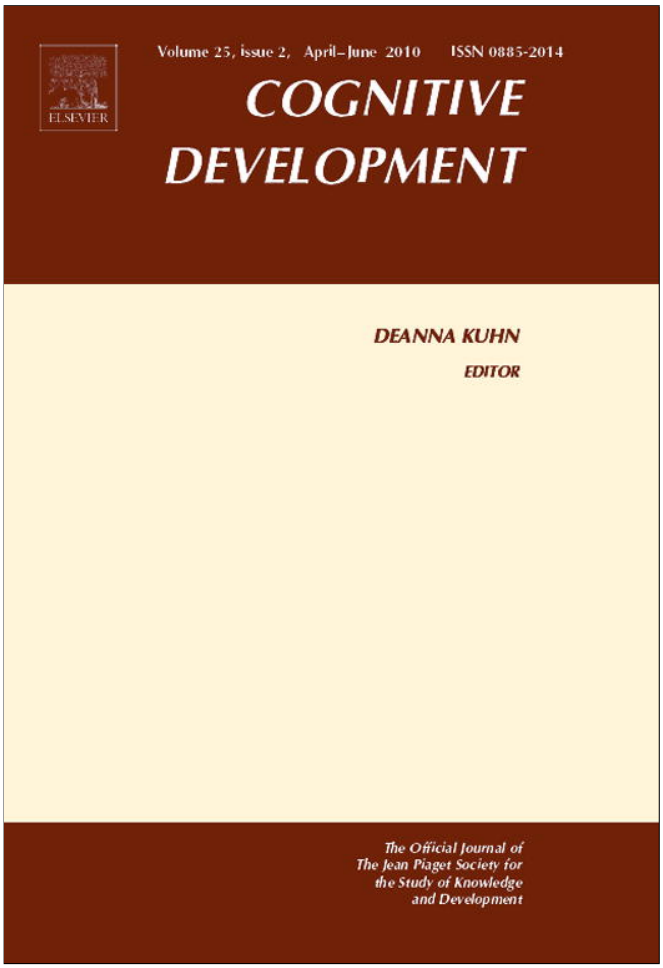

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Older children's misunderstanding of uncertain belief after passing the false belief test

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ABSTRACT

A four-location belief task was designed to examine children's understanding of another's uncertain belief after passing a false belief (FB) task. In Experiment 1, after passing the FB task, participants were asked what a puppet would do after he failed to find his toy at the falsely believed location. Most 4-year-olds and half of 6-year-olds children who passed the FB test showed difficulty in handling uncertain belief; answering that the puppet would then look for his toy at the current (moved-to) location. Eight-year-old children and adults all recognized that the puppet would look for the toy everywhere, or at random. In Experiment 2, 4- and 6-year-olds were presented two other search tasks; it was shown that preschoolers could use search strategies to solve a similar search problem when FB was not involved. This new aspect of post-FB understanding can be interpreted in terms of limited understanding of uncertainty in a less-knowledgeable individual and of limited ability to infer the consequences of belief-disconfirmation.

Theory of mind (ToM) is the set of higher order beliefs and concepts that constrain people's explanations or predictions about mental states and their antecedents and consequences. Understanding of false beliefs (FB) has been treated as a landmark in the acquisition of a mature ToM (Wellman, Cross, & Watson, 2001). It has been shown repeatedly that 4- or 5-year-old children understand that other

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people may have false beliefs about matters of which the children are well informed. By contrast 3-year-old children typically have a much more fragile grasp of such states of unequal knowledge. For example, in the location FB task (Wellman et al., 2001; Wimmer & Perner, 1983) 4–5-year-olds correctly infer that a puppet will look for a target object (that children know has been secretly moved) in the original location; however, most 3-year-olds assume that the puppet knows that the object is in the present location.

Researchers have identified a transitional period in children's understanding of FB, from an initial period of systematically wrong answers to an extended period of mixture of correct and incorrect responses, and finally to a period of systematically correct responding (Amsterlaw & Wellman, 2006). These phases are thought to reflect transition from implicit to explicit FB understanding (Ruffman, Garnham, Import, & Connolly, 2001). In a study employing the standard location FB task (Zhang, Wu, Zelazo, & Li, 2006), some children responded that Maxi would first look for chocolate in the original place, then look for it in its current place. Children's answers seem contradictory. Their first response suggests that they understand the puppet's FB and the second that they do not. Does this imply that their understanding of false belief is fragile or partial and therefore representative of an intermediate, transitional period? This may not be the case. These children simply stated that because the puppet could not find the chocolate at the original location, he looked further for it at the new location. In other words, they predicted where the puppet would look for the object after failing to find it in the original location. What does the latter response mean? The present study explores this question.

In the Zhang et al. (2006) study, there were only two locations. In a 2-alternative forced-choice (2AFC) paradigm, it might be easy to formulate a disjunctive decision schema for searching or selecting (Deák, Ray, & Brenneman, 2003). Thus, children may have proposed looking for the object in the current place because it is the only alternative. The child presumably understands the puppet has a false belief. After the puppet does not find the object, the puppet should be uncertain about the object's present location. Thus, to infer the puppet's next action, children must update a representation of the puppet's belief as the scenario progresses.

Awareness of another's knowledge is important for inferring the other's belief and behavior (Hogrefe, Wimmer, & Perner, 1986; Wellman & Liu, 2004). Children may not be aware of the puppet's ignorance of the object's current location, and so they incorrectly infer the behavior. Yet, even if children are aware of the puppet's ignorance, they may not be able to deal with the other's uncertainty. Studies have shown that 4-5-year-olds tend to say yes when they are asked whether they are certain about something that is in fact uncertain (Fay & Klahr, 1996; Klahr & Chen, 2003; Somerville, Hadkinson, & Greenberg, 1979). They usually overestimate the knowledge to be gained from ambiguous oral or visual input (Chandler & Helm, 1984; Flavell, Speer, Green, & August, 1981; Robinson & Robinson, 1982; Taylor, 1988). They confidently affirm that a piece of information that is in fact ambiguous can eliminate uncertainty (Klahr & Chen, 2003); however, children in this period may treat the ambiguous messages as tentative retrospectively (Beck & Robinson, 2001; Beck, Robinson, & Freeth, 2008).

If children in the FB task failed to represent epistemic uncertainty states—that is, awareness of having inadequate information to form a confident belief about reality, or being in a state of doubt or confusion—and if they did not represent this important alternative to true- or false-belief states, they might by default predict the puppet's behavior according to their own knowledge. Although previous studies have addressed children's understanding of uncertainty, few have investigated how children infer another's behavior in the case of the other's uncertainty. Sodian (1988) found that most 4-year-olds could share the speaker's perspective but not the listener's. In that study, the listener did not know where the object was. Children tended to overestimate the listener's knowledge about the object's location according to the speaker's state. Somerville et al. (1979) told 5–6-year-olds a story in which a man saw a girl go to one of two places, but the girl's friend did not know. Similarly, children overestimated the friend's knowledge. The listener and the friend's ignorance parallel the puppet's uncertainty after failing to identify the object's location.

In general, we know much less about children's understanding of ToM following successful response to the FB question. Previous studies have shown that before 7 years, children rigidly use a "seeing = knowing" rule (Ruffman, 1996; Sodian & Wimmer, 1987); children from 5 years to 7 years have difficulties in recognizing the unpredictability of different people's interpretations of ambigu-

ous visual or verbal input (Carpendale & Chandler, 1996; Taylor, 1988); children at about 6 years can understand second-order belief (Perner & Wimmer, 1985) and master false belief/desire distinctions (Leslie, Friedman, & German, 2004; Leslie, German, & Pollizi, 2005). Recently, it has been shown that although 4–6-year-olds infer false belief, their processing is much slower than that of adults (Liu, Sabbagh, Gehering, & Wellman, 2009).

Another group of relevant studies address understanding of referential opacity. The acquisition of FB understanding marks the beginning of understanding referential opacity, but much time is needed for children to become proficient (Apperly & Robinson, 1998, 2001, 2003; Hulme, Mitchell, & Wood, 2003; Russell, 1987; Sprung, Perner, & Mitchell, 2007). For example, most 7-year-olds incorrectly said "Yes" in a task in which they were told that when George slept, a red-haired thief stole his watch and they were asked if could George tell that a red-haired thief stole his watch (Russell, 1987). Children's failure indicates their lack of understanding of more complex mental states subsequent to the acquisition of FB understanding. Failure could be due to the complex syntax of the question (Russell, 1987), or children's inability to handle partial representation (Apperly & Robinson, 1998, 2001, 2003; Sprung et al., 2007), or descriptive conception (Hulme et al., 2003). Or children's misunderstanding of referential opacity post-FB could be due to their inability to deal with other's uncertainty, a possibility that has not been discussed in these studies.

The present study first investigated whether children's contradictory response was accidental or would reappear in a newly designed task, the 4-location belief task (4LB). The new task is similar to the standard location false belief task. The only difference is that the 4LB has four equally plausible alternative locations, rather than two. In the new task, participants first answer the "look for" (Question 1) and "ignorance" (Question 2) questions, as in the standard location FB task. Participants who correctly answer these questions are considered to pass the standard FB task. These children then answer the following questions: "Can the puppet find the [object] in the original location" (Question 3) and "The puppet still wants the [object]; what will he do?" (Question 4). Finally, the child is asked the ignorance question (Question 5) again. Questions 3 confirms the consistency and robustness of children's understanding of the FB state; it ascertains that child can represent the consequences of the puppet's false belief, that is, that it would lead to erroneous behavior and failure to achieve the goal state. Question 5 ensures that the child has updated the critical representation of the situation—that is, child realizes that the puppet is ignorant of the object's current location. Thus, the 4LB task imposes a high criterion of understanding: the child must represent the puppet's FB in the context of an array of possible locations and update belief representation as the scenario progresses.

Question 4 is thus critical: it examines what children infer about the puppet's behavior when the unfolding scenario provides the puppet with information that should disconfirm the FB but leaves the puppet uncertain about the object's current location. The optimal answer, then, is some paraphrase of "Look in different places until he finds it" or "Look everywhere." However, children should not assume that the puppet will first look in the object's current location because the puppet had no information to privilege that location over the other two equally plausible locations. If children consistently choose that location it may indicate a failure to accurately represent the puppet's emergent uncertainty.

However, it is possible that children fail to answer Question 4 correctly because they cannot infer how insufficient information about multiple possible locations leads to uncertainty and therefore impacts one's search strategy. Perhaps they do not want to admit uncertainty, or are generally overconfident about knowledge, or fail to understand that, in this scenario, it is permissible to search multiple locations. In Somerville et al.'s (1979) study, young children were unable to use an appropriate strategy to solve the uncertainty problem. Similarly, in the 4LB task, whether children can use a search strategy should influence their performance on Q4. In experiment 2, another two tasks were designed, to rule out these alternative explanations.

1. Experiment 1

1.1. Participants

Seventy-five 4-year-olds (range: 53–60 months, $M = 56.9$ months, $SD = 2.0$), thirty-five 6-year-olds (range: 74–84 months, $M = 79.5$ months, $SD = 2.2$), thirty 8-year-olds (range: 101–108 months,

$M = 104.7$ months, $SD = 2.3$) and thirty adults (range: 18–26 years, $M = 21.7$ years, $SD = 2.9$) were recruited from affiliated schools (kindergarten, elementary school or university) in an urban university town in China. All children were only children. Five adults had brothers or sisters. All children had attended a preschool with a formal curriculum for at least 2 years. Families of the children were of the middle class; 70% of the children's parents had a university education.

1.2. Procedure

Children were told the following story: "Look, this is a little dog (card with a cartoon dog shown) and this is his toy (card with a cartoon toy car shown). There are four houses with different colors. (Four cards, each displaying a different colored house, were shown.) Tell me what colors these houses are. Great, they are the red house, yellow house, green house and blue house. Now the dog plays with his toy for a while and puts the toy in the red house. He says, "I'll play with the toy after I come back." Then the dog goes away. After the dog leaves, a little rabbit comes (card illustration shown) and plays in front of the four houses. The rabbit finds the toy in the red house and takes it out of the red house. After playing with the toy for a while, the rabbit puts the toy in the blue house. Then the rabbit goes away. After the rabbit leaves, the dog comes back." After the story, children were first asked a "look for" question (Q1) and an "ignorance" question (Q2). The "look for" question was: "When he gets back, the dog says 'I want to play with the toy!' Where will the dog look for the toy?" The ignorance question was: "Does the dog know where the toy is now?" In addition, children answered two memory control questions: "Where was the toy?" and "Where is the toy?"

Participants who correctly answered test questions and memory control questions went on to the following questions. Question 3: "Will the dog find the toy in the red house?" Question 4: "The dog wants the toy; what will he do?" and Question 5: "Does the dog know where the toy is now?" Participants who answered Q3 correctly were then asked Q4 and Q5. Children who answered any question prior to Q4 incorrectly did not answer further questions and were dropped from the analyses.

The correct answers for Q1, Q2, Q3 and Q5 were red house, no, no and no, respectively. Each correct answer was scored 1 and each incorrect answer was scored 0. For Q4, there was more than one possible correct answer. An experimenter recorded participants' answers, and coded them into one of the three categories: Correct (e.g., look for the toy everywhere, look for the toy at other three houses); Incorrect; reality-biased (look for the toy in the blue house); Other (e.g., look for the toy in the yellow house or the green house). Two 4-year-olds' answers belonged to this category; all others belonged to the first two categories.

1.3. Results

All participants answered Q2 and memory questions correctly. The percentage of 4-year-olds passing Q1, 52.8% ($n = 38$), was significantly lower than that of 6- and 8-year-olds and adults, all of whom passed Q1, Mann–Whitney test, $U = -4.458$, $p < .001$, and $U = -4.287$, $p < .001$; $U = -4.287$, $p < .001$, respectively.

All participants who passed Q1 and continued in the study answered Questions 3 and 5 correctly, confirming that they knew the puppet could not find the object in its original place and that they knew he did not know its current place. Question 4 examined what participants inferred about the puppet's behavior once the puppet was uncertain about the object's present location. Among the 4-year-old children who passed Q1 ($n = 38$), seventeen 4-year-olds (44.7%) gave the correct answer, a smaller proportion (but not significantly) than for 6-year-olds, Mann–Whitney test, $U = -1.54$, *ns*, but significantly less than for 8-year-olds and adults, $U = -4.74$, $p < .001$, and $U = -4.74$, $p < .001$; among the 6-year-old children who passed Q1 ($n = 30$), twenty-one 6-year-olds (60%) answered correctly, significantly less than for 8-year-olds or adults, $U = -3.59$, $p < .001$, and $U = -3.59$, $p < .001$, respectively. All of 8-year-olds' and adults' answers were correct.

Among the children who failed Q4 (twenty-one 4-year-olds and fourteen 6-year-olds, total $n = 35$), only two 4-year-olds thought the puppet would look for the target in the green or yellow house. The other 33 children all chose the target's present location. Responses were thus biased toward

reality, choices of the blue house more frequent than expected by chance, X^2 ($df = 2$, $n = 35$) = 58.51, $p < .001$.

1.4. Discussion

Despite demonstrating understanding of FB, most 4-year-olds and about half of 6-year-olds chose the current location in answering Q4; all 8-year-olds and adults thought that the puppet would look elsewhere. Thus, persisting with the current location is not attributable to the 2-alternative forced-choice paradigm. Correct answer to Q3 and Q5 indicates that children can re-represent the scene as the scenario progressed and update their knowledge. That 4-year-olds performed perfectly on Q5 is inconsistent with Sodian's (1988) finding that children of the same age performed at chance level when asked whether a listener knew where the object was. Both listener in Sodian's study and puppet in the present study were uncertain about the object's current location; whereas, in Sodian's study, the listener had partial knowledge of the object's location but in the present study, the puppet did not. However, Apperly and Robinson (1998, 2001, 2003) and Sprung et al. (2007) both found that a puppet's partial knowledge did not cause children's incorrect evaluation of the puppet's knowledge.

Understanding uncertainty, ambiguous, or indeterminacy is difficult for 4- to 6-year-olds (Beck & Robinson, 2001; Beck et al., 2008; Klahr & Chen, 2003). Children who thought the puppet would go to the object's current location might also not understand uncertainty—that is, being aware of having inadequate information to form a confident belief about reality—and thus may not represent this important alternative to true belief states. Thus they by default predict the puppet's behavior to unfold according to their own knowledge or choose the current location for it is the most strongly highlighted (except the original location) and easiest to represent (Tversky & Kahneman, 1986). However, it is possible that children fail to answer Q4 because they lack the strategy of searching multiple locations. In Experiment 2, this possibility is investigated.

2. Experiment 2

2.1. Participants

Seventy-five 4-year-olds (range: 53–60 months, $M = 56.9$ months, $SD = 2.0$), thirty-five 6-year-olds (range: 74–84 months, $M = 79.5$ months, $SD = 2.2$) were recruited from the same population drawn from in Experiment 1.

2.2. Procedure

All participants were presented the same task used in Experiment 1. All those who answered the FB question correctly continued in the study and were presented two further tasks.

Self task. Experimenter 1 (E1) and the participant played in a quiet room with a card showing a cartoon pencil-box. There were four cards with a brown house, white house, orange house and purple house, respectively on a table. E1 asked the participant to put the pencil-box card in the white house; then, E1 and the participant left the room. During their absence Experimenter 2 (E2) came in and took the pencil-box away. After E2 left, E1 and the participant returned, and E1 asked the participant: "Where did we put the pencil-box? Go and get it for me." The participant looked and failed to find the pencil-box at the original location. Then E1 said: "You want the pencil-box, don't you? What will you do now?" E2 recorded participants' words and behaviors through a one-way mirror.

Other task. In the next task, four cards displaying a round box, triangle box, square box and pentagonal box, a card displaying a cartoon rabbit, and a card displaying a cartoon plane were present on a table. E1 said: "This is a rabbit; he likes playing with the toy plane very much. One day, his friend tells him that there is a very nice toy plane at a place with four boxes and it is in one of the four boxes; but his friend does not tell the rabbit which box the object is in. Look, these are the four boxes – a round box, triangle box, square box and pentagonal box. After hearing that, the rabbit says he wants to have

that plane and then he goes to the place with the four boxes." E1 then asked the test question: "Now, the rabbit gets there; he wants to get the plane; what will he do next?"

If participants only gave oral responses, E1 asked them to show what they would do. If they only gave behavioral responses, E1 asked them to tell what they did.

2.3. Coding

Children who said they did not know what to do or who only searched in one or two of the houses and stopped searching were categorized as responding incorrectly. Those categorized as responding correctly reported that they would search elsewhere or turned over all the remaining houses.

2.4. Results

Children's performance in the initial task was similar to that seen in Experiment 1. All children answered Qs 2, 3, and 5 correctly, and 46.7% of 4-year-olds ($n = 28$) and all 6-year-olds answered Q1, the FB question; correctly and continued in the experiment. Among the children who passed Q1, 46.4% of 4-year-olds ($n = 13$) and 63.3% of 6-year-olds ($n = 19$) said the puppet would search for the object elsewhere.

Of the twenty-eight 4-year-olds and all thirty 6-year-olds who continued to the Experiment 2 tasks, all 6-year-olds and all but four 4-year-olds responded correctly on both the Self and Other tasks; these four responded incorrectly on both tasks. Neither age group showed partiality as to which of the three houses was turned over first in either task.

2.5. Discussion

The two search tasks in Experiment 2 were used to investigate whether children could search for the object when they were unaware of the object's location or when the puppet was unaware of it. Both 4- and 6-year-olds performed well in the two search tasks, demonstrating that children's failure on Q4 in Experiment 1 was not caused by their lack of a searching strategy. However, the good performance in the two search tasks may not indicate that 4–6-year-olds are capable of handling uncertainty. Young children are sensitive to insufficiency of information and try to resolve the uncertainty by seeking clarification (Fabricius, Sophian, & Wellman, 1987). Thus, children in these two search tasks sought clarification by using the strategy of looking for the object in each location. Somerville, Hadkinson and Greenberg's study (1978) found that 5–6-year-olds did not prefer to use strategy to solve an uncertainty problem. The difference in results might be due to differences in ways of questioning. Specifically, the open question used in the present study may have supported children's search in all possible locations.

3. General discussion

Experiment 1 showed that children who passed the FB question did think that the puppet would then look for the object in the current location. In addition, Experiment 1 showed that children's attachment to the current location was not due to the 2-alternative-forced-choice paradigm. Experiment 2 established that they could use an appropriate search strategy when they or the puppet were unaware of the object's location.

According to studies of certainty vs. uncertainty, 4–6-year-old children have difficulties in dealing with uncertainty (Beal, 1988; Beck & Robinson, 2001; Beck et al., 2008; Flavell, Speer, Green, & August, 1981; Klahr & Chen, 2003; Robinson & Robinson, 1982; Somerville et al., 1979; Taylor, 1988). It has been proposed that when making judgments of another person's knowledge, children probably overestimate the person's partial knowledge by drawing on their own knowledge (Apperly & Robinson, 2001; Sodian, 1988; Somerville et al., 1979). In the present FB task, the puppet has *no* information of the object, yet children still use their own knowledge to predict the puppet's behavior. So, it may be that the puppet's partial knowledge is a kind of interference factor.

The understanding of FB does not mean that children fully understand the representational nature of belief or knowledge (Chandler & Sokol, 1999). According to studies of referential opacity, mastering false belief is just the first step to understanding referential opacity; children still need to learn a lot to fully understand complex mental states. In the present study, 4- and 6-year-old children's bias toward the current location when the puppet is ignorant of the object's location is similar to findings from the studies on referential opacity. However, in our case the puppet had no partial knowledge of the object's current location; and after failing to find the object in the original location, he had no partial knowledge. A key feature in studies of referential opacity is that puppets are all uncertain about something; they therefore should have uncertain beliefs. As noted, the understanding of uncertainty is fragile for children aged 4–6 (Beal, 1988; Beck & Robinson, 2001; Beck et al., 2008; Flavell et al., 1981; Klahr & Chen, 2003; Robinson et al., 1982; Somerville et al., 1979; Taylor, 1988). Thus, we propose that in the present study children who failed Q4 in Experiment 1 probably lacked understanding of uncertain belief—a new conception for them and one probably harder than false belief. Although 4- and 6-year-old children predict that an individual's behaviors will be constrained by the limits of his belief (Zhang, Li, Zen, Zhang, & Liao, in press), they cannot draw correct inferences that belief-disconfirmation changes belief states into uncertainty, and they cannot predict that the person will behave according to his uncertain belief.

When children do not know how to predict an individual's behavior according to his uncertain belief, the object's current location might be the easiest choice for them. Even adults may commit egocentric errors in complex belief reasoning tasks (Keysar, Lin, & Barr, 2003). Thus, in the present task and also in other uncertainty tasks, if children cannot handle another's uncertainty, they might regress to egocentrism, relying on their own knowledge or true belief.

The present proposition that children might lack uncertain belief after understanding FB may not correspond to Moore, Pure and Furrow's (1990) findings that around 4 years, children's understanding of FB and uncertain belief are synchronous. In their study, children were asked to search for an object according to a speaker's certain or uncertain statements; the modal verbs or adjuncts were manipulated (for example, must vs. might). Older children (4–6 years) could distinguish these words while 3-year-olds could not. However, children might judge by the strength of modal verbs but not by understanding that belief could be uncertain relatively. Also, Moore et al. examined children's implicit (behave according to the statement with modal words), but not explicit understanding of modal words. It has been found that in an explicit condition in which children evaluated whether the speaker's statement with modal verbs was uncertain or certain, 4–5-year-olds performed poorly (Green, 1979). Similarly, in the present study, although children were not asked to explicitly judge the statement with modal words, they had to infer the puppet's behavior based on the puppet's uncertain belief; therefore, 4- and 6-year-olds showed their misunderstanding.

Overall, the present study shows that children who pass the standard FB task cannot infer another person's behavior when the person holds an uncertain belief. This finding highlights a potential limitation of standard FB tasks. These tests are not comprehensive indices of child's understanding of discrepant belief states (Bloom & German, 2000). In this case, simply changing a 2-alternative-forced-choice task to a task with more locations reveals a conceptual limitation on the part of children who pass the standard FB task. Once they understand FB and have acquired a primitive theory of mind, children still need to learn a lot to acquire a sophisticated folk psychology.

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