



Preschoolers represent others' false beliefs about emotions

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ARTICLE INFO

Keywords:

False beliefs

Emotion

Theory of mind

ABSTRACT

The ability to track and explicitly report another person's beliefs about the world, even when those beliefs conflict with reality, is a milestone that children typically attain between the ages of 3 and 5 years. The majority of work investigating the development of false belief representation has probed children's ability to track beliefs about tangible entities, such as an object's location. However, false beliefs are not content specific. They can be about anything that can be represented, including entities that are not directly observable — like others' emotions. Across two experiments ($N = 160$), we tested 3- to 5-year-old children's ability to track a person's false beliefs about an object's location, versus about an agent's emotional state. Our findings reveal parallel developmental progression across the two content types. Our findings suggest that over the preschool years, young children likely come to represent false beliefs about any content that they themselves can represent.

1. Introduction

From early in life, we make sense of the world around us by thinking about what other people see, want, believe, and hope for. This ability to attribute mental states to others has often been referred to as a having a Theory of Mind (ToM), and is crucial for navigating social interactions, interpreting others' behavior, and cooperating towards common goals. A critical aspect of ToM is the understanding that what others believe (and what one believes oneself) does not necessarily reflect the true state of the world—that is, beliefs can be false. Recognizing that people sometimes act based on false beliefs is seen as a milestone in representing the mind as distinct from the world (Atance & O'Neill, 2004).

Much of what we know of children's false belief understanding has come from classic tasks that used either an unexpected location or an unexpected contents paradigm. In the explicit response version of the unexpected location paradigm, children hear about a character who puts an object in one location and then leaves (e.g., Sally puts her marble in a basket). Then another character moves the object to a new location (e.g., Anne moves the marble to a box). Finally the first character returns, at which point children are asked where she will look for her object (Baron-Cohen, Leslie, & Frith, 1985; Wimmer & Perner, 1983). Typically, 5-year-old children and some 4-year-old children answer correctly, saying that Sally will search in the basket, where she last saw the marble. In contrast, 3-year-olds answer that Sally will look in the box, where the marble really is. Subsequent studies that modified the Sally-Anne task to reduce verbal processing and eliminate the need for children to make explicit predictions have found success in younger children (Rubio-Fernández & Geurts, 2013; Setoh, Scott, & Baillargeon, 2016; Surian & Leslie, 1999), including in children as young as 15 months using a looking-time measure that captures infants' spontaneous responses (Onishi & Baillargeon, 2005; Scott, Baillargeon,

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Song, & Leslie, 2010). Similarly, in the explicit response version of the unexpected contents paradigm, children see a container that they predict will contain one type of item, and then are shown that it actually contains something else (e.g., children predict that a box will contain Smarties candies, but then see that it actually contains pencils). When asked what another person will think is in the Smarties box, 4- and 5-year-old children usually answer candies, whereas 3-year-olds answer pencils (Perner, Leekam, & Wimmer, 1987). As with the unexpected location task, younger children can succeed at the unexpected contents task when the task does not require an explicit prediction (Buttelmann, Over, Carpenter, & Tomasello, 2014; Moll, Khalulyan, & Moffett, 2017).

While the above two paradigms, and the methodological modifications that followed them, have been enormously productive in revealing how children think about beliefs, they are limited in the range of belief contents that they probe. This is because nearly all extant studies probing children's false beliefs—whether measuring explicit responses or more spontaneous behaviors—center on *objects*, with stories or events that involve someone's false belief about either an object's location or its identity. Yet, beliefs can be about anything that can be represented—beliefs about objects occupy only a small area in this large space. Indeed, reasoning about others' beliefs about aspects of the world that are harder to directly observe—like beliefs about what people are feeling—may be especially important to social development. For example, recognizing the possibility of false beliefs about emotions allows children to act brave when they actually feel scared, or to feign surprise despite knowing what was about to happen.

Surprisingly, very little of the ample ToM literature has focused on whether children can represent false beliefs about non-object contents like emotions, despite the fact that children are sensitive to emotions starting in infancy and can use emotions to guide their behaviors (Reschke, Walle, & Dukes, 2017; Sorce, Emde, Campos, & Klinnert, 1985; Reschke, Walle, Flom, & Guenther, 2017; Skerry & Spelke, 2014; see Ruba & Pollak, 2020; Walle, Reschke, & Knothe, 2017 for reviews). Comparing children's ability to represent false beliefs about objects versus emotions is especially interesting because any lag between the two may help to reveal what kinds of experience might contribute to false belief representation. On the one hand, representing false beliefs about objects might be easier, and/or appear earlier in development, because objects are ubiquitous in children's environments. The sheer number of object interactions children experience, and the fact that objects are often directly perceptually accessible, may support early reasoning about object beliefs (e.g., a child might see that a bottle is under the chair, and at the same time see her parent searching for the bottle on the table, offering an opportunity to represent the parent as having a false belief about the bottle's location). Evidence that false belief reasoning about objects might precede false belief reasoning about emotions comes from findings that children sometimes struggle to understand the link between what someone knows and what emotions they will feel (Ronfard & Harris, 2014); this raises the possibility that children may also have difficulty representing others' knowledge of or beliefs about emotions. Alternatively, representing false beliefs about objects might actually be harder than representing false beliefs about emotions, precisely because objects are directly perceivable whereas emotions are invisible to perception. Representing another's false belief about an object's location or identity might be challenging because of the need to override direct perceptual evidence (e.g., the bottle can easily be seen to be under the chair), such that, counterintuitively, representing false beliefs about non-visible entities like emotions might be easier. Finally, children might reason similarly about false beliefs about objects and emotions, as well as other types of mental content. The present work is designed to investigate these possibilities.

Some research has examined children's understanding of the emotional consequences of having a false belief—that is, whether children understand that emotions are tied to the experiencer's beliefs rather than to reality (Bradmetz & Schneider, 1999, 2004; Ronfard & Harris, 2014). This work has revealed that even infants view emotions as arising from beliefs: Scott and Baillargeon (2017) found that 20-month old infants expected an agent to express surprise when she learned that her belief was false. Additional work has asked when children can use a person's emotions to infer what that person knows or desires (Wu & Schulz, 2018; Wu, Haque, & Schulz, 2018). However, the question of whether children can represent false beliefs whose contents are emotions, and how this compares to false beliefs about objects, has only been addressed in a few studies. Gross and Harris (1988) found that 6-year-old children who heard about a character who felt sad but tried to hide their feelings knew that others would not perceive the character as sad; in contrast, 4-year-olds struggled to understand this discrepancy. However, children's ability to represent false beliefs about contents other than emotions was not probed. Davis (2001) compared 3- and 4-year-olds' ability to represent someone's false beliefs about object identity (they were shown that a crayon box actually contained candles, and then were asked what someone else would think was in the box), versus about emotions (they were shown a doll with one emotional expression, heard that the doll really felt the opposite, and then were asked how someone else would think the doll felt). Children performed similarly in the object and emotion versions of the task. However, this result is difficult to interpret, as children were at chance across both conditions (except for the 3-year-olds, who were below chance in the object false belief condition). Finally, Parker, MacDonald, and Miller (2007) tested older children's ability to represent false beliefs about physical facts (including object locations) and about people's emotional states, and found no significant difference across the two domains. But because this study tested older, 5- to 8-year-old children, past the age at which major developmental shifts in explicit false belief tasks are typically seen (Wellman, Cross, & Watson, 2001), it is still unclear whether there is any developmental lag in representing false beliefs about objects versus emotions.

Therefore, in the present study we targeted children ranging in age from 3- to 5-years, in order to capture the shift from failing to passing the traditional explicit false belief task (Wellman et al., 2001). Our aims were two-fold: we wanted to know whether these younger, preschool-aged children could represent false beliefs about emotions, and we wanted to compare this to their ability to represent false beliefs about objects. In Experiment 1, children were presented with two modified Sally-Anne stories using computer animated stimuli—one story involved a false belief about an object's location, and the other involved a false belief about a character's emotional state. We found that when children were asked about the story characters' beliefs, they exhibited the typical pattern of performance—systematic failure at 3 years, intermediate performance at 4 years, and success at 5 years—across both the object and the emotion domains. In Experiment 2 we replicated these effects using a more traditional puppet version of the Sally-Anne task, and with tighter experimental controls.

2. Experiment 1

2.1. Method

2.1.1. Participants

Eighty preschool-aged children participated: 20 3-year-olds ($M_{\text{age}} = 3.41$ years; $\text{range} = 3.02$ years to 3.80 years; 12 girls), 20 4- to 4.5-year-olds ($M_{\text{age}} = 4.28$; $\text{range} = 4.03$ years to 4.47 years; 8 girls), 20 4.5- to 5-year-olds ($M_{\text{age}} = 4.72$; $\text{range} = 4.51$ years to 4.99 years; 7 girls), and 20 5-year-olds ($M_{\text{age}} = 5.53$; $\text{range} = 5.01$ years to 5.95 years; 8 girls)¹ (here we will refer to the age group including 4- to 4.5-year-olds as the 4-year-old age group and the group including 4.5- to 5-year-olds as the 4.5-year-old age group). We decided before the study began to test children in these age bins in order to capture anticipated developmental change in explicit false belief reasoning, and we tested both younger and older 4-year-olds because previous research suggests that many children start to pass explicit false belief tasks between ages 4 and 5 (Baron-Cohen et al., 1985; Wimmer & Perner, 1983); therefore this broader sample of 4-year-olds afforded us the opportunity to identify age-related changes in performance. A power analysis using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) assuming a large effect size (.80) confirmed that these samples conferred adequate power to assess the performance of children in each age group ($N = 20$) on each type of false belief question to chance using a two-tailed binomial test (at alpha .05). The parents of 64 children identified them as White, 7 as Black, and 9 as Asian. Seven additional children were tested but their data were excluded due to failure to pass the comprehension checks (see below). All children received a small gift (e.g., shirt, book, toy, or \$5 Amazon gift card) to thank them for their participation.

2.1.2. Design and procedure

Children were presented with two animated stories on a laptop computer: an Object False Belief story and an Emotion False Belief story, with story order counterbalanced across children (Fig. 1). Each story lasted approximately two minutes. Children first were familiarized to the story characters. The experimenter pointed at each character as they appeared onscreen, introducing them by name (e.g., “That’s Paul, and that’s Sam.”). Children were then asked to point to each character (“Can you point to Paul? Can you point to Sam?”)². If children pointed incorrectly, the story was replayed and they were reintroduced to the characters.

In the Object False Belief story, which was modeled on previous stories involving false beliefs about the location of a hidden object (Baron-Cohen et al., 1985; Wimmer & Perner, 1983), children heard that the two characters, Paul and Sam, went to the park together. Paul brought his backpack with a baseball inside it so that he and Sam could play catch. The experimenter showed children the baseball field and explained that Paul and Sam were going to play in the middle of field because there was a big mud puddle on one side, and the friends did not want to get dirty. Children then saw Paul and Sam throwing and catching the ball several times. When they finished, Sam watched Paul put the baseball in his backpack, and then Paul and Sam said good-bye and Sam went home (and children watched as Sam disappeared off-screen). Next, as Paul turned to go home, the baseball fell out of his backpack. Paul saw the baseball roll into the mud puddle and disappear from view. At this point, the experimenter asked two comprehension check questions to ensure that children had understood the basic events in the story. To confirm that children understood that Sam did not see the ball fall out of the backpack and roll into the mud, the experimenter asked, “Did Sam see that happen?” (Perception Check). If children answered the Perception Check question incorrectly, they were reminded that that Sam had gone home and then were re-asked the question (“Remember, Sam went home. Did he see the ball roll into the mud?”). If children did not answer correctly after three attempts they were excluded from further analysis (one child). Children were permitted three attempts to answer the Perception Check question because it was the first question they were asked; as such, this question served as a sort of warm-up for children to understand the nature of the task. Next, to confirm that children understood that Paul, who saw the ball roll into the mud, had a true belief about the ball’s location, the experimenter asked, “Where does Paul think the ball is right now: in the mud or in the backpack?” (True Belief Check). To illustrate the options, an image of the mud puddle and an image of the backpack appeared and children were asked to point or verbally indicate their answer (e.g., “mud” or “backpack”). If children answered the True Belief Check incorrectly on the first attempt, they were excluded from the final analysis (five children). We reasoned that if children had not followed the story closely enough to understand the belief of the character who had seen the critical event of the ball rolling into the mud and who was currently visible onscreen, they could not be expected to reason about the false belief of the character who had not seen the critical event. Then, in the final portion of the story, children saw Sam open the door and enter his house. The experimenter said, “Remember, Sam went home. Where does Sam *think* the ball is right now? In the mud or in the backpack?” (Object False Belief Question). Children were asked to point to either the image of the mud puddle or the backpack, or to give a verbal answer.

The Emotion False Belief story was designed to match the Object False Belief story in length, complexity, and overall structure. Children heard about two characters, Sally and Anne, who went to the park to get ice cream from an ice cream truck. Children saw Sally and Anne approach the ice cream truck and get their ice cream cones, and were told that Sally and Anne were very happy to have their ice cream cones. Both characters were seen to be smiling so that it was clear they felt happy. Then Anne had to go home (and children watched as she disappeared off-screen). As Sally started to head home too, she dropped her ice cream. At this point Sally’s facial expression was hidden so that children had to infer how she felt. The experimenter then asked two comprehension check questions. To confirm that children understood that Anne did not see the ice cream fall into the grass, the experimenter asked, “Did Anne see that

¹ Twenty-seven of these children were tested online using Google Hangouts as a result of COVID-19 related campus closures.

² Children who were tested online could not point to demonstrate their understanding, so instead were asked which character was wearing a particular color shirt (“Who is wearing the red shirt, Paul or Sam? Who is wearing the blue shirt, Paul or Sam?”).

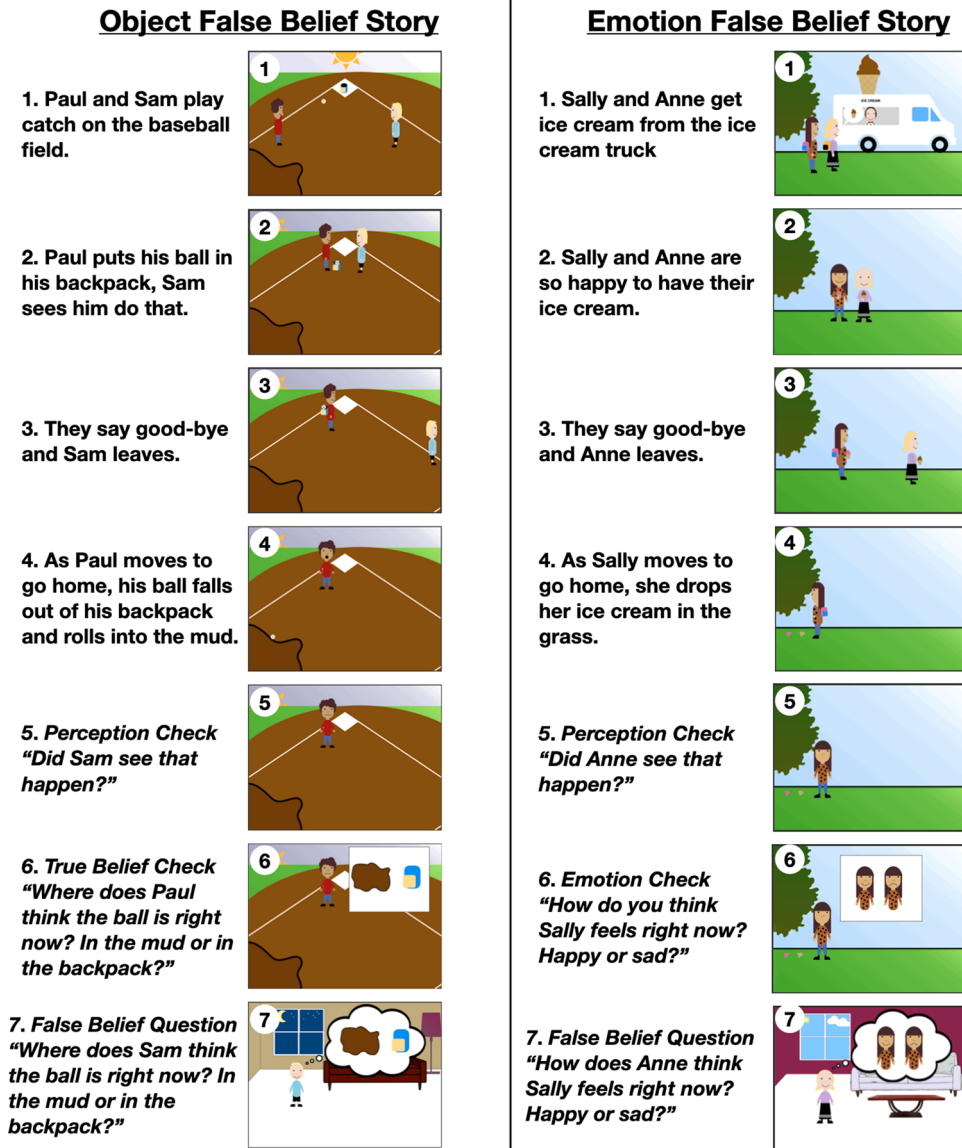


Fig. 1. Schematic of Experiment 1.

happen?" (Perception Check). If children answered incorrectly, they were reminded that Anne had gone home and then were re-asked the question ("Remember, Anne went home. Did she see the ice cream fall into the grass?"). If children did not answer correctly after three attempts they were excluded from further analysis (one child). To confirm that children understood how Sally actually felt after losing her ice cream, the experimenter asked, "How do you think Sally feels right now: happy or sad?" (Emotion Check). To illustrate the options, an image of Sally smiling and an image of Sally frowning appeared and children were asked to point or verbally answer (e. g., "happy" or "sad"). If children answered the Emotion Check incorrectly on the first attempt, they were excluded from the final analysis (two children, both of whom had also answered the True Belief Check incorrectly during the Object False Belief story). In the final portion of the story, children saw a smiling Anne open her door and enter her house. The experimenter said, "Remember, Anne went home. How does Anne *think* Sally feels right now: happy or sad?" (Emotion False Belief Question). Children were asked to point to either the image of Sally smiling or frowning or give a verbal answer. If children did not answer right away, the experimenter waited five seconds and then repeated the question. No children gave an answer other than one of the two prompted responses, or declined to answer.

False belief responses were scored as 1 if they correctly reflected the character's false belief, and 0 if they were incorrect—that is, if they reflected the true state of the world as described in the story. Responses were coded from video by the experimenter and an additional coder; agreement was 100 %.

2.2. Results

We used Generalized Estimating Equations (GEE) to analyze children's responses to the critical False Belief questions because our data consisted of repeated binary responses. The model included age in months as a continuous variable, as well as Story Type (Object or Emotion) and Story Order (Object or Emotion story first). The analysis revealed a significant main effect of age, $\beta = 1.75$, $SE = .59$, $\chi^2 [1, N = 160] = 8.77$, $p < .01$, 95 % CI [0.59, 2.92], with older children performing better overall. Critically, there was no effect of Story Type, $\beta = 0.67$, $SE = 2.11$, $\chi^2 [1, N = 160] = 0.10$, $p = .75$, $[-3.45, 4.80]$ —children performed similarly when asked to reason about a person's false belief regarding an object's location, and when asked to reason about a person's false belief about how someone else was feeling. There was no effect of Story Order, $\beta = -1.41$, $SE = 4.08$, $\chi^2 [1, N = 160] = 0.12$, $p = .73$, $[-9.42, 6.59]$, no interaction between Age and Story Order, $\beta = 0.26$, $SE = 0.90$, $\chi^2 [1, N = 160] = .08$, $p = .77$, $[-1.50, 2.02]$, and no interaction between Age and Story Type, $\beta = -0.27$, $SE = 0.46$, $\chi^2 [1, N = 160] = 0.34$, $p = .56$, $[-1.17, 0.63]$.

Given the significant effect of age, we also analyzed children's performance with age treated categorically, as in many previous studies (Fig. 2; see Wu & Schulz, 2018). A two-tailed binomial test revealed that on the Object False Belief question, 3- and 4-year-old children performed significantly below chance, answering in accord with reality rather than with the character's false belief (3-year-olds: 4/20 correct, $p = .01$; 95 % CI [0.06, 0.44]; 4-year-olds: 4/20 correct, $p = .01$, [0.06, 0.44]). The 4.5-year-old children performed at chance (12/20 correct, $p = .50$, [0.36, 0.81]), and 5-year-old children performed significantly better than chance (15/20 correct, $p = .04$, [0.51, 0.91]). Notably, this pattern replicates previous tasks probing children's reasoning about false beliefs concerning object location (Dalke, 1995; Wimmer & Perner, 1983). On the Emotion False Belief question, 3- and 4-year-old children performed significantly below chance (3-year-olds: 3/20 correct, $p < .01$, [0.03, 0.38]; 4-year-olds: 5/20 correct, $p = .04$, [0.09, 0.49]), whereas the 4.5- and 5-year-olds performed significantly better than chance (4.5-year-olds: 15/20 correct, $p = .04$, [0.51, 0.91]; 5-year-olds: 16/20 correct, $p = .01$, [0.56, 0.94]).

3. Experiment 2

Consistent with previous research on children's ToM (e.g., Liu, Wellman, Tardif, & Sabbagh, 2008; Wellman, 2014; Wellman et al., 2001), Experiment 1 found that children's ability to reason about another person's false beliefs improves with age, with children younger than 4 years systematically being misled by the true state of the world, children between 4 and 5 performing at or above chance, and children 5 years and older successfully reasoning about others' beliefs. Our results extend this work, showing that children's false belief reasoning develops similarly regardless of whether children are reasoning about others' beliefs about object locations, or about beliefs about other people's emotions.

However, there is at least one alternative interpretation of the older children's success in our Emotion False Belief story. In the final image of the Emotion story, the character whose belief children were asked about was seen to be smiling (Fig. 1). This leaves open the possibility that children used this visual evidence to answer the question, rather than representing Anne's belief about Sally's mental state (i.e., children could have reasoned that Anne is clearly smiling so Sally is probably smiling too). Therefore, in Experiment 2 we aimed to replicate the findings of Experiment 1 using a design that eliminated all perceptual cues to the characters' emotional states. Instead of animated stories, Experiment 2 used a live task with puppets (which had no visible facial expressions). The act-out nature of this method more closely mirrored the original Sally-Anne task (Baron-Cohen et al., 1985). An additional feature of Experiment 2 was the tighter match in structure across the Object and Emotion stories. Children heard two stories: one about two characters who baked cookies and one about two characters who made a paper airplane. For half the children the cookie story involved a false belief about an object's location and the paper airplane story involved a false belief about someone's emotion, and for half the children this pairing was reversed.

3.1. Method

3.1.1. Participants

Eighty preschool-aged children participated: 20 3-year-olds ($M_{\text{age}} = 3.51$ years; $\text{range} = 3.04$ years to 3.93 years; 10 girls), 20 4- to 4.5-year-olds ($M_{\text{age}} = 4.23$; $\text{range} = 4.05$ years to 4.47 years; 7 girls), 20 4.5- to 5-year-olds ($M_{\text{age}} = 4.73$; $\text{range} = 4.50$ years to 4.99 years; 12 girls), and 20 5-year-olds ($M_{\text{age}} = 5.44$ years; $\text{range} = 5.05$ years to 5.82 years; 10 girls)³. The parents of 64 children identified them as White, 6 as Black, and 10 as Asian. Five additional children were tested but their data were excluded from analysis due to failure to pass the comprehension checks (2) or because of experimenter error (3).

3.1.2. Design and procedure

As in Experiment 1, children were tested on an Object False Belief story and an Emotion False Belief story, with order counterbalanced across participants. Stories were acted out live using animal puppets and object props⁴ (Fig. 3). The puppets were Elephant, Tiger, Giraffe, and Monkey; which two participated in the Object False Belief story and which two participated in the Emotion False Belief story was counterbalanced across participants. The pronouns used for the puppets were gender-matched to each child.

Children sat at a small table across from the experimenter. In the Cookie False Belief story, the experimenter introduced children to

³ Seventeen children were tested online using Google Hangouts as a result of COVID related campus closures.

⁴ Children who were tested online watched a video of the puppet show, and then were asked questions by the experimenter.

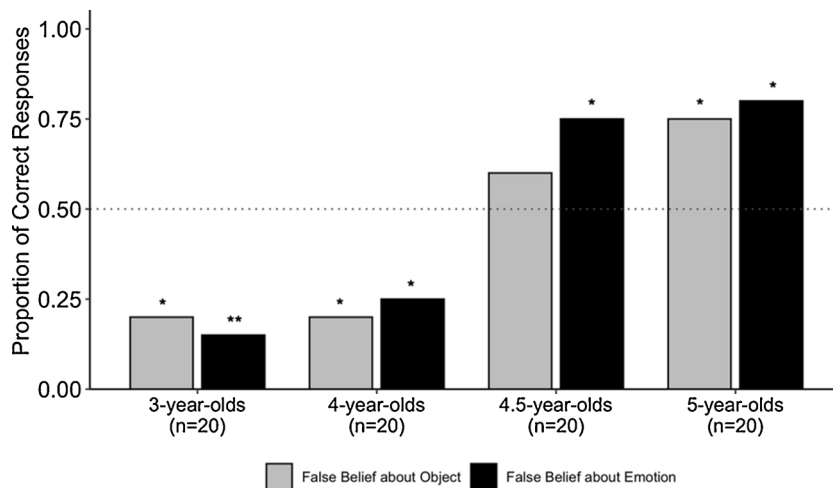


Fig. 2. Children's Performance on the False Belief Questions in Experiment 1.

Note. Dotted line indicates chance. * $p < .05$, ** $p < .01$.

two puppets (e.g., Elephant and Tiger), and told them that Elephant and Tiger decided to make some cookies because they love cookies. When their cookies were done baking, children saw Elephant put his cookie (a plastic toy cookie) into the cookie jar (a plastic container on the table), whereas Tiger took his cookie home—at this point children saw Tiger leave with his cookie and disappear under the table. Next the experimenter explained that while Tiger was gone, Elephant got hungry so he took his cookie out of the cookie jar so he could eat it. But as Elephant started to eat his cookie, he accidentally dropped it. Elephant picked up his fallen cookie and put it in the trashcan (a different container on the table). At this point the experimenter asked two comprehension check questions depending on condition: “Did Tiger see that happen?” (Perception Check) and either “Where does Elephant think the cookie is right now? In the cookie jar or in the trashcan?” (True Belief Check), or “How does Elephant feel right now? Happy or sad?” (Emotion Check). As in Experiment 1, if children failed the Perception Check they were reminded that that Tiger went home and were re-asked the question (up to three times). If children answered incorrectly on the third attempt they were excluded from analysis (one child). If children failed the True Belief Check or the Emotion Check on their first attempt, they also were excluded from analysis (one child). Finally, children saw Tiger return to the scene and were asked the critical question: either “Where does Tiger *think* Elephant’s cookie is right now? In the cookie jar or in the trash can?” (Object False Belief question) or “How does Tiger *think* Elephant feels right now? Happy or sad?” (Emotion False Belief question).

In the Paper Airplane False Belief story, the experimenter introduced children to two puppets (e.g., Giraffe and Monkey), and told them that Giraffe and Monkey were playing together and that Monkey made Giraffe a paper airplane because Giraffe loves paper airplanes. Children saw Giraffe put his airplane (a small pre-folded paper airplane) into his toybox (a plastic container on the table), because he wanted to play with it later. After observing this, Monkey had to go home—at this point children saw Monkey disappear under the table. Next the experimenter explained that while Monkey was gone, Giraffe wanted to play with his airplane, so he took it out of the toybox. But as he was playing with it, the airplane went too fast and crashed. Giraffe picked up his crushed airplane and put it in the recycling bin (a different container on the table). At this point the experimenter asked two comprehension check questions depending on condition: “Did Monkey see that happen?” (Perception Check) and either “Where does Giraffe think the airplane is right now? In the toybox or in the recycling bin?” (True Belief Check) or “How does Giraffe feel right now? Happy or sad?” (Emotion Check). Finally, children saw Monkey return and were asked the critical question: either “Where does Monkey *think* Giraffe’s airplane is right now? In the toybox or in the recycling bin?” (Object False Belief question) or “How does Tiger *think* Elephant feels right now? Happy or sad?” (Emotion False Belief question). If children were asked about an object’s location in the first story, they were asked about one of the puppet’s emotions in the second story.

3.2. Results

As in Experiment 1, we used GEE to examine children’s responses to the critical False Belief questions. The model included age as a continuous variable, as well as Story Type (Object or Emotion) and Story Order (Object or Emotion story first). This analysis revealed a significant main effect of age, $\beta = 1.47$, $SE = 0.58$, $\chi^2 [1, N = 160] = 6.40$, $p = .01$, 95 % CI [0.33, 2.61], with older children performing better overall. Critically, there was no effect of Story Type, $\beta = 1.93$, $SE = 1.71$, $\chi^2 [1, N = 160] = 1.58$, $p = .21$, [−5.52, 1.21]—as in Experiment 1, children performed similarly when asked to reason about an agent’s false belief regarding an object’s location versus a false belief about how someone was feeling. There was no effect of Story Order, $\beta = 1.93$, $SE = 3.39$, $\chi^2 [1, N = 160] = 0.32$, $p = .57$, [−4.72, 8.57], no interaction between Age and Story Order, $\beta = -0.49$, $SE = 0.74$, $\chi^2 [1, N = 160] = 0.44$, $p = .51$, [−1.95, 0.97], and no interaction between Age and Story Type, $\beta = 0.57$, $SE = 0.39$, $\chi^2 [1, N = 160] = 2.18$, $p = .14$, [−0.19, 1.33].

As in Experiment 1, we also analyzed children’s performance binned by age (Fig. 4). A two-tailed binomial test revealed that on the

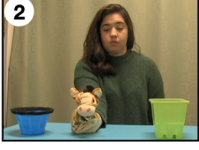
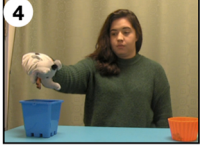
Cookie Story		Paper Airplane Story	
1. Elephant and Tiger make cookies. Elephant puts Elephant's cookie in the cookie jar.		1. Monkey makes Giraffe a paper airplane. Giraffe puts his/her new paper airplane in the toy box.	
2. Tiger goes home with Tiger's cookie.		2. Monkey goes home.	
3. Elephant takes his/her cookie out of the cookie jar, but drops it on the floor!		3. Giraffe takes the paper airplane out of the toybox to play with it, but it crashes and breaks!	
4. Elephant puts his/her cookie in the trashcan.		4. Giraffe puts the broken paper airplane in the recycling bin.	
5. Perception & True Belief Check "Did Tiger see that happen?" <u>Object Question</u> "Where does Elephant think their cookie is right now? In the cookie jar or in the trash can?" <u>Emotion Question</u> "How does Elephant feel right now? Happy or sad?"		5. Perception & True Belief Check "Did Monkey see that happen?" <u>Object Question</u> "Where does Giraffe think their paper airplane is right now? In the toybox or in the recycling bin?" <u>Emotion Question</u> How does Giraffe feel right now? Happy or sad?"	
6. False Belief Question <u>Object Question</u> "Where does Tiger think Elephant's cookie is right now? In the cookie jar or in the trash can?" <u>Emotion Question</u> "How does Tiger think Elephant feels right now? Happy or sad?"		6. False Belief Question <u>Object Question</u> "Where does Monkey think Giraffe's paper airplane is right now? In the toybox or in the recycling bin?" <u>Emotion Question</u> "How does Monkey think Giraffe feels right now? Happy or sad?"	

Fig. 3. Schematic of Experiment 2.

Note. Children were tested with two stories: one about a Cookie and one about a Paper Airplane. After one story children were asked about a puppet's false belief about an object's location, and after the other story they were asked about a puppet's false belief about another puppet's emotion. Which question was asked for which story was counterbalanced across children.

Object False Belief question, 3-year-old children performed significantly below chance (3-year-olds: 5/20 correct, $p = .04$, 95 % CI [0.09, 0.49], 4-year-old children performed at chance (4-year-olds: 7/20 correct, $p = .26$, [0.15, 0.59]), and 4.5- and 5-year-old children performed significantly better than chance (4.5-year-olds: 16/20 correct, $p = .01$, [0.56, 0.94]; 5-year-olds: 17/20 correct, $p = .003$, [0.62, 0.97]). A similar pattern was observed for the Emotion False Belief question. Three-year-old children performed significantly below chance (5/15 correct, $p = .04$, [0.09, 0.49]), 4- and 4.5-year-old children performed at chance (4-year-olds: 6/20 correct, $p = .12$, [0.12, 0.54]; 4.5-year-olds: 13/20 correct, $p = .26$, [0.41, 0.85]), and 5-year-old children performed better than chance (15/20 correct, $p = .04$, [0.52, 0.91]). These results replicate the key findings from Experiment 1: children's ability to represent

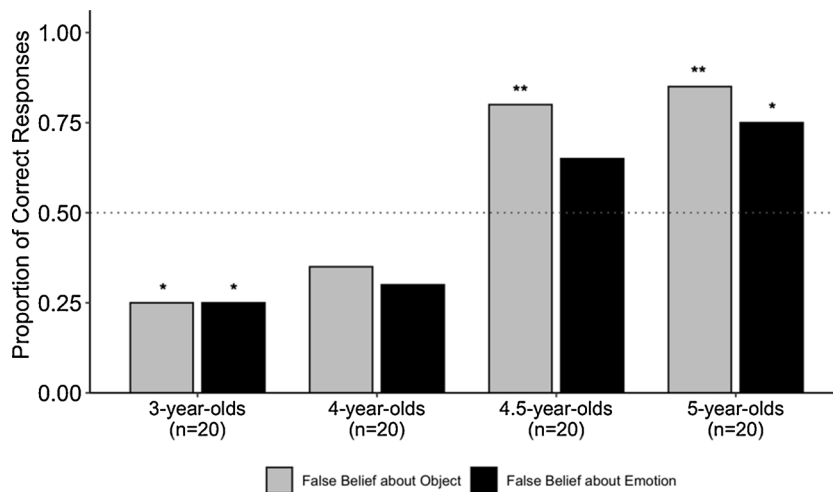


Fig. 4. Children's Performance on the False Belief Questions in Experiment 2.

Note. Dotted line indicates chance. * $p < .05$, ** $p < .01$.

false beliefs increased between the ages of 3 and 5 years, and children's ability to reason about another person's false beliefs about someone's emotions mirrored the ability to represent false beliefs about an object's location.

Experiments 1 and 2 revealed comparable performance when children were asked to reason about an agent's false beliefs regarding objects and regarding someone else's emotional state. Combining across the two experiments offers additional power for detecting any difference in children's false belief reasoning across the two domains. We used GEE to compare false belief performance across Experiments 1 and 2, including Experiment (Experiment 1 vs. Experiment 2), Age (as a continuous variable), Story Type (Object or Emotion), and Story Order (Object or Emotion story first). The GEE revealed no main effect of Experiment, $\beta = -1.41$, $SE = 3.82$, $\chi^2 [1, N = 320] = 0.14$, $p = .71$, 95 % CI $[-8.90, 6.07]$ – children performed similarly across the story-book and puppet-show versions of our false belief task. The model showed a main effect of Age, $\beta = 1.48$, $SE = 0.59$, $\chi^2 [1, N = 320] = 6.31$, $p = .01$, $[0.33, 2.64]$. There were no other main effects or interactions. Critically, there was no effect of Story Type, $\beta = -2.16$, $SE = 2.12$, $\chi^2 [1, N = 320] = 0.16$, $p = .31$, $[-6.31, 1.99]$, nor any interaction between Story Type and Age, $\beta = 0.57$, $SE = 0.48$, $\chi^2 [1, N = 320] = 1.46$, $p = .23$, $[-0.36, 1.51]$. Even with the larger sample of 160 children created by combining across our experiments, we saw no evidence that children's ability to

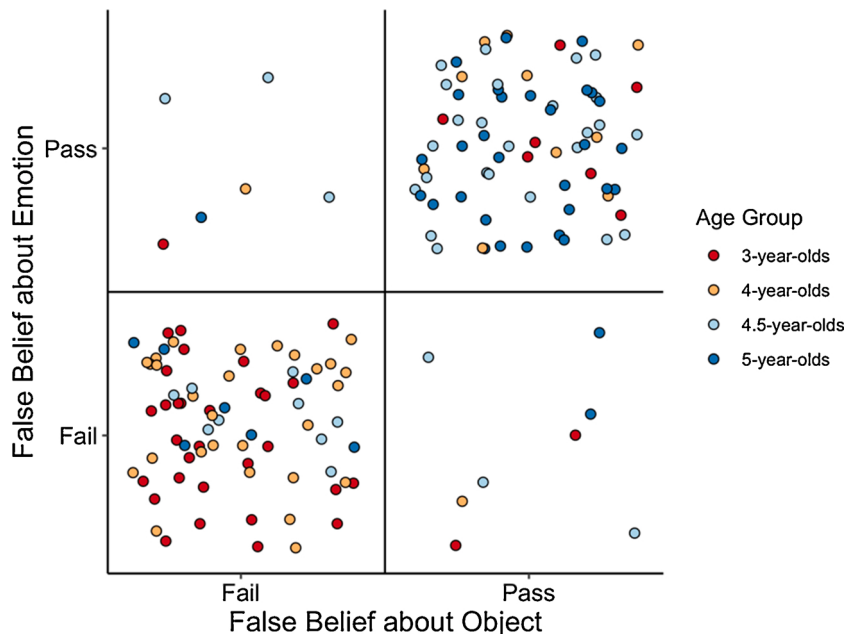


Fig. 5. Distribution of Pass-Fail Outcomes across Experiments 1 and 2.

Note. Each point in this figure represents an individual child. The points have been jittered for ease of reading and do not reflect any continuous measure.

Table 1
Pass-Fail Outcomes by Age and Experiment.

Experiment	3-year-olds						4-year-olds						4.5-year-olds						5-year-olds						All Ages					
	Pass			Fail			Pass			Fail			Pass			Fail			Pass			Fail			Pass			Fail		
	Both	Emotion Only	Pass Only	Both	Emotion Only	Pass Only	Both	Emotion Only	Pass Only	Both	Emotion Only	Pass Only	Both	Emotion Only	Pass Only	Both	Emotion Only	Pass Only	Both	Emotion Only	Pass Only	Both	Emotion Only	Pass Only	Both	Emotion Only	Pass Only	Both	Emotion Only	Pass Only
1	2	15	1	15	1	2	4	15	1	12	5	3	0	15	4	1	15	4	1	0	33	39	6	2	39	35	6	45	46	5
2	5	15	0	15	0	0	6	13	0	13	4	0	3	15	3	0	15	3	0	2	39	35	0	6	45	46	5	45	46	5
Combined	18 %	75 %	3 %	75 %	3 %	5 %	25 %	70 %	3 %	63 %	23 %	8 %	8 %	75 %	18 %	3 %	75 %	18 %	3 %	5 %	45 %	46 %	4 %	5 %	45 %	46 %	5 %	45 %	46 %	5 %
Percentage																														

reason about false beliefs regarding objects differed from their ability to reason about false beliefs regarding emotions.

If children reason similarly when thinking about false beliefs about objects and false beliefs about emotions, then individual children should perform similarly across the two question types. That is, children should either succeed at both types of false belief representation, or fail at both, but should be unlikely to succeed at one and fail at the other. To test this prediction, we split children into two groups: children who answered the Object False Belief question correctly and children who answered it incorrectly, and then conducted a two-tailed binomial test on children's responses to the Emotion False Belief question. The binomial test revealed that 90 % of children who passed the Object False Belief question also passed the Emotion False Belief question (72/80, $p < .001$, [0.81, 0.96]), whereas only 10 % of children who passed the Object False Belief question failed the Emotion False Belief question (8/80, $p < .001$, [0.04, 0.19]).

To further test the relationship between Object and Emotion False Belief question performance we analyzed the distribution of responses using a Phi-Coefficient test, which measures the strength of the relationship between two categorical variables with binary outcomes. We found that across both experiments and age groups, performance in the Object False Belief story was significantly related to performance in the Emotion False Belief story, $\Phi = .825$, $p < 0.001$. Seventy-two out of 160 children passed both the Object and Emotion False Belief Questions, 74 children failed both false belief question types, 6 children passed the Object False Belief question but failed the Emotion False Belief question, and 8 children passed the Emotion False Belief question but failed the Object False Belief question (Fig. 5). That is, 91 % of the children in our sample either passed both or failed both question types (see Table 1). These findings strongly suggest that children develop the capacity to explicitly track an agent's false belief about another agent's emotional state at the same time they develop the ability to explicitly track an agent's false belief about an object's location.

To further examine the age at which this ability emerges, we ran additional binomial tests collapsing across Story Type and Experiment, given that there were no main effects or interactions of either factor in any of our previous analyses. These revealed that 3- and 4-year-olds performed significantly below chance (3-year-olds: 17/80 correct, $p < .001$, 95 % CI [0.13, 0.32], 4-year-olds: 22/80 correct, $p < .001$, [0.18, 0.39]), whereas 4.5- and 5-year-olds performed significantly above chance (4.5-year-olds: 56/80 correct, $p < .001$, [0.59, 0.80], 5-year-olds: 63/80 correct, $p < .001$, [0.68, 0.87]), suggesting that successful explicit false belief tracking develops around 4.5 years of age.

4. General discussion

Our aim in the current experiments was to ask whether the ability to track an agent's false belief about another agent's emotional state develops at the same rate as the ability to track another agent's belief about an object's location. In Experiments 1 and 2 we found no difference between children's ability to track false beliefs about these two types of information. Younger children systematically failed at both, older children succeeded at both, and children between 4 and 5 years were at chance on both. This suggests that false belief tracking may be domain general, in that the representation of a false belief can include contents about observable states of the world (e.g., objects' locations and features) and about invisible mental states (e.g., emotions).

One criticism of tests of false belief tracking has been that success in the Sally-Anne task only requires children to remember where the object was located the last time Sally was present; they need not represent Sally's actual mental state (Butterfill & Apperly, 2013). Our task may be less susceptible to such an interpretation, because the false belief contents targeted in the emotion condition of Experiment 2 could not be readily observed. For example, children in Experiment 2 heard no mention of emotions until the Emotion check and critical False Belief questions. In order to succeed, children had to have represented what happened in the story, infer the emotional consequence of these events, and then inhibit their own beliefs regarding the true state of the character's emotions in order to report the other character's false belief. Thus, the finding that the older children in our sample understood that a character could have a false belief about someone else's emotions highlights their sophisticated mental reasoning.

An intriguing aspect of theory-of-mind research in the past several decades has been the dissociation between performance on explicit response tasks (like the ones we used here, and those by Wimmer & Perner, 1983 and many others) and implicit tasks that measure children's spontaneous responses using looking-times or patterns of brain activation as they track someone else's beliefs (e.g., Kampis, Parise, Csibra, & Kovács, 2015; Onishi & Baillargeon, 2005; Surian, Caldi, & Sperber, 2007). Whereas 3-year-old children systematically give the wrong response in explicit tasks (reporting that others will act in accord with reality, as opposed to their beliefs), much younger children show evidence of successfully tracking false beliefs in spontaneous response tasks (but see Powell, Hobbs, Bardis, Carey, & Saxe, 2018). The causes of this dissociation are still being debated. However, we hypothesize that any differences in children's reasoning about object-related false beliefs in implicit versus explicit tasks may also be seen for implicit tasks testing emotion-related false beliefs (perhaps as well as other types of content including quantities, and others' goals, dispositions, or preferences). Future work may test this prediction by measuring infants' spontaneous responses to false beliefs of varying kinds.

In addition, recent work has brought into question the claim that beliefs are the most basic kind of ToM representations. Phillips et al. (2020) argue that the ability to represent someone's knowledge is prior (in a developmental sense, as well as an evolutionary sense) to the ability to represent someone's beliefs. Understanding others' knowledge may be easier because it is impossible to have false knowledge (e.g., either you know an object is in the basket or you do not). The ability to attribute knowledge states to others appears early in development; by 6 months, infants can infer what an agent might reach for, given the agent's perceptual access (Luo & Johnson, 2009), and 10-month-old infants can use knowledge about what a third party saw, or was unable to see, when determining who they might later share with (Meristo & Surian, 2013). Given findings like these, it is possible that children younger than 4.5-year-olds could succeed in the emotion conditions of our task if we asked them, "Does Anne know how Sally is feeling right now? Why or why not?" rather than "How does Anne think Sally is feeling? Happy or sad?". More generally, previous empirical investigations of children's ability to represent others' knowledge are limited in the same way as investigations of their ability to represent others'

beliefs, in that they have focused on knowledge concerning concrete objects. Given the findings of Experiments 1 and 2 in the present work, we predict that children's ability to represent others' knowledge about objects and their ability to represent others' knowledge about other types of content (including what people are feeling) should track together over development.

In this vein, we also predict that manipulations that make ToM tasks harder should do so across various types of content. For example, most typically developing children pass explicit false belief tasks by 5 years of age when asked about first-order false beliefs (e.g., they can reason that Sally has a false belief about where an object is). But representing second-order false beliefs appears to be more challenging. Second-order false belief tasks require children to represent the belief that one character ascribes to another (e.g., reasoning that Anne falsely believes that Sally believes the ball is in the basket (when Sally actually believes the ball is in the box)). Perner and Wimmer (1985) found that children did not reliably pass second-order false belief tasks until around 7 years of age; subsequent work suggests that when the task is simplified, children as young as 5.5 years succeed (Sullivan, Zaitchik, & Tager-Flusberg, 1994). This is considerably closer to the age of robust success with explicit first order belief tasks, but still suggests some lag between first- and second-order belief reasoning. It may be tempting to conclude that representing false beliefs *about beliefs* is harder than representing false beliefs about object locations or emotions, and thus that children do not reason equally easily about all types of content. However, second-order false belief tasks are likely harder than first-order false belief tasks for other reasons. They involve longer, more complex stories, and, critically, require recursive embedding (representing a belief about a belief) (Sullivan et al., 1994). These increased information processing demands may be fully or partially responsible for the observed lag in passing first-versus second-order false belief tasks. Future work can test this by comparing children's ability to reason about second-order beliefs about objects versus second-order beliefs about emotions. If information-processing demands rather than content-specific differences are behind the developmental lag in second-order belief task performance, we should expect to see similar performance across these two types of content.

More broadly, the exploration of young children's emotion understanding and their understanding of non-social entities has historically proceeded rather separately. However, more recent work has encouraged the investigation of emotion representation through a wider cognitive lens, whereby the ability to reason about others' emotions is intertwined with children's thinking about many other aspects of the world (see Reschke, Walle, Dukes et al., 2017; Reschke, Walle, Flom et al., 2017; Wu, Schulz, Frank, & Gweon, *in press for reviews*). In the present experiments, children spontaneously represented where objects were and what various characters were feeling, as well as where people *believed* objects were and what people *believed* others were feeling, all without prior prompting to attend to any of these. It seems that young children very naturally integrate their understanding of objects' locations and states (a ball in the mud; a crumpled paper airplane) with others' beliefs about those objects (e.g., the false belief that the ball is in the backpack, or that the airplane is intact), and with the emotional consequences of those beliefs. Given that children use information about the physical state of the world to draw inferences about people's hidden emotions, and vice versa (as shown in work by others), it makes sense that belief reasoning about objects and emotions appears to develop in tandem.

In sum, our work provides additional insight into young children's ability to represent the mental states of others. Our findings suggest that children can track beliefs across domains by 4.5-years-old. Since the degree to which entities are directly observable did not influence children's ability to reason about their role in other people's beliefs, we suggest that children readily represent beliefs about any contents that they themselves can represent.

Data availability statement

The data that support the findings of this study are available upon request from the corresponding author.

Funding statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethics approval statement

This study was conducted with approval from the Johns Hopkins University Institutional Review Board (Approval #HIRB00009205, "Children's reasoning about emotions").

Declaration of Competing Interest

The authors declare no conflicts of interest.

Acknowledgements

We thank Xue Fang Deng and Isabel Rios-Pulgar for help with data collection and coding. We also thank Lindsey Powell for helpful discussion of results and analysis.

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