey's] snack? There it is! Good job, now [Bunny/Monkey] can have snack!"

The second test trial proceeded the same way except with two new animals (Cow and Piggy) and two new foods (tomatoes and corn).

Unambiguous Identity condition. The test trials proceeded similarly to the test trials in the Ambiguous Identity condition except that instead of saying "One of them is going to go down the slide first, but I don't know which one," the experimenter explicitly told children which animal would slide down the slide. In the first test trial she said "[Bunny/Monkey] is going to go down the slide first," and in the second test trial she said "[Cow/Piggy] is going to go down the slide first" (with animal identity counterbalanced across children).

Analysis approach and hypotheses

We compared children's choices in the Unambiguous Identity condition, where children were told which animal would slide down the slide, with their choices in the Ambiguous Identity condition, where the identity of the animal that would slide down the slide was uncertain. In the Unambiguous Identity condition, we hypothesized that children would frequently choose only one snack (e.g., choosing the carrots when told that Bunny would slide down the slide).[1] In the Ambiguous Identity condition, we hypothesized two potential patterns for children's responses. If children had a *minimal representation of possibility* (Leahy & Carey, 2020), we predicted that they would simulate a single animal

[1] Our primary measure of interest was whether children chose one snack or both snacks. In the Unambiguous Identity condition, we also coded whether children chose the "correct" snack given a particular animal's identity. Descriptive statistics are reported in the Results.

sliding down the slide and therefore would choose one snack *at rates similar to the Unambiguous Identity* condition. That is, under this hypothesis the Unambiguous Identity and Ambiguous Identity conditions should produce similar patterns of behavior in children. However, if children were *able to represent mutually exclusive possible identities,* they should choose *both* snacks in the Ambiguous Identity condition, covering both possible identities. Under this hypothesis, children in the Ambiguous Identity condition should choose both snacks significantly more often than children in the Unambiguous Identity condition.

Regarding age-related effects, we hypothesized that 3- and 4-year-olds should select only one snack at similar rates in the Unambiguous Identity condition. In the Ambiguous Identity condition, we hypothesized that, if developmental trends observed in previous tasks that required representing possible trajectories and locations held in our task, 4-year-olds should outperform 3-year-olds, with 3-year-olds selecting one snack more often than 4-year-olds and at similar rates to their age counterparts in the Unambiguous Identity condition.

We planned to concentrate our analyses on children's responses in the first test trial only, before children received any feedback about the success or failure of their choices. Details regarding the second trial are available in the supplementary material (first and second trial data did not differ significantly; see Fig. S2). Because of low variability in the data, we used 2 × 2 non-parametric tests to compare children's responses between conditions and age groups (other statistical methods, such as generalized linear mixed models, were not possible due to violations of distribution assumptions and concerns about model convergence; see Turan-Küçük & Kibbe, 2024, for a similar approach). We report effect sizes for all 2 × 2 contingency tables as odds ratios (ORs).

Data for Experiments 1 and 2 are available at the Open Science Framework (https://osf.io/gsy3b).

Results

Children's choices in the first test trial are shown in Fig. 2. In the Unambiguous Identity condition, where children were told which animal would slide down the slide, we found that the majority of children in both age groups (23 of 24 3-year-olds and 23 of 24 4-year-olds [both 95%]) selected only one snack, with no difference between the age groups (Fisher's exact test, $p = 1$, two-tailed, OR = 1.00). Children's food item choices matched with the animal they were told would slide down (96% of 3-year-olds and 100% of 4-year-olds who selected only one snack correctly chose the named animal's "favorite snack," i.e., carrot for bunny and bananas for monkey). In the Ambiguous Identity condition, where children were told that only one animal would slide down but the animal's identity was not known, a minority of children selected only one snack (11 of 24 3-year-olds [46%] chose one snack and 5 of 24 4-year-olds [21%] chose one snack), and there was no significant difference between the age groups[2] (Fisher's exact test, $p = .125$, two-tailed, OR = .31).

Critically, we found significant differences in children's choices between the Ambiguous Identity and Unambiguous Identity conditions in both age groups; both 3-year-olds and 4-year-olds were significantly less likely to choose only one snack in the Ambiguous Identity condition compared with the Unambiguous Identity condition (Fisher's exact test; 3-year-olds: $p < .001$, OR = .04; 4-year-olds: $p < .001$, OR = .01).

Discussion

In Experiment 1, we presented children with a scenario in which one of two animals would slide down a slide, and children needed to "get snack ready" for the animal to eat when the animal reached the bottom of the slide. We found that when 3- and 4-year-old children were told which animal would

[2] Although we did not observe significant differences in children's pattern of responses in the first and second test trials in either condition, we did find that, in the second test trial of the Ambiguous Identity condition, 4-year-olds selected both snacks at rates significantly greater than 3-year-olds (Fisher's exact test, $p = .004$, OR = .06; see Fig. S2 in supplementary material), potentially suggesting developmental improvements in children's ability to prepare for multiple mutually exclusive possible identities, particularly after receiving feedback on the task. However, this result should be interpreted with caution for three reasons. First, we did not observe significant differences across the two test trials. Second, our task was not designed to detect such learning effects. Third, we did not observe any such effects in Experiment 2 (see Fig. 2 and Fig. S2).

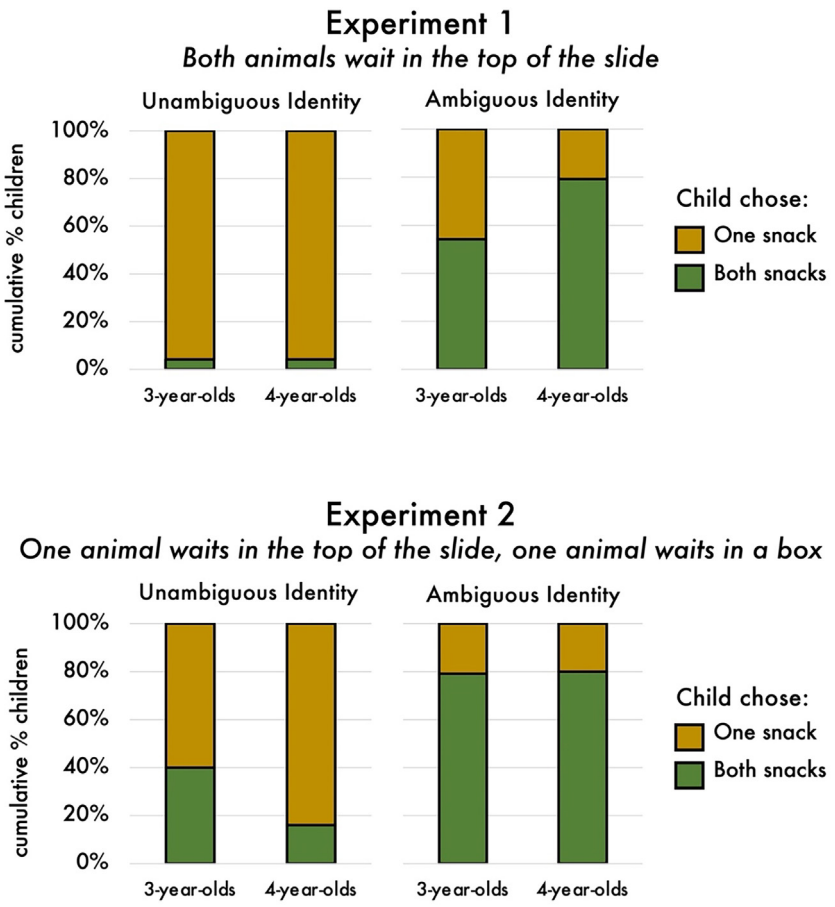

Fig. 2. Cumulative percentage of children's responses (choosing only one food item or choosing both food items) in the first test trial of Experiments 1 and 2.

slide down the slide, they selected a single snack. By comparison, when children were told that one animal would slide down the slide but that the experimenter did not know which animal it would be, they were more likely to select *both* snacks, suggesting that they represented that *either* Bunny *or* Monkey would emerge from the slide and therefore that they would need to cover both possibilities. This result suggests that children in our task could represent multiple mutually exclusive identities.

However, there is another potential explanation for children's pattern of responses in Experiment 1. Specifically, although children in the Ambiguous Identity condition were told that the animals could not both slide down the slide at the same time and that they would need to take turns, children might not have understood. Since both animals were waiting in the top of the slide, children may have expected both animals to slide down the slide or may have thought that the animals would slide down one after the other in quick succession and therefore chose both snacks expecting both animals. For children in the Unambiguous Identity condition, on the other hand, the fact that a single animal was going to slide down the slide was made more explicit by the fact that they were told the identity of the animal that would emerge from the bottom of the slide.

To examine this potential explanation for the results of Experiment 1, we conducted Experiment 2. Experiment 2 was similar in structure to Experiment 1 except that we told children that one of the

animals would wait its turn inside a separate box that was physically removed from the slide apparatus so that there was only one animal waiting in the top of the slide. As in Experiment 1, the experimenter first placed both animals inside the top of the slide. She then showed children a separate empty box, placed one of the animals inside the box (behind the playground structure so that children could not see which animal was placed in the box), shook the box so that the animal rattled around, and told children that one of the animals was inside. In the Unambiguous Identity condition, children were told which animal was waiting inside the box (e.g., "Cow is going to wait his turn in this box"). In the Ambiguous Identity condition, the experimenter told children that one of the animals would wait its turn inside the box but that she did not know which one. The experimenter then placed the box under the table out of view. Children were then told that an animal would slide down the slide, and they were asked to "get snack ready." Critically, this manipulation meant that all children knew that only one animal was inside the slide structure, and therefore only one animal could slide down. If children's responses in the Ambiguous Identity condition of Experiment 1 were driven by the mistaken belief that both animals would slide down the slide, we predicted that children in Experiment 2's Ambiguous Identity condition should select one snack at rates similar to children in the Unambiguous Identity condition, since it was made explicit in both conditions that only a single animal was waiting to slide down. Alternatively, if children are able to represent multiple mutually exclusive possible identities and prepare for those possibilities, we predicted that children would choose both snacks in the Ambiguous Identity condition significantly more than children in the Unambiguous Identity condition.

Experiment 2

Method

Participants

A total of 105 3- and 4-year-old children participated in Experiment 2, with 49 in the Ambiguous Identity condition (n = 24 3-year-olds, mean age = 41.33 months, range = 36–47, 13 girls and 11 boys; n = 25 4-year-olds, mean age = 53.68 months, range = 48–59 months, 13 girls and 12 boys) and 56 in the Unambiguous Identity condition (n = 25 3-year-olds, mean age = 42 months, range = 36–48, 5 girls and 20 boys; n = 31 4-year-olds, mean age = 54 months, range = 48–59, 13 girls and 18 boys). Children were tested at the Museum of Science, Boston. We aimed to recruit 96 children (48 children per condition), corresponding to the sample size of Experiment 1. The final sample of 105 was due to overrecruitment in the museum setting. An additional 9 participants were tested but were excluded from analysis due to experimenter error (n = 3) or caregiver interference (n = 6). The institutional review boards of the Boston University Charles River Campus and the Museum of Science, Boston, approved the study.

Apparatus and stimuli

The apparatus for Experiment 2 included the same playground and animals that were used in Experiment 1 plus two new animals, a dog and a panda, and two new plastic food items, a muffin and a strawberry (similar in size to the stimuli used in Experiment 1). In addition, Experiment 2 included a separate black foam core box ($10 \times 10 \times 10$ cm), with a flap that could be opened or closed, into which a single animal could be placed.

Procedure

Children were assigned to either the Ambiguous Identity condition or the Unambiguous Identity condition. All children completed two familiarization trials, followed by two condition-specific test trials.

Familiarization trials. The first familiarization trial was identical to the familiarization trial of Experiment 1. In the second familiarization trial, we aimed to familiarize children with two animals and turn-taking before introducing them to the removal of one of the animals from the scene. To this

end, the second familiarization trial was identical to the first test trial in the Ambiguous Identity condition of Experiment 1, in which children were told that both animals wanted to slide down the slide but they needed to take turns, the experimenter did not know which animal would go first, and children were asked to "get snack ready." Thus, this trial served to familiarize children with the apparatus and the concept of "turn-taking" as well as serving as a direct replication of Experiment 1's Ambiguous Identity condition.

Test trials. The test trials proceeded similarly to Experiment 1 except that one of the animals was placed inside an opaque box, such that there was only a single animal waiting in the top of the slide. In the first test trial, the experimenter introduced Piggy and Cow and their favorite snacks, hid the animals inside the top of the slide apparatus, and told children, "They want to go down the slide, but they can't go down the slide at the same time because they won't fit and they might get hurt! So, they have to take turns!" The experimenter then showed children an opaque black box, shook the box, and said, "Look, this box is empty!" She then held the box up to the back of the slide apparatus and placed one of the animals inside the box out of children's view (which animal was placed inside the box was counterbalanced across children).

In the Ambiguous Identity condition, the experimenter then said, "This time, one of them is going to wait their turn in this box. [experimenter shook box] See, one of them is inside the box! I'm going to put the box away for now." After placing the box under the table, she said, "One of them is going to go down the slide, but I don't know which one: Piggy or Cow. Can you get snack ready?".

In the Unambiguous Identity condition, the experimenter placed an animal inside the box and said, "This time, [Piggy/Cow] is going to wait their turn in this box. [The experimenter shook the box] See, [Piggy/Cow] is inside the box! I'm going to put the box away for now." After placing the box under the table, the experimenter said, "One of them is going to go down the slide. Can you get snack ready?" Note that, unlike in the Unambiguous Identity condition of Experiment 1, the experimenter did not explicitly tell children which animal would slide down the slide. Instead, children needed to infer the identity of the animal and then select the appropriate food for that animal.

After children made their choices, the experimenter gave feedback as in Experiment 1. The second test trial proceeded similarly except with Dog and Panda and their favorite snacks, a muffin and a strawberry, respectively.

Analysis plan and hypotheses

Analyses were conducted as in Experiment 1. We hypothesized that, if children represent multiple mutually exclusive possible identities for the animal inside the slide, they would select both snacks significantly more often in the Ambiguous Identity condition compared with the Unambiguous Identity condition.

In addition, we analyzed the results of the second familiarization trial and compared the results with the Ambiguous Identity condition of Experiment 1 to examine whether the results replicated across experiments.

Results

Familiarization trial

In the second familiarization trial, a minority of children (12 of 49 3-year-olds [24%] and 14 of 56 4-year-olds [25%]) chose only one snack, not significantly different from children's choices in the first test trial of the Experiment 1 Ambiguous Identity condition in either age group ($ps > .62$).

Test trial

The results of the first test trial are shown in Fig. 2. In the Unambiguous Identity condition, where children were told the identity of the animal that was waiting in a separate box, the majority of children from both age groups chose *only one* snack (3-year-olds: 15 of 25 children [60%] chose one snack; 4-year-olds: 26 of 31 children (84%) chose one snack), and the difference between the age groups was not significant (Fisher's exact test, $p = .07$, OR = .29). Children in both age groups were largely successful at inferring the identity of the animal that was waiting in the slide after hearing which animal was

waiting its turn inside the box, as evidenced by children's choice of snack (11 of 15 3-year-olds [73%] and 19 of 26 4-year-olds [73%] chose the correct snack for the animal); the majority of children chose Cow's favorite food when they were told that Piggy was waiting inside the box and chose Piggy's favorite food when they were told that Cow was waiting inside the box, with no differences between the age groups (Fisher's exact test, $p = .74$, OR = .68).[3]

In the Ambiguous identity condition, where children were told that one animal was waiting inside a separate box but were not told the identity of the animal, the majority of children in both age groups selected *both* snacks (3-year-olds: 5 of 24 children [21%] chose one snack; 4-year-olds: 5 of 25 children [20%] chose one snack), and there were no significant differences in children's choices between age groups (Fisher's exact test, $p = 1$, OR = .95). Children's choices in the Ambiguous Identity condition did not differ significantly between Experiment 1 and Experiment 2 (Fisher's exact test, $p = .174$, OR = .51).

Importantly, we observed significant differences in children's snack choices across the two conditions in both age groups; children in the Unambiguous Identity condition were significantly more likely to select only one snack than children in the Ambiguous Identity condition (3-year-olds: Fisher's exact test, $p = .009$, OR = .18; 4-year-olds: Fisher's exact test, $p < .001$, OR = .05).

Children's responses on the second test trial are shown in the supplementary material (first and second trial data did not differ significantly; see Fig. S2).

Discussion

In Experiment 2, we found that 3- and 4-year-olds, when tasked with preparing for two mutually exclusive possible identities, were able to do so successfully. These results are consistent with the results of Experiment 1 while ruling out a potential confounding factor from Experiment 1. In Experiment 2, only one animal was available to slide down the slide after the other animal was physically removed from the scene. Children again selected one snack significantly more often when they could infer the specific identity of the animal inside the slide (Unambiguous Identity condition) compared with children who did not know the specific identity of the animal inside the slide (Ambiguous Identity condition), who were more likely to select both snacks, accounting for both possible identities. We discuss the implications of the results of both experiments in the General Discussion.

General discussion

In two experiments, we asked whether U.S. 3- and 4-year-old children could represent mutually exclusive possible identities. Children were tasked with preparing "snack" for one of two possible animal characters that was going to slide down a single playground slide. Children could choose one or both of the snacks that corresponded to the animals' favorite foods. We found that when 3- and 4-year-old children were explicitly told the identity of the animal that would slide down the slide, they selected only one of the two possible snacks. However, when the identity of the animal was uncertain (i.e., children knew that one of the two animals would slide down the slide but did not know which one), children in both age groups were more likely to select *both* snacks, accounting for both possible identities. Our results suggest that both 3- and 4-year-old children were able to represent multiple mutually exclusive possible identities and could take the relevant actions to prepare for those possibilities.

[3] Interestingly, while children in Experiment 1′s Unambiguous Identity condition were nearly at ceiling in correctly selecting only a single snack and correctly selecting the particular animal's favorite snack, a subset of children in Experiment 2′s Unambiguous Identity condition selected two snacks and sometimes made errors with their choice of one snack at greater rates than in Experiment 1 ($p = .002$). Experiment 2′s Unambiguous Identity condition required children to infer the identity of the animal inside the slide by excluding the known identity of the animal inside the box. Reasoning by exclusion about object identities can be challenging for younger children (Cheng & Kibbe, 2024). We speculate that children who had more difficulty in reasoning by exclusion may have selected both snacks because they were uncertain about which animal was hidden inside the slide and wanted to cover both possibilities.

These results extend the literature on modal reasoning, which has largely focused on children's reasoning about possible object locations, to include reasoning about possible identities. Children encounter many scenarios in everyday life that may prompt them to think about mutually exclusive possible identities. A child with a new unopened pack of Pokémon cards knows that the cards inside the pack depict Pokémon with a range of possible specific identities, but the identities of the specific cards in the pack are unknown until the pack is opened and the cards are examined. A child at her birthday party may recognize that a wrapped present contains a LEGO set based on the box's size and shape, but whether she will get to build a castle or a spaceship or some other set is not known. In these example cases, specific identity is uncertain, but the possibility space is fairly well-defined and the possibilities are restricted by mutual exclusivity. We constructed a similar type of scenario in our experiments and found that 3- and 4-year-old children could represent mutually exclusive possible identities and could generate appropriate behavioral responses based on those representations. Our results suggest that young children's capacity for modal representation may include possible identity.

Previous research using physical-reasoning-demanding modal tasks often observed age differences, with 3-year-olds typically performing worse than 4-year-olds on tasks that require modal reasoning about multiple mutually exclusive possible locations of an object (Leahy, 2023, 2024; Leahy et al., 2022; Mody & Carey, 2016; Redshaw & Suddendorf, 2016; Redshaw et al., 2018; Suddendorf et al., 2017; Turan-Küçük & Kibbe, 2024). Our results suggest that the 3-year-old children in our sample showed some competence at representing mutually exclusive possibilities in a task where they needed to represent possible identities, as evidenced by the 3-year-olds selecting both snacks more often in the Ambiguous Identity conditions compared with the Unambiguous Identity conditions in both experiments. This result joins other recent work suggesting that younger children may be more competent at modal reasoning tasks than previously thought (Alderete & Xu, 2023; Turan-Küçük & Kibbe, 2024). We speculate that although younger children may have the *capacity* to represent mutually exclusive possibilities, they may require more scaffolding than older children to engage those representations.

One source of scaffolding in our task was the fact that children did not need to engage in physical reasoning about objects' trajectories and possible locations and did not need to coordinate motor actions to anticipate and engage with those possible locations (for related discussion on the cognitive demands of action planning, see Turan-Küçük & Kibbe, 2024; see also Phillips & Kratzer, 2024). Perhaps this explains why our findings contrast with a previous study by Robinson et al. (2006), who found that even 5- and 6-year-olds struggled with a task that required both representing possible identities and predicting multiple possible object trajectories. In our task, children needed to think about the possible identity of an animal in a single location with a single exit (requiring simultaneous representation of possible identities without extensive simulation of possible trajectories) and needed to place relevant objects in an area where an animal will appear. This may have made it easier for younger children to demonstrate their competence with representing possibility.

Another potential source of scaffolding for younger children in our task was the language used to describe the scenario to children. Children in the Ambiguous Identity conditions of Experiments 1 and 2 heard modal language—specifically the word *one* combined with the disjunction *or*—in our description of the task scenario (e.g., "*One* of them will slide down, but I don't know which *one, Bunny or Monkey*"). One advantage of physical-reasoning-heavy modal reasoning tasks is that they rely on children's intuitions that objects that are released will drop down (even if children's intuitions about those trajectories are not always accurate; e.g., Hood, 1995, 1998; Hood et al., 2006), and therefore these tasks can be deployed with less exposition about what the task requires. We attempted to reduce physical reasoning demands in our task, but in doing so we introduced language that could provide clues into the modal nature of the task. Younger children in particular may have benefitted from such modal language, allowing them to engage representations of possibility that might not necessarily have been spontaneously available to them. Whether these younger children would spontaneously represent mutually exclusive possible identities in the absence of such language is an open question that we plan to pursue in future studies.

On the other hand, some previous work has found that younger children sometimes are confused by disjunctive language—in some contexts, children (and adults) may interpret the disjunctive word

"or" as the conjunctive "and" (e.g., Singh et al., 2016; Tieu et al., 2016). For example, a young child who views a picture of a person holding an apple and hears the statement "The boy is holding an apple or a banana" may report that this statement is false (although it is logically true; Singh et al., 2016). If children in our task interpreted the word "or" as "and", they may have selected both snacks because they expected both animals to slide down the slide. We think that a conjunctive interpretation of "or" in our task is unlikely for several reasons. First, other work suggests that, given additional context, young children can and do show that they interpret "or" disjunctively and not conjunctively (Jasbi & Frank, 2021; Skordos et al., 2020). Second, children were explicitly told at the outset that only one animal could slide down the slide at once. Third, the sentence in which "or" was embedded did not require children to use implicature to interpret the meaning of the word "or"—children were explicitly told that the "or" statement refers to a single animal's identity: "*One* of them will slide down, but I don't know which *one, Bunny or Monkey*." In this context, interpretation of "or" as "and" would result in a pragmatically odd interpretation. Finally, the way that "or" was used in our task is common in children's natural language environments. For example, a child might be asked, "Do you want ice cream or cookies?" (to which it would be unnatural to reply "Yes!" as if the question was conjunctive, although we suspect a child might reply with "Both!"). Nevertheless, future work should aim to better understand how children think about mutually exclusive possible identities in tasks without modal language.

It is also worth noting that, although we did not find significant differences in task performance based on age, inspection of Fig. 2 and Fig. S2 suggests that 3-year-olds may have found our task a bit more challenging than 4-year-olds did. Developmental change in modal representational capacity could be one factor driving this (as suggested by Leahy and colleagues; e.g., Leahy & Carey, 2020), but development of other cognitive processes that are undergoing substantial change between 3 and 4 years of age, such as future-oriented thinking and planning (Atance et al., 2023; Atance & O'Neil, 2005; Blankenship & Kibbe, 2019, 2022; Prabhakar & Hudson, 2014), general language abilities (Conti-Ramsden & Durkin, 2012), and executive functions (e.g., Zelazo et al., 2003), could also drive developmental differences. Further work is needed to identify potential sources of developmental change driving children's performance on a variety of modal reasoning tasks, including tasks that require representation of possible identities.

Some have theorized that the capacity for thinking about possibilities may be a domain-general process that allows individuals to simultaneously represent conflicting representations as merely "possible," thereby allowing them to consider and prepare for such possibilities (e.g., Redshaw, 2014; Redshaw & Suddendorf, 2020; Suddendorf, 1999). Our study provides an additional developmental data point to this theorizing by showing that young children can represent possible identities in addition to possible object trajectories and locations. Future work is needed to examine the extent to which children in these tasks rely on a more general "metarepresentational" capacity to represent possibility across a range of different types of uncertain scenarios.

CRediT authorship contribution statement

Esra Nur Turan-Küçük: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Melissa M. Kibbe:** Writing – review & editing, Supervision, Resources, Methodology, Formal analysis, Conceptualization.

Data availability

Data are available at OSF, a link is included in the manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2024.106078.

References

Alderete, S., & Xu, F. (2023). Three-year-old children's reasoning about possibilities. *Cognition, 237*, 105472.

Atance, C. M., Ayson, G., & Martin-Ordas, G. (2023). Moving beyond "spoon" tasks: When do children autocue their episodic future thought? *Wiley Interdisciplinary Reviews: Cognitive Science, 14*(4), e1646.

Beck, S. R., Robinson, E. J., Carroll, D. J., & Apperly, I. A. (2006). Children's thinking about counterfactuals and future hypotheticals as possibilities. *Child Development, 77*(2), 413–426.

Blankenship, T. L., & Kibbe, M. M. (2019). Examining the limits of memory-guided planning in 3- and 4-year olds. *Cognitive Development, 52*, 100820.

Blankenship, T. L., & Kibbe, M. M. (2022). Two-year-olds use past memories to accomplish novel goals. *Journal of Experimental Child Psychology, 214*, 105286.

Carey, S., Leahy, B., Redshaw, J., & Suddendorf, T. (2020). Could it be so? The cognitive science of possibility. *Trends in Cognitive Sciences, 24*(1), 3–4.

Cheng, C., & Kibbe, M. M. (2024). Children's use of reasoning by exclusion to infer objects' identities in working memory. *Journal of Experimental Child Psychology, 237*, 105765.

Conti-Ramsden, G., & Durkin, K. (2012). Language development and assessment in the preschool period. *Neuropsychology Review, 22*, 384–401.

Gautam, S., Suddendorf, T., & Redshaw, J. (2021). When can young children reason about an exclusive disjunction? A follow up to Mody and Carey (2016). *Cognition, 207*, 104507.

Harris, P. L. (2022). Young children share imagined possibilities: Evidence for an early-emerging human competence. *Philosophical Transactions of the Royal Society B, 377*(1866), 20220022.

Hood, B. M. (1995). Gravity rules for 2- to 4-year olds? *Cognitive Development, 10*(4), 577–598.

Hood, B. M. (1998). Gravity does rule for falling events. *Developmental Science, 1*(1), 59–63.

Hood, B. M., Wilson, A., & Dyson, S. (2006). The effect of divided attention on inhibiting the gravity error. *Developmental Science, 9*(3), 303–308.

Jasbi, M., & Frank, M. C. (2021). Adults' and children's comprehension of linguistic disjunction. *Collabra Psychology, 7*(1), 27702.

Leahy, B. (2023). Don't you see the possibilities? Young preschoolers may lack possibility concepts. *Developmental Science, 26*(6), e13400.

Leahy, B. (2024). Many preschoolers do not distinguish the possible from the impossible in a marble-catching task. *Journal of Experimental Child Psychology, 238*, 105794.

Leahy, B. P., & Carey, S. E. (2020). The acquisition of modal concepts. *Trends in Cognitive Sciences, 24*(1), 65–78.

Leahy, B., Huemer, M., Steele, M., Alderete, S., & Carey, S. (2022). Minimal representations of possibility at age 3. *Proceedings of the National Academy of Sciences of the United States of America, 119*(52), e2207499119.

Mody, S., & Carey, S. (2016). The emergence of reasoning by the disjunctive syllogism in early childhood. *Cognition, 154*, 40–48.

Phillips, J. S., & Kratzer, A. (2024). Decomposing modal thought. *Psychological Review, 131*(4), 966–992.

Prabhakar, J., & Hudson, J. A. (2014). The development of future thinking: Young children's ability to construct event sequences to achieve future goals. *Journal of Experimental Child Psychology, 127*, 95–109.

Redshaw, J. (2014). Does metarepresentation make human mental time travel unique? *Wiley Interdisciplinary Reviews: Cognitive Science, 5*(5), 519–531.

Redshaw, J., & Ganea, P. A. (2022). Thinking about possibilities: Mechanisms, ontogeny, functions and phylogeny. *Philosophical Transactions of the Royal Society B, 377*(1866), 20210333.

Redshaw, J., Leamy, T., Pincus, P., & Suddendorf, T. (2018). Young children's capacity to imagine and prepare for certain and uncertain future outcomes. *PLoS One, 13*(9), e202606.

Redshaw, J., & Suddendorf, T. (2016). Children's and apes' preparatory responses to two mutually exclusive possibilities. *Current Biology, 26*(13), 1758–1762.

Redshaw, J., & Suddendorf, T. (2020). Temporal junctures in the mind. *Trends in Cognitive Sciences, 24*(1), 52–64.

Robinson, E. J., Rowley, M. G., Beck, S. R., Carroll, D. J., & Apperly, I. A. (2006). Children's sensitivity to their own relative ignorance: Handling of possibilities under epistemic and physical uncertainty. *Child Development, 77*(6), 1642–1655.

Singh, R., Wexler, K., Astle-Rahim, A., Kamawar, D., & Fox, D. (2016). Children interpret disjunction as conjunction: Consequences for theories of implicature and child development. *Natural Language Semantics, 24*(4), 305–352.

Skordos, D., Feiman, R., Bale, A., & Barner, D. (2020). Do children interpret "or" conjunctively? *Journal of Semantics, 37*(2), 247–267.

Suddendorf, T. (1999). The rise of the metamind. In M. Corballis & S. Lea (Eds.), *The descent of mind: Psychological perspectives on hominid evolution* (pp. 218–260). Oxford University Press.

Suddendorf, T. (2017). The emergence of episodic foresight and its consequences. *Child Development Perspectives, 11*(3), 191–195.

Suddendorf, T., Crimston, J., & Redshaw, J. (2017). Preparatory responses to socially determined, mutually exclusive possibilities in chimpanzees and children. *Biology Letters, 13*(6), 20170170.

Tieu, L., Romoli, J., Zhou, P., & Crain, S. (2016). Children's knowledge of free choice inferences and scalar implicatures. *Journal of semantics, 33*(2), 269–298.

Turan-Küçük, E. N., & Kibbe, M. M. (2024). Three-year-olds' ability to plan for mutually exclusive future possibilities is limited primarily by their representations of possible plans, not possible events. *Cognition, 244*, 105712.

Zelazo, P. D., Müller, U., Frye, D., Marcovitch, S., Argitis, G., Boseovski, J., Chiang, J. K., Hongwanishkul, D., Schuster, B. V., & Sutherland, A. (2003). The development of executive function in early childhood. *Monographs of the Society for Research in Child Development, 68*(3), vii–137.