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# Are there signature limits in early theory of mind?

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ABSTRACT

Current theory-of-mind research faces the challenge of reconciling two sets of seemingly incompatible findings: Whereas children come to solve explicit verbal false belief (FB) tasks from around 4 years of age, recent studies with various less explicit measures such as looking time, anticipatory looking, and spontaneous behavior suggest that even infants can succeed on some FB tasks. In response to this tension, two-systems theories propose to distinguish between an early-developing system, tracking simple forms of mental states, and a later-developing system, based on fully developed concepts of belief and other propositional attitudes. One prediction of such theories is that the early-developing system has signature limits concerning aspectuality. We tested this prediction in two experiments. The first experiment showed (in line with previous findings) that 2- and 3-year-olds take into account a protagonist's true or false belief about the location of an object in their active helping behavior. In contrast, toddlers' helping behavior did not differentiate between true and false belief conditions when the protagonist's belief essentially involved aspectuality. Experiment 2 replicated these findings with a more stringent method designed to rule out more parsimonious explanations. Taken together, the current findings are compatible with the possibility that early theory-of-mind reasoning is subject to signature limits as predicted by the two-systems account.



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## Introduction

Current theory-of-mind (ToM) research faces what has been termed the "puzzle of belief reasoning" (Helming, Strickland, & Jacob, 2014). On the one hand, decades of research with a variety of mostly verbal false belief (FB) tasks suggest that children acquire the competence to ascribe beliefs at around 4 years of age (for a review, see the meta-analysis of Wellman, Cross, & Watson, 2001). Numerous findings indicate that the emergence of this competence is not a local phenomenon affecting performance on one or two isolated tasks. Instead, the competence reveals itself in systematically intercorrelated ways on a range of superficially diverse tasks where the common denominator of these tasks is merely that they require an understanding of representation (for a review, see Perner & Roessler, 2012). Thus, this development seems to be best described as a conceptual revolution; it is the novel acquisition of a comprehensive and unitary cognitive capacity.

But a rapidly growing body of new evidence suggests that infants and toddlers perform competently on implicit FB tasks well before 4 years of age (for reviews, see Baillargeon, Scott, & Bian, 2016; Baillargeon, Scott, & He, 2010). Violation-of-expectation tasks have found that infants look longer at events in which a protagonist acts in a way that does not fit her beliefs (e.g., Onishi & Baillargeon, 2005; Surian, Caldi, & Sperber, 2007). Anticipatory looking studies have shown that, from the second year of life or earlier, children—just like adults—look in anticipation to where an actor is going to act based on her beliefs (Clements & Perner, 1994; Rubio-Fernández, 2013; Schneider, Bayliss, Becker, & Dux, 2012; Southgate, Senju, & Csibra, 2007). Studies with interactive measures have shown that infants and toddlers can spontaneously help and inform others in ways that are sensitive to the recipient's beliefs (Buttelmann, Carpenter, & Tomasello, 2009; Buttelmann, Over, Carpenter, & Tomasello, 2014; Knudsen & Liszkowski, 2012; Southgate, Chevallier, & Csibra, 2010).

### *Three competing accounts of early implicit ToM findings*

How can these two seemingly incompatible sets of findings be reconciled? Three main theoretical responses to this puzzle of belief reasoning are currently under discussion. Late competence accounts claim that proper ToM capacities are required only for solving explicit tasks, whereas the new implicit tasks using looking time and interaction measures reflect much simpler cognitive capacities (Heyes, 2014; Ruffman & Perner, 2005; Sirois & Jackson, 2007). According to such accounts, many of the looking time studies can be explained by low-level processes such as a novelty preference (Heyes, 2014) or the use of simple behavior rules (Ruffman & Perner, 2005).

Early competence accounts argue the converse. According to these accounts, implicit tasks are the true indicator of ToM capacities. Younger children's failures on explicit FB tasks do not reflect a deficit in ToM but merely reflect extraneous demands imposed by these tasks. These demands are extraneous in the sense that they have nothing to do with ToM per se but only with linguistic and other aspects of the explicit task structure (Baillargeon et al., 2010; Carruthers, 2013; Leslie, 2005).

Two-systems accounts oppose both late and early competence accounts. Instead, they claim, implicit tasks do tap ToM abilities of some kind, but these precocious abilities are distinct from the later-developing conceptual capacities measured in explicit tasks (e.g., Apperly & Butterfill, 2009; Low, Apperly, Butterfill, & Rakoczy, 2016; Perner & Roessler, 2012; Rakoczy, 2012). On such views, younger children's failure on explicit FB tasks is not merely a consequence of extraneous demands but reflects a true conceptual deficit.

On a particularly promising two-systems account (Apperly & Butterfill, 2009; Butterfill & Apperly, 2013; Low et al., 2016), there are at least two systems for tracking beliefs and other mental states, which we label S1 (System 1) and S2 (System 2) in this article. Relative to S2, S1 trades flexibility for gains in efficiency by relying on a simpler model of mental states. Therefore, S1 is limited in ways that S2 is not. For our purposes, the crucial limit is that S1 does not enable tracking false beliefs essentially involving *aspectuality*. To illustrate aspectuality, consider a popular film. Lois Lane is yet to discover that Clark Kent is Superman. She simultaneously believes that Superman is with her and that Clark is elsewhere. She has incompatible beliefs about one and the same person under two different aspects. Only S2 is capable of tracking Lois's beliefs, which essentially involve aspectuality. Suppose that success on implicit FB tasks is a consequence of S1 only, whereas success on explicit FB tasks requires S2. In that case, infants' performance should exhibit the limits of S1. Infants may succeed on many implicit FB tasks that do not essentially involve aspectuality, such as the many tasks that involve simple mistakes about location only. But where FB tasks essentially involve aspectuality, infants should not succeed. Or so this two-systems account implies.

### *Which of the three accounts is right?*

Late competence accounts become less and less plausible as more and more findings from various implicit tasks converge. But the empirical situation so far remains inconclusive between early competence and two-systems accounts. This is because most existing research has considered tasks for which the early competence and two-systems accounts make the same predictions. To illustrate, consider change-of-location FB tasks. The protagonist is present when an object, O, is put into Container 1 and is absent when it is then transferred to Container 2, and the question is where participants will expect the protagonist finally to search for O. Early competence accounts claim that infants operate with fully fledged propositional attitude concepts and, thus, should succeed on such FB tasks. The two-systems account claims that infants operate with relational attitudes only. This is sufficient for tracking false beliefs about location, and infants should succeed on such FB tasks. To distinguish early competence from two-systems accounts, therefore, we must look to other tests.

The two-systems account makes clear and testable predictions concerning implicit and explicit FB tasks. Concerning explicit tasks, the two-systems account predicts that whether or not a task requires dealing with aspectuality should make little difference; competence in different FB tasks should emerge in synchrony, and performance should be highly intercorrelated. This prediction is shared, naturally, with early competence accounts. But early competence accounts predict the same pattern of unity and convergence for implicit tasks as well. By contrast, the two-systems account predicts disunity and dissociation. Infants' (and others') performance on implicit tasks should depend on whether the tasks require dealing with aspectuality. Young children may master change-of-location and related implicit FB tasks but should not succeed on tasks that necessitate a grasp of aspectuality.

### *The empirical state of the art*

What is the state of the existing evidence vis-à-vis these predictions? Concerning unity of performance in various explicit FB tasks in older children, earlier studies directly investigating young children's understanding of aspectuality found evidence for disunity and dissociation; children mastered tasks of aspectuality understanding only some years after passing standard FB tasks (Apperly & Robinson, 1998; Kamawar & Olson, 1999, 2011; Russell, 1987; Sprung, Perner, & Mitchell, 2007). But more recent research suggests that these findings masked children's competence due to extraneous task (Rakoczy, 2017; Rakoczy, Fizke, Bergfeld, & Schwarz, 2015). These new studies have developed simplified aspectual tasks. For example, one used a bunny that became a carrot when turned inside out. This object was put, as a carrot, into Box 1 in the presence of the protagonist. In the second step, the protagonist was absent while the object was taken out of the box, turned inside out so that it became a bunny, and put back into Box 1 as a bunny. In the final step, the protagonist returned and observed the object being moved, as a bunny, from Box 1 to Box 2. The test question was, "Where will the protagonist look for the carrot?" To answer this question correctly ("in Box 1"), the child needs to take into account aspectuality. This is because the protagonist, being unaware that the bunny is the carrot, believes that the bunny is in Box 2 and that the carrot is in Box 1. Four-year-olds succeeded on this aspectual FB task. Furthermore, there were strong correlations between aspectual and standard FB tasks (Rakoczy et al., 2015). Thus, this recent evidence speaks strongly in favor of convergence in performance on explicit FB tasks and of unity in the underlying competence.

What about unity of performance in implicit FB tasks? A number of recent studies do initially appear to suggest that infants and toddlers can solve some implicit FB tasks requiring an understanding of aspectuality (Buttelmann, Suhrke, & Buttelmann, 2015; Scott & Baillargeon, 2009; Scott, Richman, & Baillargeon, 2015). However, all of these studies used a single isolated situation or vignette, each of which leaves room for alternative, more parsimonious explanations.[1] Even more fundamentally, it is hard to interpret these findings given that the scenarios they rely on have neither been used nor been validated in explicit tasks with older children or adults. (For preliminary evidence that adults in fact do not view the scenarios of Scott and Baillargeon (2009), as the task analysis assumes they should, see J. Low et al., unpublished data, 2017.) Thus, it remains unclear whether these implicit tasks really do tap the same representational processes as explicit tasks. Such doubt receives support from recent findings that performance on different types of implicit ToM tasks does not show the unity and convergence characteristic of performance on explicit tasks (Yott & Poulin-Dubois, 2016).

A more direct test of two-systems accounts, therefore, requires direct comparison of implicit and explicit tasks, ideally using a single scenario. Low and colleagues have done just this in a series of studies. For the explicit tasks, their results indicate that competence in standard change-of-location scenarios converges with competence in modified scenarios that involve aspectuality (Low, Drummond, Walmsley, & Wang, 2014; Low & Watts, 2013); the 3-year-olds consistently failed both non-aspectual and aspectual versions of explicit FB tasks, whereas the 4-year-olds and adults consistently mastered both types of task. By contrast, in implicit versions of the tasks, all age groups showed signs of tracking the agent's belief in the standard (non-aspectual) FB task but not in the aspectual FB task. This suggests that there are signature limits in early implicit ToM, as predicted by the two-systems account.

This interpretation of the findings in terms of signature limits, however, has recently been subject to some debate (Carruthers, 2013). Defenders of early competence accounts have worried whether the different results in the aspectual FB and standard FB tasks may have been due to different working memory demands or other performance factors (perhaps because only the aspectual FB task involves certain forms of mental rotation and simulation). Furthermore, these findings of disunity are so far restricted to looking behavior. Thus, it is unclear whether such performance patterns also translate into more active behavior.

### *Rationale of the current study*

In the current study, we intended to test whether there are signature limits in early ToM capacities. Going beyond mere looking behavior, we investigated children's spontaneous interactive behavior toward a protagonist. To directly investigate whether disunity in early ToM performance in various implicit tasks contrasts with unity in later explicit performance, we used the very same kind of materials and scenarios with which recent evidence for convergence and unity in explicit FB tasks was found (Rakoczy et al., 2015). In our non-aspectual change-of-location conditions, children saw scenarios in which a protagonist had a true belief (TB) or a false belief (FB) about an object's location (following Buttelmann et al., 2009). In our novel aspectual conditions, the protagonist did (TB) or did not (FB) know about the dual aspects of an object. The crucial difference between the non-aspectual and aspectual conditions of our helping task, thus, is whether they require tracking beliefs essentially involving aspectuality. Accordingly, the distinctive predictions of the two-systems account are, first, that children's spontaneous interactive responses should differ appropriately between the TB and FB non-aspectual conditions and, second, that there should be no such difference between TB and FB aspectual conditions.

[1] For arguments that the tasks used by Scott and Baillargeon (2009) and Scott et al. (2015) do not clearly require understanding aspectuality, see Butterfill and Apperly (2013) and Low et al. (2016). A specific worry concerning Buttelmann et al. (2015) is that it is not about children's understanding of beliefs regarding aspectuality at all but rather about their understanding of reality versus appearance, and it is not clear whether such tasks require an understanding of aspectuality at all. In addition, the effects in this study were small and basically restricted to one of four sets of stimuli.


**Fig. 1.** Examples of the stimuli used in the aspectual false belief task.

## Experiment 1

### *Method*

#### *Participants*

A total of 67 children (26 girls) were included in the final sample.[2] The children's mean age was 31 months (*SD* = 2.66, range = 26–36). An additional 9 children were not included in the analysis because they were uncooperative (*n* = 8) or due to experimental error (*n* = 1).

#### *Design*

Children were randomly assigned to one of four conditions: non-aspectual, change-of-location false belief (Loc_FB), non-aspectual, change-of-location true belief (Loc_TB), aspectual false belief (Asp_FB), or aspectual true belief (Asp_TB). Each child received two trials (in two exceptional cases three trials, as explained in the online supplementary material) in one of the conditions.

#### *Materials*

In the non-aspectual task, one toy object (a ball, soft toy rabbit, toy dog, or toy donkey) per trial and two boxes were used. In the aspectual task, one reversible soft toy (a bear, bunny, tiger, or pig), which could be turned inside out through a zipper and transformed (into a honey barrel, carrot, snail, or cake, respectively; see Fig. 1), and one box were used per trial. Boxes were covered with a tissue on the inside to leave children ignorant about their (empty) contents. A puppet called Susi (animated by Experimenter 2 [E2]) was used as protagonist.

#### *Procedure*

Each child was tested in an interactive play setting with two experimenters. A parent was present during the session. After two warm-up trials (see supplementary material for details), children standardly received two trials of the condition to which they were randomly assigned. In exceptional cases, a third trial was administered.

*Non-aspectual change-of-location tasks.* The basic sequence of events in these tasks, modeled on Buttelmann et al. (2009), was the following. There were two boxes. These were difficult to open, and the child learned how to open them. The protagonist, Susi, received a toy and expressed a liking for it. Susi then announced that she had forgotten something and needed to leave and that she would leave the toy in Box 1 during her absence. She did so with the help of Experimenter 1 (E1) because she was unable to open the box on her own. The following sequence varied between conditions (see Fig. 2 and supplementary material):

- Loc_FB condition: Susi left. In Susi's absence, E1 proposed playing a trick on Susi. E1 took the toy out of the box and sneakily placed it in the other box.

[2] For full details concerning the method of both experiments, and for complementary results and analyses, see the online supplementary material.

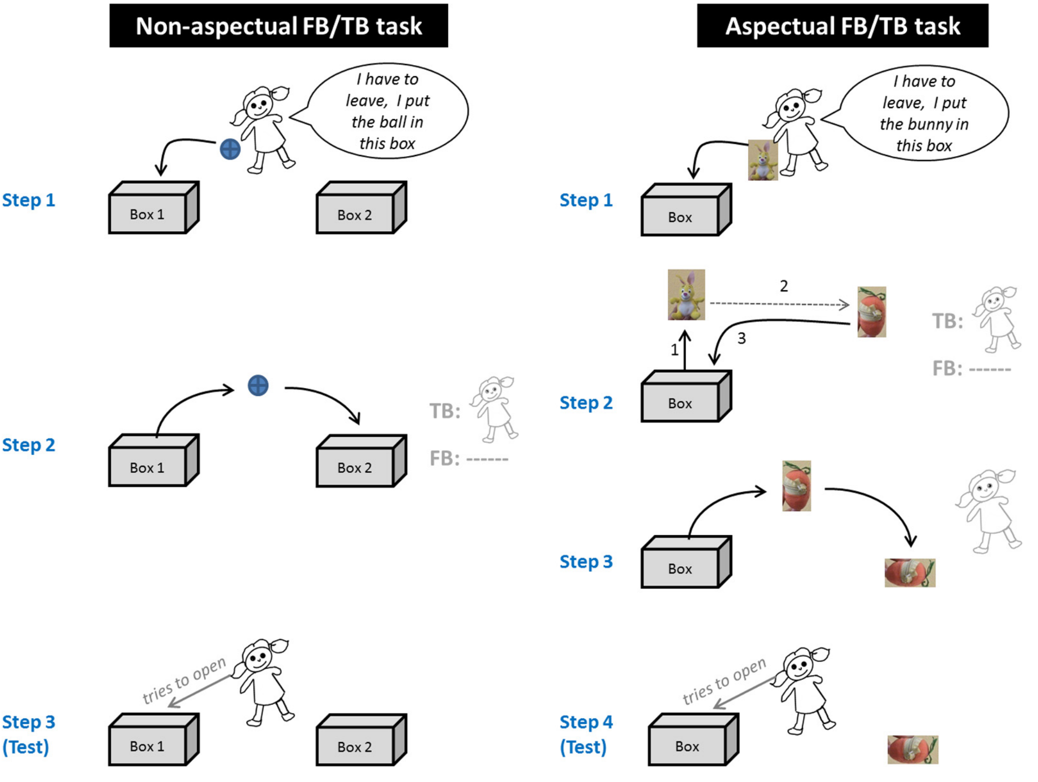


**Fig. 2.** Schematic event sequences of the non-aspectual and aspectual tasks in Experiment 1. FB, false belief; TB, true belief.

- Loc_TB condition: Susi left and then returned a few seconds later. In Susi's presence, E1 took the toy out of the box and placed it in the other box, saying "Look, Susi and [child's name]!" and alternating gaze between the child and E2. Susi observed the location change closely, saying, "Ah, I see! Yes!"

After her return (in the Loc_FB condition), or after the observed location change (in the Loc_TB condition), Susi tried to open the box where her toy was formerly located. Susi failed to open the box and showed disappointment. We call this event the *signal* in what follows. If the child did not react spontaneously, Susi asked, "Can you help me?" If the child still showed no reaction, E1 prompted the child to help. If the child still refused, E1 asked, "Should we help her together?" but did not move and waited to see where the child would go. The child's reactions to the signal were coded. The task was repeated with different boxes and a different target toy.

*Aspectual task.* Children were first familiarized with the dual aspectuality of the target objects. To this end, Susi (the protagonist) left the room and E1 showed the first soft toy to the child. Then she sneakily transformed it to its other aspect, saying (e.g.), "Look! The bunny is also a carrot!" E1 reminded the child, "Susi does not know that, right?" The child was then asked, "Can you make it so that it is a bunny again?" If the child was unable or unwilling, E1 helped. This was repeated with a second object, which was later used for the second test trial.

Following familiarization, Susi returned for the test trials. As in non-aspectual conditions, there were two boxes. These were difficult to open, but the child learned how to open them. Susi received the first soft toy and expressed her liking of it. Susi then announced that she had forgotten something and that she would leave the toy in Box 1 during her absence. She did so with the help of E1 because she was unable to open the box on her own. The following sequence varied between conditions (see Fig. 2 and supplementary material):

- Asp_FB condition: Susi left. In Susi's absence, E1 proposed playing a trick on Susi. E1 took the toy out of Box 1. E1 transformed it (e.g., a carrot) while giggling, gesturing, and whispering "Shh". E1 then returned it into the box.
- Asp_TB condition: Susi left and then returned a few seconds later. In Susi's presence, E1 took the toy out of Box 1 and transformed it while saying "Look, Susi and [child's name]!" and alternating gaze between the child and E2. E1 then put it back into the box. Susi observed this event closely, saying, "Ah, I see! Yes!"

After her return (in the Asp_FB condition), or after the observed aspect change (in the Asp_TB condition), Susi moved back to her original position. E1 said "Look, Susi and [child's name]!" before taking the transformed toy (e.g., carrot) out of the box and placing it approximately 1 m away from Box 1 at a point equidistant between Susi and the child. After observing this closely, Susi then tried to open Box 1. Susi failed to open the box and showed disappointment. This signal and the following events were the same as in the non-aspectual change-of-location tasks. The task was repeated with a different box and a different reversible toy.

*Coding*

Sessions were coded from video by one coder. The child's first reaction to the signal (Susi's failed attempt to open a box) was coded. The coder categorized this reaction as follows:

- Open Box 1: The child clearly referred to Box 1, either by approaching the box and opening it successfully or by trying unsuccessfully to open it (e.g., pulling the elastic band).
- Open Box 2 (in the non-aspectual task only): The child clearly referred to Box 2, either by approaching the box and opening it successfully or by trying unsuccessfully to open it.
- Give the object to Susi (in the aspectual task only): The child handed the toy to Susi.
- Ambiguous: The child showed a behavior that was clearly a reaction to the signal but that did not fit any of the above categories.
- Invalid: A parent interfered, the child did not show any reaction at all, the child left the scene during the trial or did not pay attention to the event sequence, or the child could not be held back from reacting too early.

A second coder, who was blind to the experimental conditions and hypotheses, coded 14 randomly selected videos (a 20% sample). The second coder agreed with the original coder on all trials ($\kappa = 1.00$).

*Predictions*

In the Loc_FB condition, a child tracking Susi's false belief may recognize that Susi is opening Box 1 because Susi believes, falsely, that her toy is in Box 1. This would give the child a reason to respond by opening Box 2, which actually contains Susi's toy. The child has no comparable reason for opening Box 2 in the Loc_TB condition. Accordingly, children who track Susi's false belief should open Box 1 more often in Loc_TB than in Loc_FB. (Of course, it is not wrong for the child to respond by opening Box 1 in Loc_FB. After all, the child may reason that the best way to help Susi is to assist with her proximal goal, which is to open Box 1.) Similar reasoning suggests that children who track Susi's belief in the aspectual conditions should open Box 1 more often in Asp_TB than in Asp_FB.

Recall that the two-systems account predicts that 2-year-olds can track some false beliefs about location but cannot track false beliefs essentially involving aspectuality. The pattern of results predicted by the two-systems account, therefore, is the following: Children should open Box 1 more often in Loc_TB than in Loc_FB but should not open Box 1 more often in Asp_TB than in Asp_FB.

*Results*

All in all, 64 children (32 each in the non-aspectual and aspectual conditions) received at least one valid (including ambiguous) trial. For each of these children, at least one trial was also unambiguous. (For details concerning more comprehensive analyses involving invalid and ambiguous trials, see supplementary material.) For the main analysis, the first valid and unambiguous trial was used. When

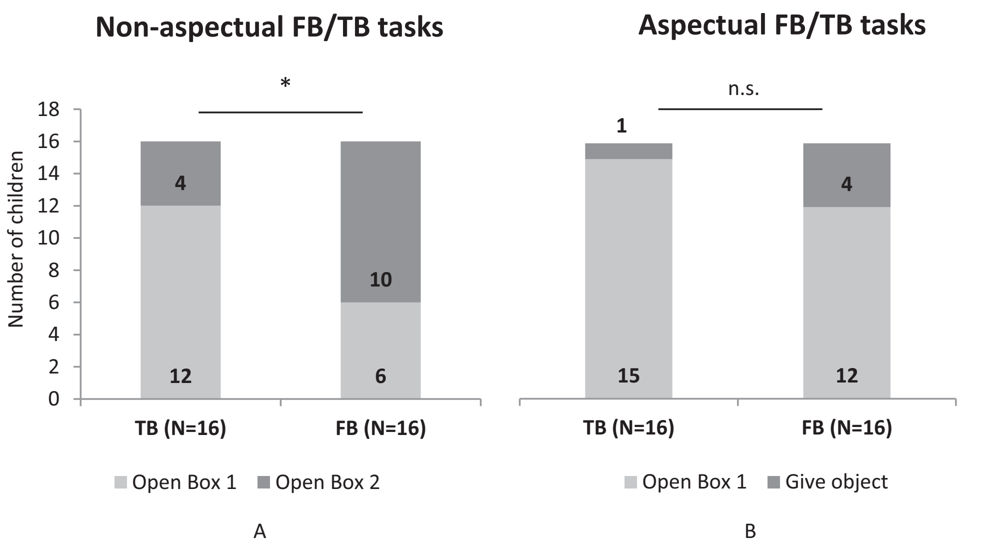


**Fig. 3.** Numbers of children showing the different kinds of helping behavior in the first valid and unambiguous trial of the non-aspectual tasks (A) and the aspectual tasks (B). FB, false belief; TB, true belief. * $p < .05$; n.s., non-significant.

possible, one-tailed tests were conducted whenever directed a priori hypotheses were tested (such that children perform more often "open Box 1" in contrast to "open Box 2/give object" behavior in the TB conditions than in the FB conditions). Fig. 3 depicts children's helping behavior in the first valid and unambiguous trial. In non-aspectual conditions, children's helping behavior differed significantly between Loc_FB and Loc_TB conditions ($p = .037$, one-tailed Fisher's exact test). In the aspectual tasks, in contrast, helping behavior did not differ significantly between Asp_FB and Asp_TB conditions ($p = .166$, one-tailed Fisher's exact test).

*Complementary analysis*

When comparing the non-aspectual and aspectual tasks for FB and TB, respectively, results revealed that children tended to perform differently in the non-aspectual FB tasks than in the aspectual FB task (opening Box 1 less often in Loc_FB than in Asp_FB, $p = .037$, one-tailed Fisher's exact test). No differences were found for the two TB tasks, Loc_TB and Asp_TB ($p = .166$).

*Discussion*

The results of the non-aspectual task in the current experiment replicate the general finding by Buttelmann et al. (2009) in the sense that toddlers responded differentially in Loc_FB and Loc_TB tasks. Performance differed on the novel aspectual tasks, which we developed to test the predictions of the two-systems theory. Children's helping behavior did not differ significantly between Asp_TB and Asp_FB conditions.

What does this pattern show? One possibility is that our results do indeed reflect the characteristic signature limits in children's early ToM abilities predicted by the two-systems account (Butterfill & Apperly, 2013). We turn to that explanation, and to alternatives, in the General Discussion. Another possibility, however, is that the difference in performance reflects the influence of different performance factors and task demands. Our aspectual task might have imposed higher working memory demands because children needed to keep in mind the two aspects of an object and Susi's visual access to these. By contrast, the non-aspectual task involved just one object and just one aspect. In light of this extraneous difference, it may be argued that our novel aspectual tasks simply failed to uncover children's existing competence. This objection is particularly pressing given our relatively small sample size and, thus, limited power. A further potential objection is that we gave children a warm-up trial in which Susi went from being knowledgeable to being ignorant concerning the location of a toy (as described in the supplementary material). This might have facilitated performance in the non-aspectual task change task only.

Thus, differences between our aspectual and non-aspectual tasks reveal the need for replication of our findings. The replication should use a more stringent minimal contrast design in which all but the crucial aspects (the content of the belief to be ascribed and whether it is true or false) are kept as constant as possible across tasks. Experiment 2, therefore, investigated possible signature limits in early belief understanding with thoroughly matched non-aspectual and aspectual tasks and with a larger sample size intended to ensure sufficient power.

## Experiment 2

To match the aspectual and non-aspectual tasks more closely, new versions of these tasks with comparable performance demands were devised. The warm-up trials were modified to minimize the risk of priming children for a change-of-location FB task. To equate working memory load as far as possible, the new version of the non-aspectual task involved two objects rather than one object. To reduce the number of trials coded "invalid" or "ambiguous", the experimental setting was changed. Children sat on the lap of a parent at the table. A younger age group was investigated, which we hoped would result in fewer children doing things like running away and turning around during testing.

### *Method*

#### *Participants*

A total of 137 children (61 girls) were included in the final sample.[3] Children's mean age was 26 months (*SD* = 1.92, range = 24–30). An additional 5 children were tested but not included in the analysis because they were uncooperative.

#### *Design*

As in Experiment 1, children were randomly assigned to one of four conditions: non-aspectual, change-of-location false belief (Loc_FB); non-aspectual, change-of-location true belief (Loc_TB); aspectual false belief (Asp_FB); or aspectual true belief (Asp_TB). Each child received two trials (in two exceptional cases three trials, as explained in the supplementary material) in one of the conditions. (Two short additional tasks were administered during warm-up and at the end of the session. Because these focused on another research question, they are not reported here.)

#### *Materials*

We used materials similar to those used in Experiment 1. For Experiment 2, we used a larger box with more openings to allow more ways of searching in it (see Fig. 4). In addition, in Experiment 2 we did not use the puppet, Susi. Instead, E2 herself played the role of the protagonist. This was because we were concerned that Susi might frighten younger children.

#### *Procedure*

We followed the same procedure used in Experiment 1 except for the warm-up trials (which are detailed in the supplementary material).

*Non-aspectual change-of-location tasks.* The basic sequence of events in these tasks, adapted from Buttelmann et al. (2009), was the following. E2 found two toys and expressed a liking for them. She then announced that she had forgotten something and needed to leave and that she would leave

[3] We reasoned that a significantly larger sample in Experiment 1 would be appropriate because the tasks used in Experiment 2 may be more demanding, potentially making competence harder to detect and effect sizes smaller.

**Fig. 4.** Example of the boxes used in Experiment 2.

the toys in the box during her absence. The following sequence varied between conditions (see Fig. 5 and supplementary material):

- Loc_FB condition: E2 left, and E1 reappeared from behind some curtains. E1 greeted the child and proposed playing a trick on E2. To this end, E1 took one of the toys out of the box and sneakily hid it under a tissue.

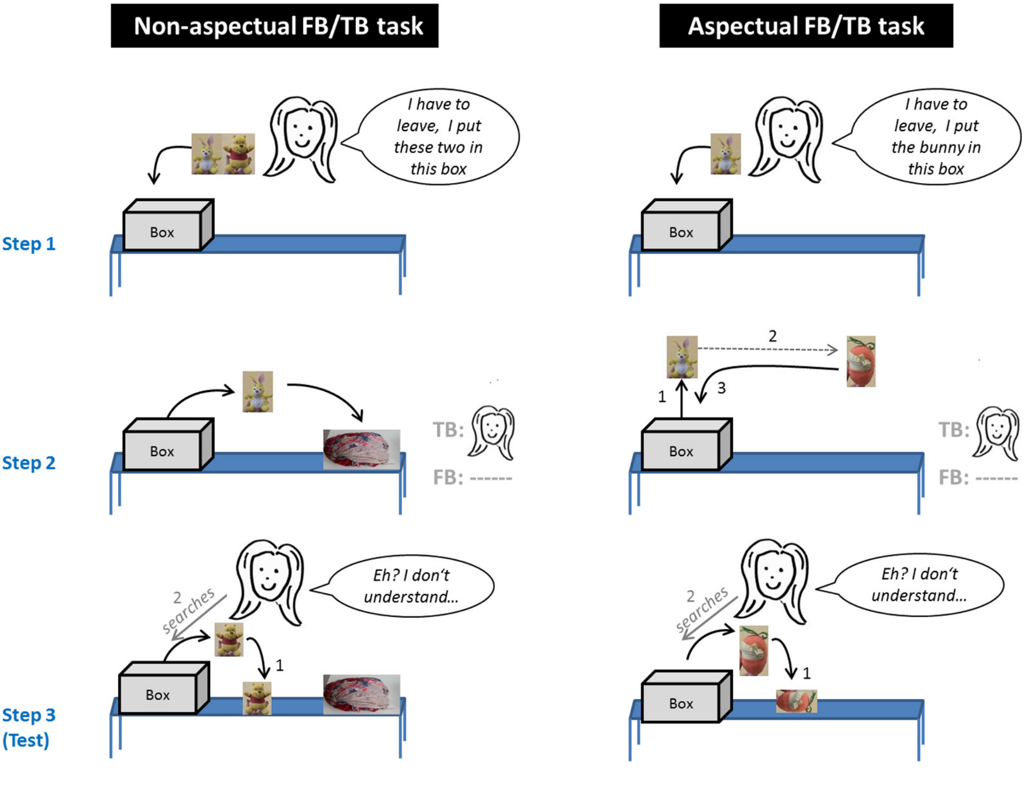


**Fig. 5.** Schematic event sequences of the location and aspectual false belief (FB)/true belief (TB) tasks in Experiment 2.

- Loc_TB condition: E1 appeared from behind the curtains, telling E2 that she wanted to show her something before E2 left. As in Loc_FB, E1 then took one of the toys out of the box and hid it under a tissue. The only difference was that E1's actions were manifestly witnessed by E2, who did not leave the room. After E1 had hidden the toy, E2 told the child that she now really needed to leave and then left the room for several seconds.

On her return (in both conditions), E2 approached the table and reached into the box. She took out the remaining object and put it beside the box. She then began to search in the box again, saying, "Hmm, eh? I don't understand . . . but where is . . .." As in Experiment 1, this event is referred to as the *signal.* If the child did not react to the signal spontaneously, E2 sat down and expressed disappointment, saying, "Hmm. Oh no!" If the child did not react, E2 asked, "Can you help me?" The task was repeated with a different box and two different toys.

*Aspectual task*

The procedure for the aspectual task was exactly as for the non-aspectual task except for the following differences. When E1 appeared from behind the curtains for the first time, she introduced only one reversible toy to the child. She then transformed it into its other aspect, saying (e.g.) "Look! The bunny is also a carrot!" In Asp_FB, she did this in a sneaky way, whispering "Shh" and telling the child, "[E2] does not know that, right?" The child was then asked "Can you make it so that it is a bunny again?" (and was helped by E1 if the child was unwilling or unable). E1 then placed the toy in its original aspect (e.g., bunny) on the table and returned to her place behind the curtains. After this, E2 came back, found the toy, expressed her liking for it, and put it into the box before leaving again. Then, in either the absence (Asp_FB) or presence (Asp_TB) of E2, and in exactly the same sneaky or not sneaky way as in the non-aspectual tasks, E1 appeared from behind the curtains, took the toy out of the box, transformed it into its second aspect (e.g., carrot), and put it back into the box. When E2 reentered the room, she reached into the box, took out the toy in its second (carrot) aspect, put it aside, and began to search again. E2 did all this in the same manner in which she acted in the non-aspectual tasks.

*Coding*

As in Experiment 1, the child's first reaction to the signal was coded. The coder categorized this reaction as follows:

- Help to search in the box: The child touched the box, pulled a grip, opened one of the doors, or tried to look inside.
- Give the object: The child took the object, either from under the tissue (in the non-aspectual tasks) or from on the table (in the aspectual tasks), or the child pointed to the object.
- Ambiguous: The child showed a behavior that was clearly a reaction to the signal but that did not fit any the above categories.
- Invalid: A parent interfered, the child did not show any reaction at all, the child left the scene during the trial or did not pay attention to the event sequence, or the child could not be held back from reacting too early.

A third coder, who was blind to the experimental conditions and hypotheses, coded 27 randomly selected tapes (36 trials, a 20% sample). This coder agreed with the original coder on nearly all trials ($\kappa = .96$).

*Results*

All in all, 109 children (51 in the non-aspectual conditions and 58 in the aspectual conditions) received at least one valid (including ambiguous) trial. Of these children, 48 had at least one valid and unambiguous trial per type of condition. (For details regarding the distribution of all trials, including invalid ones, see supplementary material.) As in Experiment 1, the first valid and unambiguous trial was used for the main analysis (see Fig. 6; for an analysis including ambiguous trials, see supplementary material). In non-aspectual conditions, children's helping behavior differed significantly

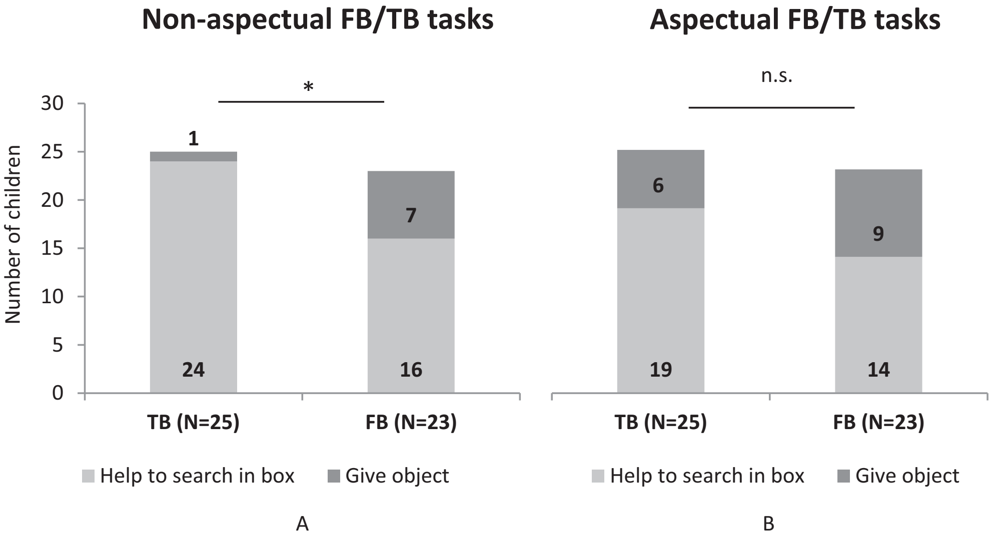


**Fig. 6.** Numbers of children showing the different kinds of helping behavior in the first valid and unambiguous trial of the non-aspectual tasks (A) and the aspectual tasks (B). FB, false belief; TB, true belief. $^{*}$ $p < .05$; n.s., non-significant.

between Loc_FB and Loc_TB conditions ($N = 48$, $p = .018$, one-tailed Fisher's exact test). In the aspectual tasks, helping behavior did not differ significantly between Asp_FB and Asp_TB conditions ($N = 48$, $p = .207$, one-tailed Fisher's exact test).

*Complementary analysis*

Comparing the Loc_TB and Loc_FB conditions revealed that children tended to open the box more often in Loc_TB than in Asp_TB ($N = 48$, $p = .049$, one-tailed Fisher's exact test). No differences were found between Loc_FB and Asp_FB ($N = 48$, $p = .379$, one-tailed Fisher's exact test).

*Discussion*

In Experiment 2, we aimed to test for the patterns of results found in Experiment 1 with more stringent contrasts. To this end, the non-aspectual and aspectual tasks were matched as closely as possible in terms of irrelevant performance factors. The results largely converge with those of Experiment 1. Children's helping behavior differed between the two non-aspectual conditions, Loc_FB and Loc_TB, but did not differ bewteen the two aspectual conditions, Asp_TB and Asp_FB.

## General discussion

*Summary and limitations of the current experiments*

Two experiments tested for signature limits in toddlers' early understanding of false belief as indicated in their active helping behavior. Both experiments found, in line with previous work, that children's helping behavior differed between a condition in which the protagonist had a true belief and a condition in which she had a false belief about the location of an object. However, in parallel aspectual tasks where the protagonist had a true or false belief essentially involving aspectuality, toddlers' helping behavior did not differ significantly between true and false belief conditions. Experiment 2 controlled for differences in inferential complexity between the tasks in terms of working memory and other performance factors, replicating the basic results of Experiment 1.

It should be noted, however, that these findings are not particularly strong or unambiguous. It is true that a key prediction of the two-systems account was borne out in the difference between performance on non-aspectual change-of-location tasks and performance on aspectual tasks; opposing accounts cannot be entirely ruled out by our findings. But when comparing performance on just the aspectual and non-aspectual FB tasks, we found a difference in Experiment 1 only. Although the two-systems account does not directly generate a prediction concerning this comparison, we would be more confident in our findings if we had found a difference on just the aspectual and non-aspectual FB tasks in both experiments. Clearly, more comprehensive, systematic, and sensitive tests for such potential patterns of contrast between aspectual and non-aspectual FB/TB tasks will be needed in future research.

Furthermore, although we attempted to match the non-aspectual and aspectual tasks as carefully matched as possible, some differences do remain. One such difference may complicate the interpretation of our findings. Consider the range of appropriate behaviors in each FB task. In neither the non-aspectual FB task nor the aspectual FB task is there a single correct response. When the protagonist asks for help, it is not incorrect to help her with what is certainly her proximal goal (opening this box) rather than with what is plausibly her more distal goal (getting her toy). But for methodological reasons, our tasks focus on trials where children help the protagonist with her more distal goal. And helping the protagonist with her more distal goal may be more demanding on our aspectual FB task than on our non-aspectual FB task. On the aspectual FB task, helping the protagonist with getting her toy would ideally involve not only giving the toy to the protagonist but also pointing out, by communication or by turning it inside out, the hidden aspect under which the protagonist is actually looking for the object. If children appreciated that helping would ideally involve this, the complexity of the aspectual FB condition might in principle have simply overwhelmed and paralyzed children. Although we cannot rule out this possibility altogether, we believe it is unlikely. This is in part because children did not need to show such complex responses; they could succeed merely by pointing to, or giving, the toy without any further communicative attempt. Furthermore, in another recent study with an analogous design but where the aspectuality was not realized by revertible objects with hidden aspects, children showed qualitatively the very same pattern of responses (Oktay-Gür, Schulz, & Rakoczy, 2017).

*What do the results show?*

Keeping in mind their limitations, what do the current findings show? On the one hand, children's performance might reflect the true limits of their ToM capacities. The limits observed here are the very signature limits in early mind-reading predicted by the two-system account (Apperly & Butterfill, 2009; Butterfill & Apperly, 2013). On this account, an early-developing system is assumed to enable a person to solve some ToM tasks but not others. Limits on which tasks such a system could solve follow from conjectures about the kind of mental state that they represent. In the case of non-aspectual, change-of-location FB tasks, operating with relational attitudes is sufficient for solving the task. In the case of tasks that require tracking beliefs or other mental states that essentially involve aspectuality, in contrast, operating with relational attitudes is not sufficient. Rather, fully fledged propositional attitude concepts are needed. The pattern of findings in our studies, thus, might indeed reflect signature limits of an early-developing ToM capacity that operates by tracking relational attitudes rather than by ascribing fully fledged propositional attitudes. This possibility gains plausibility when considering the current findings in concert with a recent study that investigated the same structured contrast between aspectual and non-aspectual tasks but used explicit tasks rather than implicit tasks (Rakoczy et al., 2015). In those experiments, children aged 4 to 6 years performed equally well on both aspectual and non-aspectual tasks, and both tasks were highly correlated with each other and with a standard FB task. Taking these two sets of studies together highlights a contrast. There is a pattern of unity and convergence for performance on explicit FB tasks, and there is a pattern of disunity and dissociation for performance on implicit tasks. This contrast was recently found in another line of research (Low & Watts, 2013; Low et al., 2014). It is just what is to be expected according to the two-systems account.

Alternatively, however, the current findings might be explained in terms of performance (rather than competence) factors. For example, participants in our experiments may have assumed, for some reason, that the protagonist was omniscient about aspects of objects but not about their locations. Such an assumption might in principle have been triggered by participants' difficulty in understanding and coordinating different aspects of objects (Perner, Mauer, & Hildenbrand, 2011). Crucially, according to this interpretation, children were led by extraneous task demands to make such an omniscience assumption in the aspectual conditions but not in the non-aspectual conditions, even though in principle they would be capable of understanding that people can fail to be omniscient of objects' aspects as well as their locations.

How might future research decide between these two interpretations? The two-systems interpretation predicts that the difference in performance between non-aspectual and aspectual tasks will be observed in implicit tasks but not in explicit tasks, whereas the alternative (omniscience/extraneous task demands) interpretation predicts that, all other things being equal, this difference in performance will appear in explicit tasks as well as in implicit tasks. A fundamental problem for the omniscience interpretation, however, is that other studies have measured implicit and explicit responses to a single scenario. These studies have uniformly observed a difference in performance between aspectual and non-aspectual implicit tasks that disappears on explicit tasks (Low et al., 2014). Furthermore, as already mentioned, another study developed explicit tasks implementing the very same contrasts between aspectual and non-aspectual that we used and found no performance differences between aspectual and non-aspectual tasks (Rakoczy et al., 2015). This suggests that an interpretation in terms of omniscience about aspectuality and extraneous task demands is unlikely to explain the current findings.

Three potential methodological caveats with regard to the current findings should be mentioned. First, it might be wondered whether the stimuli in the current study were appropriate for testing children's understanding of false beliefs involving aspectuality. The objects used here (e.g., bunny/rabbit) were selected because earlier research on children's object individuation with exactly these stimuli show that even 1-year-olds do understand the dual nature of these objects (Cacchione, Schaub, & Rakoczy, 2013). However, it might be objected that children could have represented the situation in terms that would undermine our claim to be testing an understanding of false beliefs involving aspectuality. After all, children might have represented the protagonist as having beliefs about one object (e.g., a bunny) with another object (e.g., a carrot) hidden inside it. If this were true, what we term *aspectual* tasks would in fact have been non-aspectual tasks about location and containment. As this objection nicely illustrates, it is difficult or impossible to create situations that can only be understood as involving aspectuality. However, two points should be noted in response to this objection. First, if the children in the aspectual conditions really had represented the protagonist as having beliefs about one object being hidden in another, we would expect their performance to differ between FB and TB just as it did in the non-aspectual conditions. In fact, this is not what we observed. Second, a recent study with older children (Rakoczy et al., 2015) compared performance on tasks involving the stimuli used here with that involving new stimuli that also had dual aspects but could not be construed as involving one object hiding another (e.g., a single object featured both as Susi and as the doctor). Children's performance with the two sets of stimuli was absolutely comparable. This suggests that the findings from the current experiments are unlikely to depend on irrelevant peculiarities of the stimuli.

A second methodological caveat concerns the dependent measure of our tasks. We asked the question: What will toddlers spontaneously do in response to a protagonist's attempt to open, or search in, a box? Using this dependent measure limits the strength of the findings compared with standard explicit ToM tasks that use a two-alternative forced-choice measure with exactly one correct answer. Future studies might extend the current work to compensate for this weakness by, for example, combining multiple dependent measures. For example, our tasks could be combined with measures of proactive gaze and action trajectories.

Third, and relatedly, null findings in the aspectual tasks from Experiments 1 and 2 are inherently difficult to interpret statistically. The absence of significant differences between FB and TB cases may simply be due to a lack of power. This is a particularly pressing concern given the fundamentally binary quality of our data. Future studies might overcome this weakness not only by combining multiple dependent measures but also by using continuous measures.

## Conclusions and future directions

All in all, the two experiments reported here present preliminary evidence compatible with the claim that early-developing ToM capacities are subject to signature limits. Taken together with recent findings that on an explicit level older children do not show the same signature limits but perform uniformly across a wide range of FB tasks (Rakoczy et al., 2015), and taken together with converging evidence from similar studies with looking time measures (Low & Watts, 2013; Low et al., 2014), the current findings are in line with predictions of the two-systems account of mind-reading.

But although they are in line with the predictions of the two-systems account, the current findings by themselves cannot strictly decide between this account and alternative accounts given the methodological caveats just identified. Further research is needed to test for patterns of performance in early theory of mind, in particular for signature limits. What is required if we are to decide between competing accounts is a broad range of implicit tasks concerning the generality and flexibility of young children's abilities to track beliefs and other mental states (Yott & Poulin-Dubois, 2012, 2016). Such tasks must involve a broad range of scenarios, belief contents, and methods (e.g., violation-of-expectation, anticipatory looking, communicative, and interactive measures). Perhaps most important, more attention to when and why infants fail to track mental states is required, ideally in conjunction with further direct comparisons between performance on implicit and explicit tasks. This is, after all, where the competing accounts make clearly different predictions.

One particularly instructive strategy in this context may be to investigate children's readiness to *learn* to track beliefs about novel scenarios (see also Heyes, 2014). For example, when children are repeatedly confronted with scenarios in which novel objects change their (unusual) locations or their (unusual) aspects in novel ways, children's learning history might be particularly instructive. According to an early competence account, infants and young children have a full-blown concept of belief. It follows that after initial asymmetries regarding previous experience with unusual locations or unusual aspects have been evened out through training, young learners should be capable of solving aspectual and non-aspectual FB tasks with equal ease. In contrast, the two-systems theory would predict that an initial asymmetry in performance between aspectual and non-aspectual FB tasks should persist even despite learning about objects' unusual locations and aspects.

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## Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jecp.2017.05.005.

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