False-Belief Understanding in 2.5-Year-Olds:

Evidence from Violation-of-Expectation Change-of-Location and Unexpected-Contents Tasks

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Abstract

Until recently, it was generally assumed that the ability to attribute false beliefs did not emerge until about 4 years of age. However, recent reports using spontaneous- as opposed to elicited-response tasks have suggested that this ability may be present much earlier. To date, researchers have employed two kinds of spontaneous-response false-belief tasks: violation-of-expectation tasks have been used with infants in the second year of life, and anticipatory-looking tasks have been used with toddlers in the third year of life. In the present research, 2.5-year-old toddlers were tested in violation-of-expectation tasks involving a change-of-location situation (Experiment 1) and an unexpected-contents situation (Experiment 2). Results were positive with both situations, providing the first demonstrations of false-belief understanding in toddlers using violation-of-expectation tasks and, as such, pointing to a consistent and continuous picture of early false-belief understanding.

Our ability to make sense of others' actions depends largely on our ability to understand the mental states that underlie these actions. Critical to this understanding is the recognition that beliefs can conflict with reality. Thus, when a long-term friend looks for our cookie jar in the kitchen cupboard where it used to be stored, we readily realize that she is unaware that the jar is now kept in a different cupboard and contains flour; in other words, we attribute to our friend false beliefs about the jar's location and contents.

Until recently, it was generally assumed that the ability to attribute false beliefs to others did not emerge until about 4 years of age. The evidence for this conclusion came from elicited-response tasks, in which children are asked a direct question about an agent's false belief (e.g., Callaghan et al., 2005; Gopnik & Astington, 1988; Perner, Leekam, & Wimmer, 1987; Wellman & Bartsch, 1988; Wellman, Cross, & Watson, 2001; Wimmer & Perner, 1983). However, recent reports using spontaneous-response tasks suggest that the ability to attribute false beliefs is present much earlier (for a review, see Baillargeon, Scott, & He, in press). In these tasks, children's understanding of an agent's false belief is inferred from behaviors they spontaneously produce as they observe a scene unfold (just as adults watching a play may spontaneously produce responses that reveal their understanding of a character's mental states). Spontaneous-response tasks include violation-of-expectation (VOE) tasks and anticipatory-looking (AL) tasks. VOE tasks test whether children look reliably longer when agents act in a manner that is inconsistent, as opposed to consistent, with their false beliefs; AL tasks examine whether children visually anticipate where an agent with a false belief about the location of an object will search for the object. To date, VOE tasks have been used with infants in the second year of life (e.g., Onishi & Baillargeon, 2005; Scott & Baillargeon, 2009; Song & Baillargeon, 2008; Song, Onishi, Baillargeon, & Fisher, 2008; Surian, Caldi, & Sperber, 2007; Träuble, Marinovic, & Pauen, in press), whereas AL tasks have been used with toddlers in the third year of life (e.g., Clements & Perner, 1994; Garnham & Ruffman, 2001; Southgate, Senju, & Csibra, 2007).

Because different spontaneous-response tasks have been used with infants and toddlers, it remains uncertain whether the positive findings from these tasks point to a consistent and continuous picture of early false-belief understanding. Such a picture would certainly be undermined if infants were found to fail at AL tasks, or if toddlers were found to fail at VOE tasks. To address this issue, new research efforts are attempting to cross ages and tasks: just as infants are being tested with AL tasks (e.g., He & Baillargeon, 2009; Sodian, Neumann, & Thoermer, 2009), in the present research 2.5-year-old toddlers were tested with VOE tasks.

Initially, investigations of false-belief understanding in infants and toddlers focused primarily on false beliefs about location (in a typical change-of-location situation, an object hidden in one location is moved to a different hiding location in an agent's absence; e.g., Onishi & Baillargeon, 2005; Song et al., 2008; Southgate et al., 2007; Surian et al., 2007). However, recent reports have begun to explore other belief-inducing situations, in order to ascertain the breadth and robustness of early false-belief understanding. To date, these other belief-inducing situations have included false perceptions (misleading perceptual cues lead an agent to draw an erroneous conclusion about what type of object is present in a scene; Song & Baillargeon, 2008) and false beliefs about identity (misleading contextual cues lead an agent to draw an erroneous conclusion about what specific object token is present in a scene; Scott & Baillargeon, 2009). In line with these various efforts, Experiment 1 examined toddlers' ability to attribute to an agent a false belief about an object's location, whereas Experiment 2 focused on a different belief-inducing situation. Building on previous work with preschoolers (e.g., Gopnik & Astington, 1988; Perner et al., 1987), Experiment 2 examined toddlers' ability to attribute to an agent a false belief about an object's contents: in the situation used here, the contents of two familiar, commercially available packages were switched before the agent entered the scene. Because infants are generally unfamiliar with commercial packages, they cannot easily be tested with unexpected-contents situations; by focusing on toddlers, who usually recognize at least a few commercial packages, we could for the first time use an unexpected-contents situation in a spontaneous-response task.

We reasoned that positive findings in the present experiments would be important for several reasons. First, positive results in Experiments 1 and 2 would extend VOE findings with infants, would provide converging evidence for AL findings with toddlers, and as such would bolster claims of consistency and continuity in early false-belief understanding. Second, positive results in Experiment 2 would broaden the belief-inducing situations explored in spontaneous-response tasks to include unexpected-contents situations, thus supporting claims about the robustness of early false-belief understanding. Finally, evidence that toddlers succeed at VOE false-belief tasks would also be important for two methodological reasons: it would broaden the arsenal of experimental tools available for exploring the differences between spontaneous- and elicited-response false-belief tasks, and it would provide an alternative method for assessing false-belief understanding in atypical populations, such as late-signing deaf children and children with autism (e.g., Baron-Cohen, Leslie, & Frith, 1985; Peterson, Wellman, & Liu, 2005; Tager-Flusberg, 2005).

Experiment 1

Experiment 1 tested 2.5-year-olds' false-belief understanding in a VOE task involving a change-of-location situation. The children were assigned to a false-belief, a knowledge, or an ignorance condition. In the false-belief condition, an object was hidden in one of two locations in an agent's presence and then moved to the other location in her absence. In the knowledge condition, the agent was present when the object was moved to the other location. Finally, in the ignorance location, the object was hidden while the agent was absent from the scene.

The ignorance condition was included to address an alternative interpretation that has been offered for VOE change-of-location tasks. It has been suggested that young children might succeed at these tasks because they (1) recognize that the agent is ignorant about the object's current location and (2) bring to bear general expectations about how ignorant agents behave. This ignorance interpretation has two versions. According to the error version (e.g., Southgate et al., 2007; see also Ruffman, 1996; Saxe, 2005), children expect ignorance to lead to error: if an agent is absent when an object is moved from location-A to location-B, children expect the agent to search in the incorrect location, location-A, and they look reliably longer when the agent searches location-B instead. According to the uncertainty version (e.g., Wellman, in press), children expect ignorance to lead to uncertainty, rather than to error: they look reliably longer when an ignorant agent approaches location-B confidently, as opposed to tentatively, as would befit an ignorant agent. Scott and Baillargeon (2009) recently reported findings with 18-month-olds that provided evidence against both versions of the ignorance interpretation: when an agent mistakenly believed that her toy was hidden in location-A as opposed to location-B (false-belief condition), infants expected her to reach for location-A and were surprised if she reached for location-B; by contrast, when an agent did not know whether her toy was hidden in location-A or location-B (ignorance condition), infants looked about equally when she reached for either location. The fact that different results were obtained in the false-belief and ignorance conditions indicated that the infants in the false-belief condition were not surprised merely because the agent did not reach for the incorrect location (contradicting the error version) or reached confidently for the correct location (contradicting the uncertainty version). By including an ignorance condition in Experiment 1, we sought evidence that 2.5-year-olds also hold different expectations for mistaken and ignorant agents.

Design

All children in Experiment 1 received two familiarization trials and one test trial; each trial consisted of an initial and a final phase. The children in the false-belief condition received a left- and a right-container familiarization trial (see Fig. 1). During the initial phase of the left-container trial (which lasted about 40 s), an experimenter knelt at a window in the right wall of the apparatus (from the children's perspective); another experimenter, called the agent, sat at a window in the back wall, behind a green curtain. On the apparatus floor were two identical lidded containers and a toy frog. To start, the agent opened the curtain and then watched as the experimenter hid the toy in the left container. Next, the agent closed the curtain, and the experimenter counted aloud from 1 to 10. When the experimenter was done counting, the agent re-opened the curtain, and the experimenter asked her "Where is the toy?" During the final phase of the trial, the agent repeatedly said "Here it is!" while pointing to the left container. The right-container trial was identical except that the experimenter hid the toy in the right container and the agent pointed to the right container (the order of the two familiarization trials was counterbalanced). Next, the children received a test trial similar to the left-container familiarization trial except that the experimenter moved the toy to the right container while she counted (see Fig. 2). When asked where the toy was, the agent pointed either to the left container, where she had seen the agent hide the toy (<u>points-left trial</u>), or to the right container, where the toy was currently hidden (<u>points-right trial</u>).

The children in the <u>knowledge</u> condition received similar trials except that the agent moved the (open) curtain from one side of her window to the other, instead of opening and closing it. The agent thus remained present throughout the trials and therefore knew in the test trial that the experimenter had moved the toy to the right container.

Finally, the children in the <u>ignorance</u> condition received trials similar to those in the false-belief condition, with one exception: in the test trial, the experimenter hid the toy in the left container and then immediately took it out again. After the agent closed the curtain, the experimenter hid the toy in the right container as she counted.

Our reasoning was as follows. If the children (1) considered what information was available to the agent about the toy's location in the test trial and (2) expected the agent to act in accordance with this information (even when it differed from their own), then three distinct looking-patterns should be observed in the three conditions. In the false-belief condition, the children should expect the agent to point to the left container, where she falsely believed the toy was still hidden, and they should detect a violation when she pointed to the right container instead; the children who received the points-right trial should thus look reliably longer than those who received the points-left trial. In the knowledge condition, the children should expect the agent to point to the right container, where she knew the toy was now hidden, and they should detect a violation when she pointed to the left container instead; the children who received the points-left trial should thus look reliably longer than those who received the points-right trial. Finally, the children in the ignorance condition should have no expectation about which container the agent would choose, since she had no way of knowing where the experimenter had hidden the toy; the children should thus look about equally at the points-left and points-right trials.

Method

Participants

Participants were 54 English-speaking 2.5-year-olds, 28 male (ages 29 months, 5 days to 35 months, 15 days, M = 31 months, 14 days). Another 20 children were tested but excluded: 4 because they were upset (2), inattentive (1), or distracted (1), 3 because they looked over 2.5 standard deviations from the mean of their condition in the test trial, 2 because they looked for less than the minimum required in the test trial, and 11 because they looked for the maximum allowed in the test trial; of these 11 children, 6 were in the false-belief condition and 5 were in the knowledge condition. Eighteen children were randomly assigned to the false-belief (M = 31 months, 17 days), knowledge (M = 31 months, 6 days), and ignorance (M = 31 months, 19 days) condition.

Participants were recruited from purchased mailing lists and locally published birth announcements. Parents were offered reimbursement for their transportation expenses but were not compensated for their participation.

Apparatus

The apparatus consisted of a wooden display booth (127.5 cm high X 101 cm wide X 73.5 cm deep) mounted 76 cm above the floor of a brightly lit test room. The child sat on a parent's lap and faced a large opening (44 cm X 93.5 cm) in the front of the apparatus; between trials, a muslin-covered frame (61 cm X 99.5 cm) was lowered to hide this opening. The back and side walls of the apparatus were painted white; the floor extended 11.5 cm behind the back wall and was covered with granite-patterned contact paper.

The experimenter and agent (who both spoke during the trials) were native English-speakers. The experimenter wore a blue shirt and knelt at a window (56 cm X 47.5 cm) in the right wall of the apparatus; the agent wore a red shirt and sat at a window (60 X 101 cm) in the back wall. A green curtain hung from a rod mounted outside the back wall; the curtain was clipped to the rod by rings and could be drawn aside to reveal the agent. A green valance, mounted inside the apparatus above the window, concealed the rod and rings. A large muslin-covered screen behind the agent hid the test room.

Each container (6 cm X 14 cm in diameter) had a lid (2 cm X 14.5 cm in diameter) with a small wooden knob at its center; the containers and lids were covered with yellow contact paper and decorated with red and green dots. The toy was a stuffed green frog (3 cm X 15 cm X 15 cm at its largest points).

<u>Procedure</u>

Two naive observers monitored the child's looking behavior through peepholes in large cloth-covered frames on either side of the apparatus. Each observer depressed a button linked to a computer when the child looked at the events shown during a trial. Looking times during the initial and final phases of each trial were computed separately, using the primary observer's responses.

In each condition, about half the children received the left-container familiarization trial first, and half received the right-container familiarization trial first. The children were highly attentive during the initial phase of each trial: on average, they looked for 39.1/40 s in the left-container trial and for 39.0/40 s in the right-container trial. The final phase of each trial ended when the child (1) looked away for 2 consecutive seconds after having looked for at least 5 cumulative seconds or (2) looked for a maximum of 30 cumulative seconds. There were no reliable differences in the looking times of the children in the different conditions during the left- and right-container familiarization trials, all $ps > .88$.

In each condition, half the children received the points-left test trial, and half received the points-right test trial. The children were highly attentive during the initial phase of the test trial and looked for 39.0/40 s on average. The final phase of the trial ended when the child (1) looked away for 1.5 consecutive seconds after having looked for at least 9 cumulative seconds or (2) looked for a maximum of 60 cumulative seconds.

To assess interobserver agreement during the familiarization and test trials, the final phase of each trial was divided into 100-ms intervals, and the computer determined in each interval whether the two observers agreed that the infant was or was not looking at the event. Percent agreement was calculated for each trial by dividing the number of intervals in which the observers agreed by the total number of intervals in the trial. Agreement was measured for 52/54 toddlers (only one observer was present for the other 2 children) and averaged 97% per trial per toddler.

Preliminary analyses of the test data revealed no significant interaction of condition and trial with either sex or order of the left- and right-container familiarization trials; the data were therefore collapsed across sex and order in subsequent analyses.

Results and Discussion

The children's looking times during the final phase of the test trial (see Fig. 3) were analyzed by a 3 x 2 analysis of variance (ANOVA) with condition (false-belief, knowledge, or ignorance) and trial (points-left or points-right) as between-subjects factors. The only significant effect was the predicted condition x trial interaction, F (2, 48) = 6.52, $p < .005$. Planned comparisons indicated that, in the false-belief condition, the children who received the points-right trial (M = 35.4, SD = 16.8) looked reliably longer than those who received the points-left trial (M = 17.9, SD = 9.3), F (1, 48) = 7.96, $p < .01$; in the knowledge condition, the children who received the points-left trial (M = 34.6, SD = 13.1) looked reliably longer than those who received the points-right trial (M = 20.9, SD = 9.1), F (1, 48) = 4.93, $p < .05$; and in the ignorance condition, the children who received the points-left (M = 26.8, SD = 16.2) and points-right (M = 24.3, SD = 12.2) trials looked about equally, F (1, 48) = 0.16. Wilcoxon rank-sum tests confirmed the results of the false-belief (W_S = 55, $p < .05$), knowledge (W_S = 60, $p < .05$), and ignorance (W_S = 85, $p > .40$) conditions.

When the agent was asked where the toy was in the test trial, the children expected her (1) to point to the left container if she had not seen the experimenter move the toy and thus falsely believed it was still hidden in the left container (false-belief condition); (2) to point to the right container if she had seen the experimenter move the toy and thus knew it was now hidden in the right container (knowledge condition); and (3) to point to either container if she did not know in which container the experimenter had hidden the toy (ignorance condition). Together, these results suggest that 2.5-year-olds can attribute to an agent a false belief about an object's location.

The change-of-location results of Experiment 1 extend prior VOE results with infants (Onishi & Baillargeon, 2005; Scott & Baillargeon, 2009; Song & Baillargeon, 2008; Song et al., 2008; Surian et al., 2007; Träuble et al., in press), and provide converging evidence for prior AL results with toddlers (Southgate et al., 2007): together, these results suggest that toddlers not only anticipate that an agent who falsely believes that a toy is in a given location will search that location, but look reliably longer when the agent searches a different location instead. The present results also provide additional evidence against the suggestion that children succeed at VOE false-belief tasks by attributing ignorance rather than false beliefs to agents (Scott & Baillargeon, 2009). The distinct looking-patterns obtained in the false-belief and ignorance conditions of Experiment 1 make clear that 2.5-year-olds treat false belief and ignorance as distinct informational states (see also Southgate et al., 2007).

Experiment 2

Experiment 2 tested 2.5-year-olds' false-belief understanding in a VOE task involving an unexpected-contents situation. The children were assigned to a false-belief, a knowledge, or a reverse-false-belief condition. In the false-belief condition, an experimenter switched the contents of two familiar, commercially available packages, one containing cheerios and one containing crayons; next, an agent entered the scene, announced that she wanted to eat (eat group) or color (color group), and then reached for one of the packages. In the knowledge condition, the agent was present when the experimenter switched the contents of the packages. Finally, in the reverse-false-belief condition, the agent was again present when the contents of the packages were switched—but was absent when they were switched back.

The false-belief condition presented the children with an unexpected-contents situation, whereas the reverse-false-belief condition presented them with a change-of-location situation. This last condition not only served to confirm the results of the false-belief condition in Experiment 1, but also helped address a possible low-level interpretation of the false-belief condition in Experiment 2. If the children in this condition merely (1) recognized that the agent was ignorant about the packages' current contents and (2) expected her to reach for whichever package usually contained the items she wanted, then the children in the reverse-false-belief condition should respond in the same manner, because the agent was again ignorant about the packages' current contents. Finding opposite looking patterns in the false-belief and reverse-false-belief conditions of Experiment 2 would thus rule out the possibility that the toddlers in these conditions simply expected the agent to reach for the package that appeared to contain the items she wanted.

Design

The children in the false-belief condition (see Fig. 4) received one familiarization trial. The experimenter knelt at the right window, but the agent was absent: the green curtain filled the back window. On the apparatus floor, facing the child, were a box of crayons (Rose Art brand), on the left, and a box of cheerios (Cheerio brand), on the right (we established through piloting that these boxes were familiar to many 2.5-year-olds; the typical contents of the boxes were also displayed on the packages). In front of each box was a transparent plastic tray. During the initial phase of the trial (which lasted about 65 s), the experimenter switched the contents of the two boxes: first, she poured the contents of the cheerio box onto its tray and the contents of the crayon box onto its tray; next, she switched the two trays; finally, she placed the crayons into the cheerio box and poured the cheerios into the crayon box, closing each box as she went. During the final phase, the experimenter paused with her hands grasping the bottom of her window, and the children watched this paused scene until the trial ended. Next, the children received two test trials (see Fig. 5). The set-up at the start of each trial was similar to that in the familiarization trial. During the initial phase (which lasted about 18 s), the agent opened the green curtain and said "I want to eat. I'll get the cheerios." During the final phase, the agent repeatedly said "Here they are!" while pointing to the cheerio box (matching-box trial) or the crayon box (non-matching-box trial).[1] The order of the two test trials was counterbalanced. If the children realized that the agent was likely to falsely believe that the boxes held their usual contents, they should expect her to point to the cheerio box and they should detect a violation when she pointed to the crayon box instead. The children should thus look reliably longer during the non-matching- than the matching-box trial.

The children in the knowledge condition received similar trials except that the agent was present during the familiarization trial and thus was aware that the boxes' contents had been switched. The children should now expect the agent to point to the crayon box, and they should thus look reliably longer during the matching- than the non-matching-box trial.

Finally, the children in the reverse-false-belief condition received trials similar to those in the knowledge condition with one exception: the children received a second familiarization trial in which the agent was absent and the experimenter restored the boxes' original contents. Because the agent falsely believed that the crayon box held cheerios and the cheerio box held crayons, the children should expect her to point to the crayon box; thus, as in the knowledge condition, the children should look reliably longer during the matching- than the non-matching-box trial.

To strengthen the conclusions of Experiment 2, additional children were tested in the same three conditions except that the agent said "I want to color. I'll get the crayons." in the test trials before pointing to the crayon box (matching-box trial) or the cheerio box (non-matching-box trial). In contrast to the children in the eat group, those in the color group should expect the agent to point to the box she believed contained crayons.

Method

Participants

Participants were 48 English-speaking 2.5-year-olds, 25 male (ages 29 months, 11 days to 35 months, 5 days, M = 31 months, 21 days). Another 19 children were excluded, 5 because they were distracted (3), drowsy (1), or unwilling to continue (1), 3 because the difference in their looking times during the two test trials was over 2.5 standard deviations from the mean of their condition, 2 because of parental interference, and 9 because they looked for the maximum allowed in both test trials; of these 9 children, 2 were in the false-belief condition, 5 were in the knowledge condition, and 2 were in the reverse-false-belief condition. Sixteen children were randomly assigned to the false-belief (M = 32 months, 13 days), knowledge (M = 31 months, 20 days), and reverse-false-belief (M = 30 months, 29 days) conditions. Within each condition, 8 children were assigned to the eat group, and 8 to the color group.

Apparatus

The apparatus was the same as Experiment 1. Stimuli included two transparent plastic trays (2.5 cm X 13 cm X 13 cm); a crayon box (12.5 cm X 14.5 cm X 3.5 cm) containing 6 new crayons; and a cheerio box (14.5 X 8 X 3.5 cm) containing about 50 cheerios. The top of each box was hinged with tape, for easy opening.

Procedure

The children were highly attentive during the initial phase of the first familiarization trial: on average, they looked for 61.9/65 s (and for 61.2/65 s during the second familiarization trial, reverse-false-belief condition only). The criteria for ending each familiarization trial were the same as in Experiment 1. There were no reliable differences in the looking times of the children in the different conditions during the first familiarization trial, $p > .14$.

The children were also highly attentive during the initial phase of each test trial: on average, they looked for 17.7/18 s in the matching-box trial and for 17.6/18 s in the non-matching-box trial. The final phase of each trial ended when the child (1) looked away for 0.5 consecutive second after having looked for at least 7 cumulative seconds, or (2) looked for a maximum of 45 cumulative seconds.[2]

Interobserver agreement during the familiarization and test trials was measured for 47/48 toddlers (only one observer was present for the other child) and averaged 96% per trial per toddler. Preliminary analyses of the test data revealed no significant interaction of condition and trial with either sex or order of the test trials; the data were therefore collapsed across sex and order in subsequent analyses.

Results and Discussion

The children's looking times during the final phases of the two test trials (see Fig. 6) were analyzed by a 2 x 2 x 2 ANOVA with condition (false-belief, knowledge, or reverse-false-belief condition) and group (eat or color) as between-subject factors and trial (matching- or non-matching-box) as a within-subject factor. The analysis yielded only a significant main effect of trial, F (1, 42) = 5.35, p < .05, and a significant condition x trial interaction, F (2, 42) = 15.67, p <.0001. As predicted, the children in the false-belief condition looked reliably longer during the non-matching-box (M = 32.9, SD = 12.7) than the matching-box (M = 24.4, SD = 12.0) trial, F (1, 42) = 10.41, p < .0025; the children in the knowledge condition looked reliably longer during the matching-box (M = 33.3, SD = 12.2) than the non-matching-box (M = 24.4, SD = 13.6) trial, F (1, 42) = 11.30, p <.0025; and the children in the reverse-false-belief condition looked reliably longer during the matching-box (M = 34.7, SD = 10.4) than the non-matching-box (M = 24.4, SD = 11.6) trial, F (1, 42) = 14.97, p < .0005. Similar looking-patterns were obtained in the eat and color groups separately. Wilcoxon signed-rank tests confirmed the results of the false-belief (T = 17, p < .01), knowledge (T= 3, p < .001), and reverse-false-belief (T = 15.5, p < .01) conditions.

After the agent announced that she wanted to eat or color, the children expected her (1) to point to the matching box (cheerio box for the eat group, crayon box for the color group) if she had not observed the experimenter switch the boxes' contents and thus falsely assumed that each box held its typical contents (false-belief condition); (2) to point to the non-matching box if she had observed the switch and thus knew what the boxes contained (knowledge condition); and (3) to point to the non-matching box if she had observed the switch, was unaware that the experimenter had subsequently restored the boxes' contents, and thus falsely believed that the cheerio box held crayons and the crayon box cheerios. Together, these results provide evidence that 2.5-year-olds can attribute to an agent a false belief about objects' contents (false-belief condition) and location (reverse-false-belief condition).

The results of Experiment 2 provide converging evidence, with very different events, for the change-of-location results of Experiment 1, and extend demonstrations of early false-belief understanding to situations where an agent is unaware that a familiar, commercially purchased package holds something other than its usual contents. Beginning at about age 4, children succeed at elicited-response false-belief tasks involving change-of-location (e.g., Baron-Cohen et al., 1985; Wellman & Bartsch, 1988) and unexpected-contents (e.g., Gopnik & Astington, 1988; Perner et al., 1987) situations. The present evidence that 2.5-year-old toddlers succeed with the same situations in spontaneous-response tasks supports claims about the breadth and robustness of early false-belief understanding.

General Discussion

The present research provides evidence using VOE tasks that 2.5-year-olds can attribute false beliefs about the location and contents of objects to agents. These results extend prior VOE findings with infants (e.g., Onishi & Baillargeon, 2005; Scott & Baillargeon, 2009; Song & Baillargeon, 2008; Song et al., 2008; Surian et al., 2007) as well as prior AL findings with toddlers (e.g., Clements & Perner, 1994; Garnham & Ruffman, 2001; Southgate et al., 2007), and as such point to a consistent and continuous picture of early false-belief understanding.

Alternative interpretations

Could weaker interpretations be offered for the present results? Two of the alternative interpretations that have been offered for prior reports of early false-belief understanding assume that children attribute ignorance, rather than false beliefs, to agents; we refer to these interpretations as the ignorance and the behavioral-rule interpretation (for fuller discussion, see Baillargeon et al., in press).

The ignorance interpretation, discussed earlier, assumes that young children in VOE false-belief tasks (1) recognize that the agent is ignorant about some aspect of the scene and (2) bring to bear expectations (learned outside the laboratory) about how ignorant agents typically behave (e.g., Southgate et al., 2007; Wellman, in press). As noted earlier, Scott and Baillargeon (2009) recently provided evidence against the ignorance interpretation, and the present results support their findings: the children in the false-belief and ignorance conditions of Experiment 1 produced distinct looking patterns, indicating that they responded differently when the agent held a false belief or was merely ignorant about the toy's location. Together, these results indicate that young children distinguish between mistaken and ignorant agents: they expect mistaken agents to act in accordance with their false beliefs, and ignorant agents to act randomly (at least in the simple situations explored here).

The behavioral-rule interpretation assumes that young children in VOE and AL false-belief tasks (1) recognize that the agent is ignorant about some aspect of the scene and (2) bring to bear expectations or rules (learned outside the laboratory) about how agents typically behave in specific situations, such as when searching for objects (e.g., Perner & Ruffman, 2005; Ruffman & Perner, 2005). From this perspective, the present false-belief results could all be explained with two assumptions. First, children brought to the laboratory two rules: agents typically search for an object where they saw it disappear (rule-1) or where it is usually found (rule-2). Second, children had learned that, when the two rules give conflicting answers, rule-1 trumps rule-2. With these assumptions, one could explain the results of the false-belief condition in Experiment 1 and the reverse-false-belief condition in Experiment 2 (rule-1; toddlers expected the agent to search for the toy, cheerios, or crayons where she last saw them) as well as the results of the false-belief condition in Experiment 2 (rule-2; toddlers expected the agent to search for the cheerios or crayons where they are usually found).

There are, however, several problems with the behavioral-rule interpretation. One problem is that there is as yet no evidence that infants and toddlers learn ordered lists of behavioral rules such as that described above (e.g., Apperly & Butterfill, in press). Another problem is that, as more and more belief-inducing situations are examined, more and more behavioral rules must be posited to explain positive results, and the claim that infants and toddlers come to the laboratory equipped with the same extensive list of ordered rules becomes less and less plausible (e.g., Song & Baillargeon, 2008; Scott & Baillargeon, 2009). Finally, to test the behavioral-rule interpretation directly, researchers have begun to explore situations where infants expect an agent not to follow a behavioral rule because the agent has information—now outdated and hence false—that the rule does not apply in the situations. If the behavioral-rule interpretation must concede that infants sometimes expect agents to act on false information, it does not provide a viable alternative account of early false-belief findings (e.g., Scott, Baillargeon, Song, & Leslie, 2010).

Why are elicited-response false-belief tasks difficult for young children?

If young children can attribute false beliefs to agents, why do they fail at elicited-response tasks until about age 4? According to the response account (Baillargeon et al., in press; Scott & Baillargeon, 2009), elicited-response tasks involve at least three processes: a false-belief-representation process (as the scene unfolds, children must represent the agent's false belief); a response-selection process (when asked the test question, children must access their representation of the agent's false belief to select a response); and a response-inhibition process (when selecting a response, children must inhibit any prepotent tendency to answer the test question based on their own knowledge) (e.g., Birch & Bloom, 2003; Carlson & Moses, 2001; Hala, Hug, & Henderson, 2003; Kikuno, Mitchell, & Ziegler, 2007; Kovács, 2009; Leslie, German, & Polizzi, 2005; Moses, Carlson, & Sabbagh, 2005; Roth & Leslie, 1998). Spontaneous-response tasks, in contrast, involve only the false-belief-representation process. According to the response account, young children fail elicited-response tasks because simultaneously executing the false-belief-representation, response-selection, and response-inhibition processes overwhelms their limited resources, and/or because the neural connections between the brain regions that serve these different processes are still immature. Neuroscience findings suggest that (1) the right temporo-parietal junction plays an important role in the false-belief-representation process (e.g., Saxe & Wexler, 2005; Sommer et al., 2007); (2) regions of the anterior cingulate and prefrontal cortex play an important role in the response-selection process (e.g., Mueller et al., 2007;

Obhi & Haggard, 2004; Waszak et al., 2005); and (3) the connections between the frontal and temporal brain regions mature later and more slowly than other connections (e.g., Lebel et al., 2008). Thus, it could be that, in early childhood, the response-selection process has difficulty tapping the false-belief-representation process because the connections between the relevant brain regions are still slow and inefficient.

The response account makes a number of interesting predictions concerning young children's performance in various false-belief tasks. For example, one prediction is that young children should succeed at indirect-elicited-response tasks that require them to answer questions that do not directly tap their representation of an agent's false belief (e.g., Buttelmann, Carpenter, & Tomasello, 2009; Southgate, Chevallier, & Csibra, in press). Another prediction is that young children should succeed at elicited-response tasks when response-selection and response-inhibition demands are substantially reduced (e.g., Setoh, Scott, & Baillargeon, 2010). Yet another prediction is that young children should succeed at VOE tasks in which they observe an adult "participant" receive an elicited-response task. In a recent experiment with toddlers (e.g., Bolz, He, & Baillargeon, 2009), while a "participant" watched, an agent hid her toy in one of two containers and then left; next, an experimenter moved the toy to the other container and then asked the "participant" where the agent would look for her toy when she returned. The children looked reliably longer when the "participant" pointed to the toy's current location, rather than to its original location, suggesting that they expected the "participant" to understand that the agent would hold a false belief about her toy's location.

Apperly and Butterfill (in press) have recently proposed a very different account of the development of false-belief understanding. They suggest that humans may be equipped with two distinct mechanisms for reasoning about beliefs: one that emerges early and is efficient but inflexible (this mechanism would account for infants' and toddlers' success in spontaneous-response false-belief tasks), and one that emerges later, is dependent on the development of language and executive-function abilities, and is more flexible but also more demanding in terms of processing resources (this system would account for children's success, beginning at about age 4, in elicited-response false-belief tasks). Because the early system trades flexibility for efficiency, it is limited in important ways. Apperly and Butterfill speculated that some of these "signature limits" might include: limitations in the types of beliefs (including false beliefs) that can be attributed to agents; difficulties in understanding causal interactions among beliefs and other mental states; and an inability "to use all cognitively available facts to ascribe any belief that the subjects can themselves entertain" (pp. 38-39). However, the findings presented here as well as those reviewed in this article do not support the notion that early false-belief understanding suffers from these particular limitations. First, there is rapidly accumulating evidence that young children can attribute a variety of false beliefs to agents, including false beliefs about location (e.g., Buttelmann et al., 2009; Onishi & Baillargeon, 2005; Southgate et al., in press; Surian et al., 2007; Träuble et al., in press; Experiment 1), identity (Scott & Baillargeon, 2009), number (He & Baillargeon, 2008), properties (Scott et al., 2010), and contents (Experiment 2), as well as false perceptions (Song & Baillargeon, 2008). Second, in several of these experiments, children could succeed only by attributing to the agent a complex set of causally interrelated mental states including dispositions, goals, knowledge of specific facts about the scene (derived from what the agent could directly perceive and could infer based on previous trials), and multiple false beliefs (e.g., Song & Baillargeon, 2008; Scott & Baillargeon, 2009). Finally, the results of Experiment 2 suggest that toddlers are able "to use all cognitively available facts" when attributing false beliefs to others (see Scott et al., 2010, for similar evidence with 18-month-old infants). In the false-belief condition of Experiment 2, the children kept track of the fact that the agent was not present when the contents of the two boxes were switched, and they expected her to falsely assume that each package held its usual (or displayed) contents. In the reverse-false-belief condition, the children kept track of the fact that the agent was present when the contents of the packages were switched but was absent when they were restored, and they expected her to falsely believe that the contents of the two packages were switched. The children in Experiment 2 were thus capable of reasoning flexibly about the scenes they were shown, taking into account all of the relevant information available to them to attribute particular (and opposite) false beliefs to the agent.

Concluding remarks

The present findings indicate that 2.5-year-olds succeed at VOE false-belief tasks involving change-of-location and unexpected-content situations. These findings support prior VOE results with infants, provide converging evidence for prior AL results with toddlers, and extend the belief-inducing situations used in these tasks to include unexpected-contents situations. The present results thus give additional weight to claims about the continuity, breadth, and flexibility of early false-belief understanding.

Finally, the present results suggest new ways of investigating the differences between elicited- and spontaneous-response tasks (e.g., Bolz et al., 2009), and also provide an alternative method for assessing late-signing deaf children and children with autism, who often fail elicited-response false-belief tasks (e.g., Baron-Cohen et al., 1985; Peterson et al., 2005; Tager-Flusberg, 2005). Because VOE tasks have fewer extraneous components than elicited-response tasks, ascertaining whether or not these children perform better in these tasks would provide important information about their psychological-reasoning abilities.

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Footnotes

1. Readers may wonder why we used a between-subjects design in Experiment 1 (children received either the points-left or the points-right test trial) but a within-subject design in Experiment 2 (each child received both a matching-box and a non-matching-box test trial). When piloting Experiment 1, we began with a within-subject design; however, it immediately became clear that children showed the predicted pattern only in the first test trial, so a between-subjects design was adopted. To date, most spontaneous-response false-belief tasks have used a between-subjects design (Onishi & Baillargeon, 2005; Song & Baillargeon, 2008; Song et al., 2008; Southgate et al., 2007; Surian et al., 2007); two exceptions come from the tasks of Scott and Baillargeon (2009) and Träuble et al. (in press). Interestingly, in both of these tasks, the agent's goal was not simply that of retrieving a hidden object, but of doing something with that object. In Scott and Baillargeon, the agent faced two toy penguins that were identical except that one could come apart and one could not; in each familiarization trial, the agent hid a key in the penguin that came apart. In Träuble et al., the agent faced a balanced beam with a box at each end; in the familiarization trials, the agent placed a ball in one of the boxes and then moved the beam, causing the ball to roll into the other box. It may be that richer or more elaborate goals generally make it easier for children to keep track of agents' mental states and hence to repeatedly predict or interpret their actions across trials. The present research fit this analysis: in Experiment 1, where the agent simply sought a hidden toy, children showed the expected pattern in the first test trial only; by contrast, in Experiment 2, where the agent wanted to eat cheerios or to color with crayons, children showed the expected pattern in the first pair of test trials.

2. Readers may wonder why different criteria were used to end the test trials in Experiments 1 and 2. The computer program we use to conduct VOE experiments (which is available free of charge on R. Baillargeon's website) allows investigators to set, for each research project, the parameters that best capture children's responses. These

parameters are typically established during piloting and then used for data collection in the remainder of the project. Just as a whole host of factors can affect response parameters in visual-recognition tasks (e.g., Hunter & Ames, 1988; Hunter, Ames, & Koopman, 1983; Rose, Gottfried, Melloy-Carminar, & Bridger, 1982), many factors can affect response parameters in VOE tasks, including age, number of familiarization trials, similarity of the familiarization and test trials, complexity of the events shown in the test trials, and so on. Comparison of the criteria used to end trials in prior VOE false-belief tasks (Onishi & Baillargeon, 2005; Song & Baillargeon, 2008; Song et al., 2008; Surian et al., 2007; Träuble et al., in press) reveals that each project had its own, slightly different set of criteria. Of course, within any one project, conditions are run using the same criteria, so that conclusions are based on intra-project comparisons. Still, readers might wonder what would have happened if the same criteria had been used in Experiments 1 and 2. To address this question, we recoded the test looking times of the 54 toddlers in Experiment 1 using the (shorter) criteria from Experiment 2. As in the original ANOVA, the only significant effect was the condition x trial interaction, F (2, 48) = 3.77, $p < .05$. Planned comparisons again indicated that, in the false-belief condition, the children who received the points-right trial (M = 24.0, SD = 12.6) looked reliably longer than those who received the points-left trial (M = 14.1, SD = 5.1), F (1, 48) = 4.34, $p < .05$; and in the ignorance condition, the children who received the points-right (M = 18.4, SD = 7.8) and points-left (M = 22.5, SD = 13.0) trials looked about equally, F (1, 48) = 0.73. The only difference involved the knowledge condition: although the children who received the points-left trial (M = 24.2, SD = 11.5) still looked longer than those who received the points-right trial (M = 16.7, SD = 7.8), this difference was no longer significant, F (1, 48) = 2.50, p = .12. It may be that, because the familiarization and test trials in the knowledge condition were highly similar (the agent always knew where the toy was hidden), the children tended to be somewhat less attentive in the test trial; thus, ending the trial when the children looked away for 1.5 s (as we originally did in Experiment 1), as opposed to 0.5 s (as we did when we used the criteria from Experiment 2), may have allowed the children to reconsider what they had seen—to look back at the scene and examine more closely whether the agent was searching for the toy in the correct location.

Figure Captions

Figure 1: Schematic drawing of the familiarization trials in Experiment 1. False-belief and ignorance conditions. During the (40-s) initial phase of the left-container familiarization trial in the false-belief and ignorance conditions, the agent (in the back window) first slid open the green curtain filling her window, and then the experimenter (in the right window) said "Watch!" and hid the toy frog in the left container. Next, the agent closed the green curtain, and the experimenter counted aloud to 10. The agent then returned and the experimenter asked "Where is the toy?". During the final phase of the trial, the agent first said "Here it is!" while pointing to the left container (1 s) and then tapped the knob on the container's lid 4 times (4 s); this 5-s sequence was repeated until the trial ended. In the right-container familiarization trial, the experimenter hid the toy in the right container and the agent pointed to the right container. Knowledge condition. The agent remained present throughout the knowledge condition familiarization trials: instead of opening and closing the green curtain, she moved the open curtain from one side of her window to the other.

Figure 2: Schematic drawing of the test trials in Experiment 1. False-belief condition. The points-left test trial in the false-belief condition was identical to the left-container familiarization trial in the same condition, except that the experimenter moved the toy to the right container while she counted aloud. In the points-right test trial, the agent pointed to the right container in the final phase of the trial. Knowledge condition. The agent remained present throughout the knowledge condition test trials: instead of opening and closing the green curtain, she moved the open curtain from one side of her window to the other. Ignorance condition. The ignorance condition test trials were identical to those in the false-belief condition with one exception: in each test trial, after placing the toy into the left container; the experimenter immediately took it out again. After the agent closed the green curtain, the experimenter hid the toy in the right container while she counted aloud.

Figure 3: Mean looking times of the children in the false-belief, knowledge, and ignorance conditions of Experiment 1

during the final phase of the points-left or points-right test trial. Error bars represent standard errors, and asterisks indicate significant differences (p < .05 or better).

Figure 4: Schematic drawing of the set-up for the familiarization trials of Experiment 2. False-belief condition. At the start of the false-belief condition familiarization trial, only the experimenter was present (the green curtain was closed). On the apparatus floor were a crayon box (containing six crayons) and a cheerio box (containing about 50 cheerios); in front of each box was a transparent tray. During the (65-s) initial phase of the trial, the experimenter emptied the cheerio box into its tray, emptied the crayon box into its tray, switched the two trays, placed the crayons inside the cheerio box, and finally poured the cheerios into the crayon box. During the final phase of the trial, the experimenter paused as shown until the trial ended. Knowledge condition. In the knowledge condition familiarization trial, the agent was present (the green curtain was open) throughout the trial. Reverse-false-belief condition. The infants in the reverse-false-belief condition received two familiarization trials. The first was identical to that in the knowledge condition; in the second, the agent was absent (the green curtain was closed), and the experimenter repeated the actions she had performed before and thus effectively restored the boxes' original contents.

Figure 5: Schematic drawing of the test trials in Experiment 2. Eat group. During the (18-s) initial phase of the matching-box trial, the agent opened the green curtain and said "I want to eat. I'll get the Cheerios." while looking at a neutral mark on the apparatus floor between the two trays. During the final phase of the trial, the agent first said "Here they are!" while pointing to the cheerio box (1 s) and then tapped the top of the box 4 times (4 s); this 5-s sequence was repeated until the trial ended. In the non-matching box trial, the agent pointed to the crayon box. Color group. The color group test trials were identical except that the agent said "I want to color. I'll get the crayons." and pointed to the crayon box in the matching-box trial and to the cheerio box in the non-matching-box trial.

Figure 6: Mean looking times of the children in the false-belief, knowledge, and reverse-false-belief conditions of

Experiment 2 during the final phase of the matching- and non-matching-box test trials. Error bars represent standard errors, and asterisks indicate significant differences ($p < .05$ or better).

Figure 1

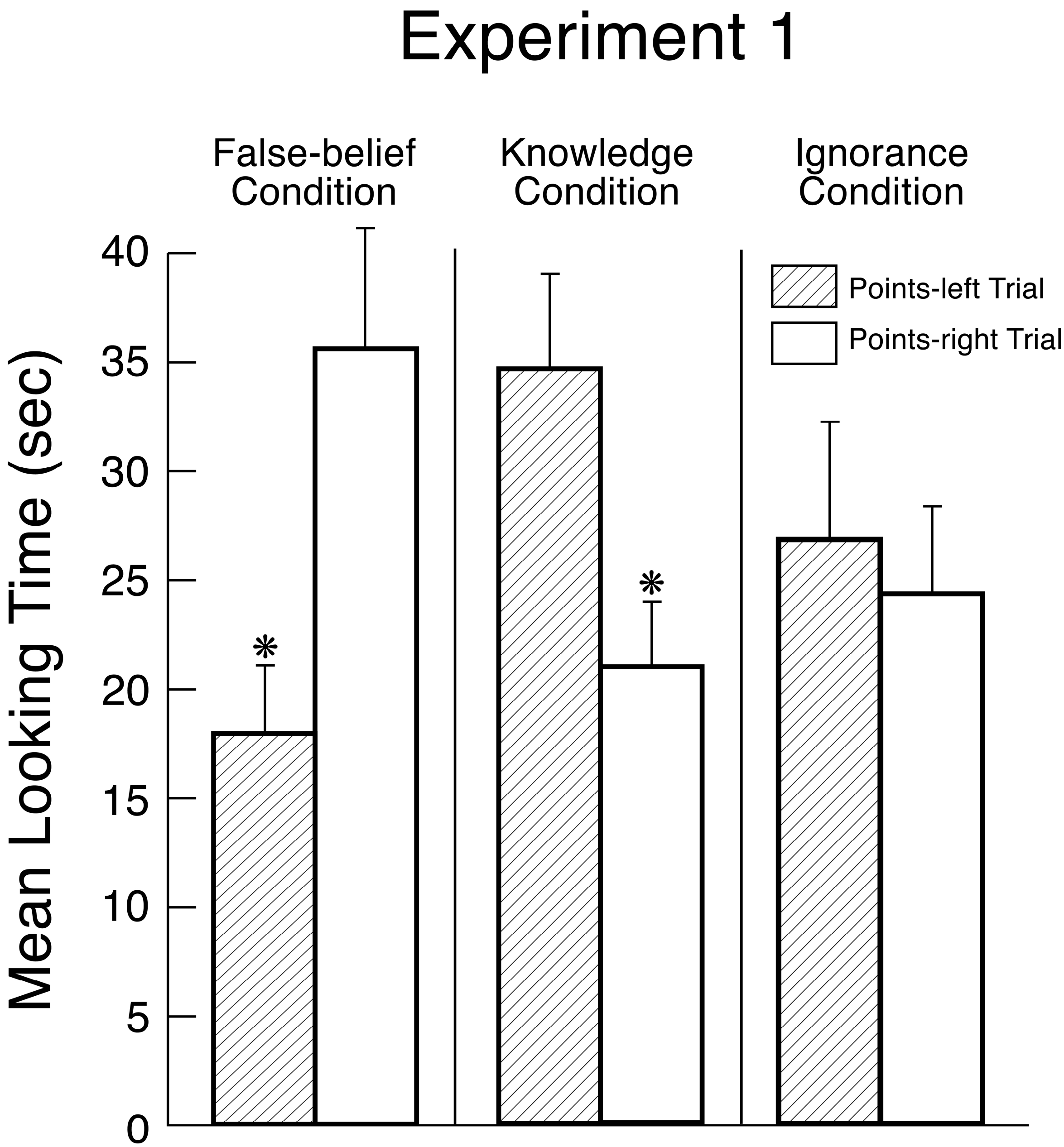

Experiment 1
False-belief Condition
Knowledge Condition
Ignorance Condition
Mean Looking Time (sec)
40
35
30
25
20
15
10
5
0
Points-left Trial
Points-right Trial
*
*

Figure 2

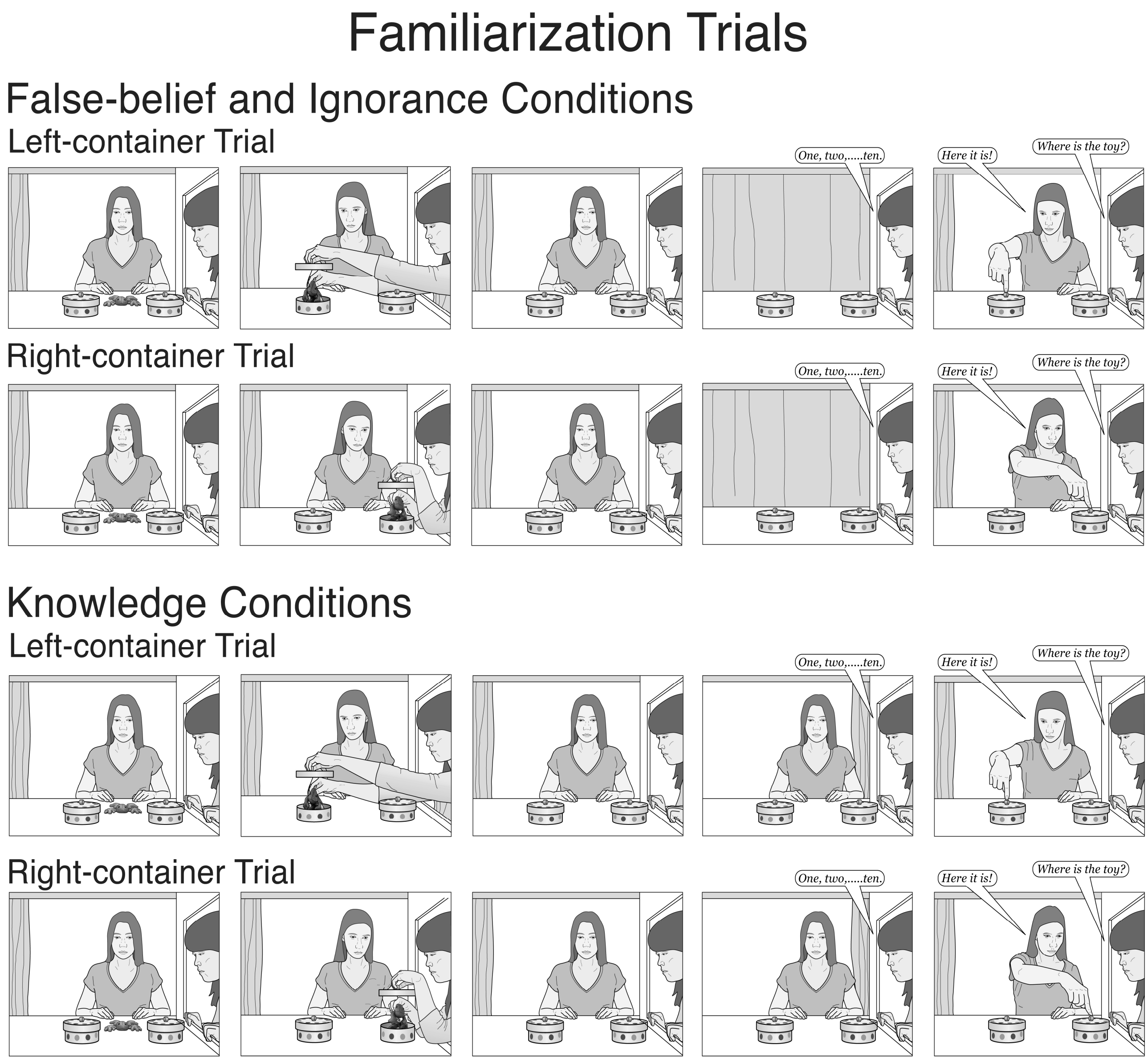

Familiarization Trials
False-belief and Ignorance Conditions
Left-container Trial
One, two,.....ten.
Here it is!
Where is the toy?
Right-container Trial
One, two,.....ten.
Here it is!
Where is the toy?
Knowledge Conditions
Left-container Trial
One, two,.....ten.
Here it is!
Where is the toy?
Right-container Trial
One, two,.....ten.
Here it is!
Where is the toy?

Figure 3


Test Trials
False-belief Condition
Points-left Trial
One, two,.....ten.
Here it is!
Where is the toy?
Points-right Trial
One, two,.....ten.
Here it is!
Where is the toy?
Knowledge Condition
Points-left Trial
One, two,.....ten.
Here it is!
Where is the toy?
Points-right Trial
One, two,.....ten.
Here it is!
Where is the toy?
Ignorance Condition
Points-left Trial
One, two,.....ten.
Here it is!
Where is the toy?
Points-right Trial
One, two,.....ten.
Here it is!
Where is the toy?

Figure 4

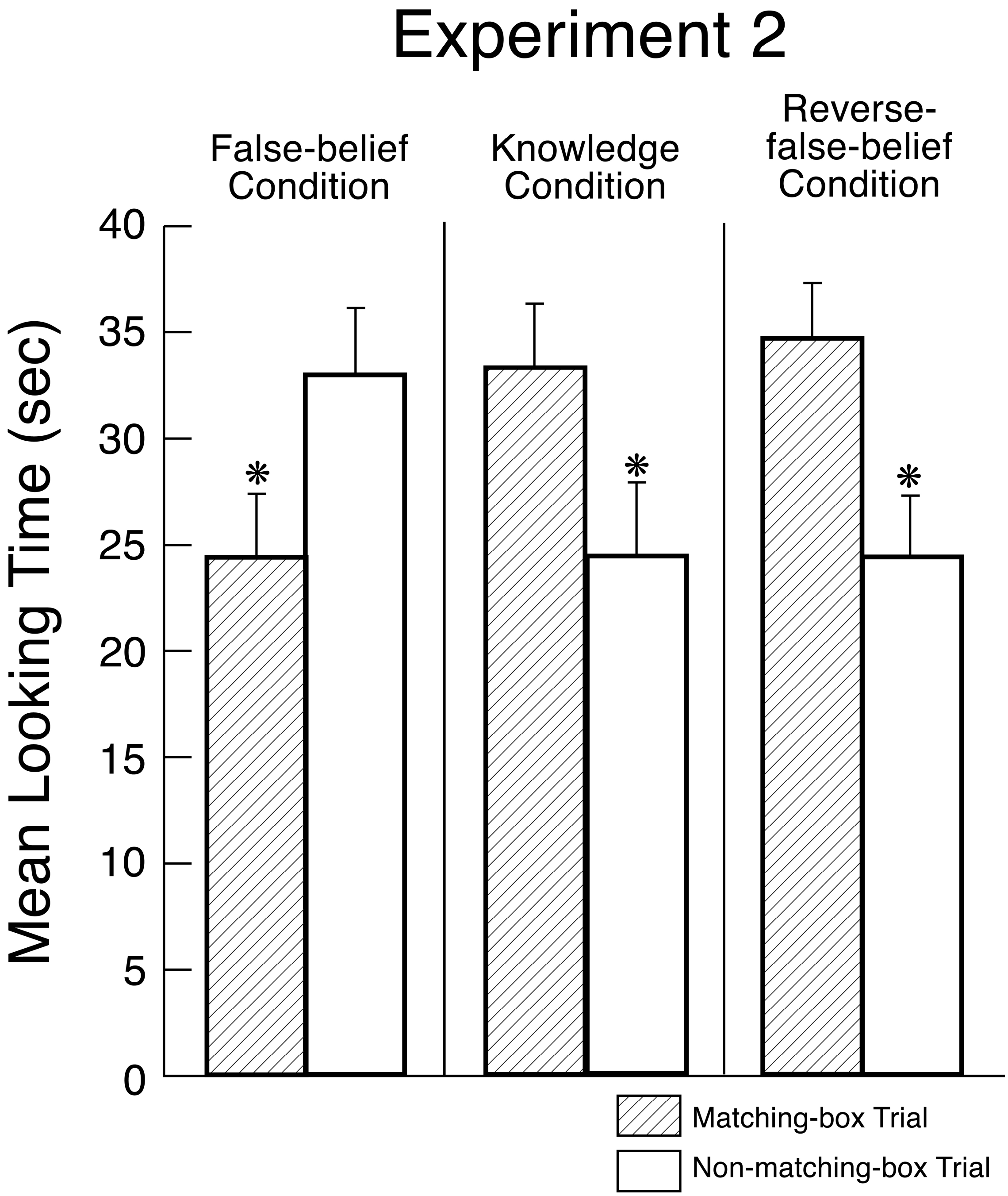

Experiment 2
False-belief Condition
Knowledge Condition
Reverse-false-belief Condition
Mean Looking Time (sec)
40
35
30
25
20
15
10
5
0
*
*
*
Matching-box Trial
Non-matching-box Trial

Figure 5

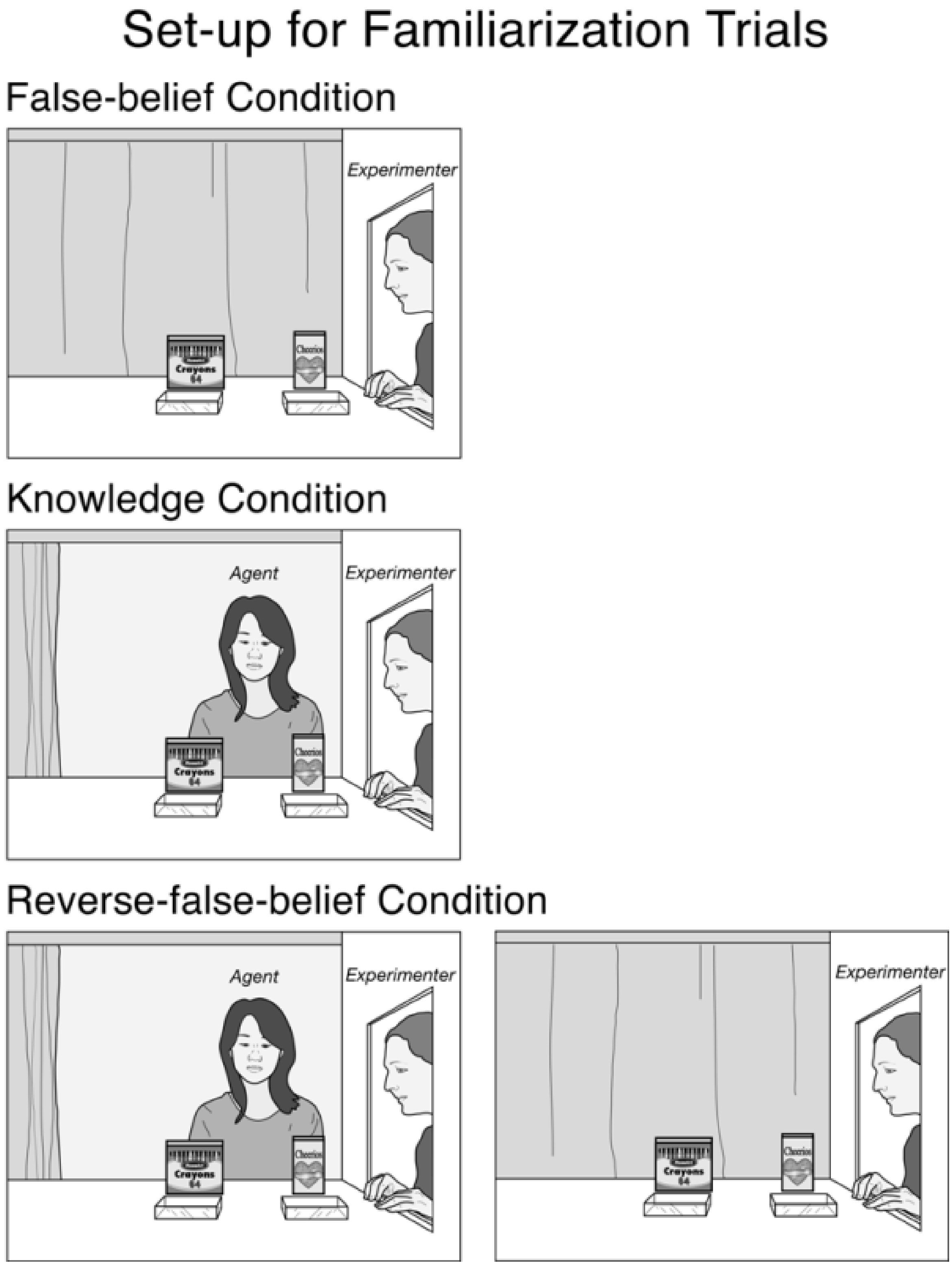
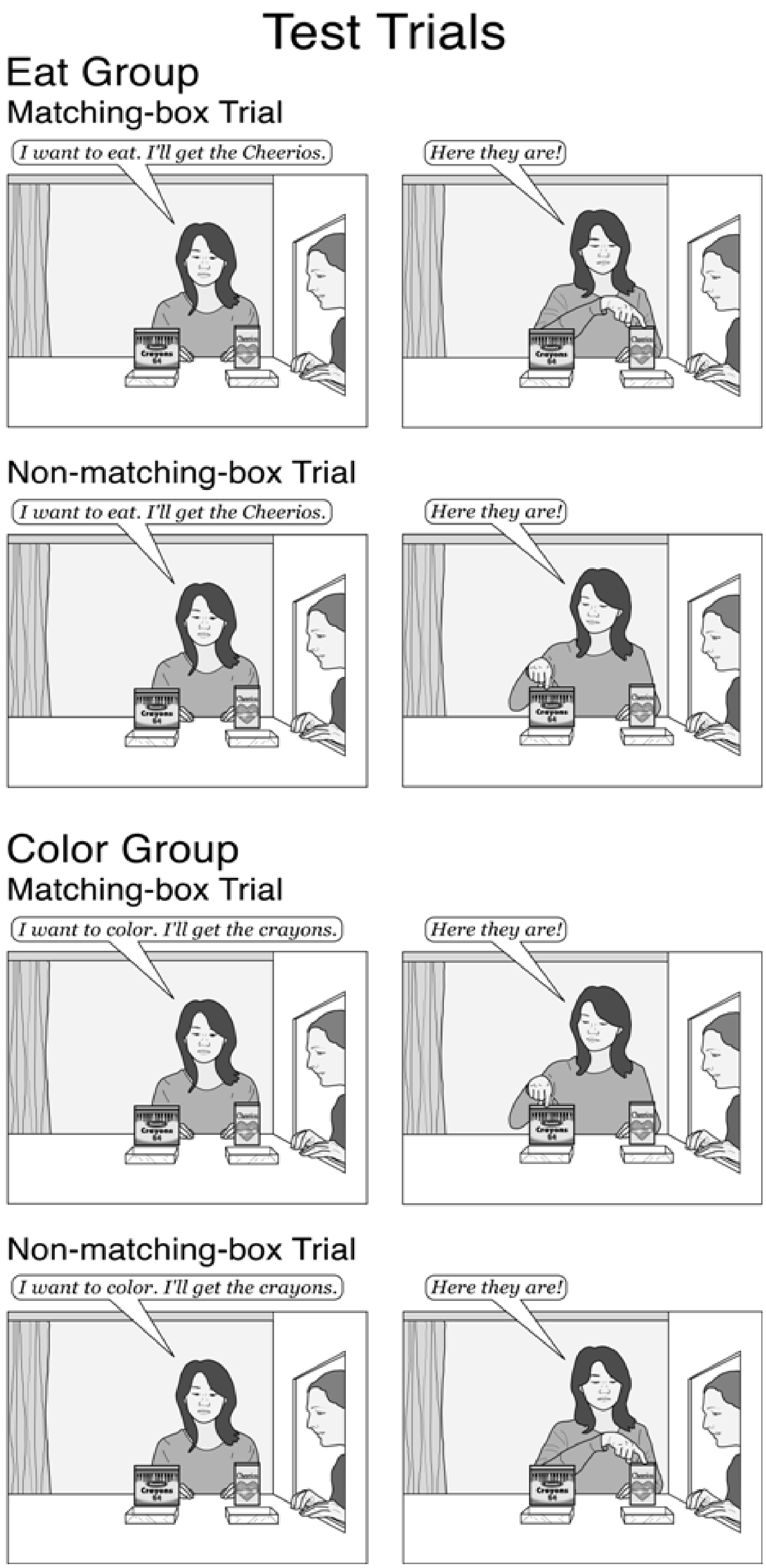

Set-up for Familiarization Trials
False-belief Condition
Experimenter
Crayons 64
Cheerios
Knowledge Condition
Agent
Experimenter
Crayons 64
Cheerios
Reverse-false-belief Condition
Agent
Experimenter
Crayons 64
Cheerios
Experimenter
Crayons 64
Cheerios

Figure 6


Test Trials
Eat Group
Matching-box Trial
I want to eat. I'll get the Cheerios.
Here they are!
Non-matching-box Trial
I want to eat. I'll get the Cheerios.
Here they are!
Color Group
Matching-box Trial
I want to color. I'll get the crayons.
Here they are!
Non-matching-box Trial
I want to color. I'll get the crayons.
Here they are!