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Direct and indirect admission of ignorance by children



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ABSTRACT

Research has shown that children are able to admit their own ignorance directly (i.e., verbally) by 3 years of age when they are totally ignorant about what is hidden in a box (total ignorance task) but fail to do so until 5 or 6 years of age when having seen different objects without seeing which of them is being hidden (partial exposure task). This study investigated whether an earlier understanding of own ignorance in the partial exposure task is found when using an indirect measure—when children are allowed to either opt out from a risky decision (Experiment 1) or seek clarifying information by peeking inside (Experiment 2). No evidence for an earlier understanding was found in Experiment 1. In Experiment 2, however, 3- and 4-year-olds searched for clarifying information under partial exposure more often when being ignorant than when being knowledgeable. We argue that this discrepancy is related to whether spontaneous information seeking involves metacognitive processes or not.

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Introduction

Metacognition is commonly defined as cognition about cognition or, in everyday parlance, thinking about thinking (Dunlosky & Metcalfe, 2009; Flavell, 1979). In developmental psychology, it was first

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studied as metamemory, that is, what children know about their memorial abilities (Flavell, 1979). In this study, however, we focused on the development of meta-knowing. Interestingly, a firm understanding of “knowing about knowing” develops surprisingly late—not until around 6 years of age (Rohwer, Kloo, & Perner, 2012).

An early impetus came from Nelson and Narens (1990), who put the field on a theoretical footing as a cognitive system that monitors and affects more basic cognitive processes. If metacognition is not just a system for monitoring but can also influence cognition, it becomes of great practical significance. This spurred intensive research in different fields of psychology (e.g., social, developmental, educational). To illustrate, one of the sections of the European Association for Research on Learning and Instruction (EARLI) is devoted to metacognition. In particular, there is research on monitoring one’s learning progress (Metcalfe, 2008), how metacognition shapes the course of learning and problem solving (Metcalfe & Finn, 2008; Simon, 1979; Simon & Reed, 1976), comprehension monitoring (e.g., Baker & Brown, 1984; Markman, 1977; Myers & Paris, 1978), communicative competence (e.g., Flavell, Speer, Green, August, & Whitehurst, 1981), and memory performance (e.g., Dufresne & Kobasigawa, 1989; Lockl & Schneider, 2004).

This large body of research investigates practical issues of metacognitive development and focuses on how much children know about their own mental abilities. At the same time, relatively little is known about the foundational issue of when children acquire a conception of having inner mental states and can reflect on them in principle (Beran, Brandl, Perner, & Proust, 2012, p. 11). Existing research on this basic question takes a very direct approach. Children are shown a box and asked whether they know what is inside; either they have been shown or told what is inside or they are without any information in total ignorance. In the *informed* (or *knowledge*) condition, nearly all children from 3 years of age onward correctly acknowledge that they know (e.g., Pillow, 1989; Pratt & Bryant, 1990; Ruffman & Olson, 1989; Tardif, Wellman, Fung, Liu, & Fang, 2005). In the *total ignorance* condition of the very first study (Wimmer, Hogrefe, & Perner, 1988, Experiment 1), only about 50% of 3-year-olds correctly denied any knowledge. However, later research found that by 3 years (Pratt & Bryant, 1990) or even 2 years (Rohwer et al., 2012, Experiment 1), practically all children acknowledged their ignorance.

Quite a different picture of metacognitive competence emerges when we look to *partial exposure* tasks. Sodian and Wimmer (1987, Experiment 1) showed children in one of their control conditions a tray with beads of different colors. One of the beads was taken out and put inside a bag without the children being able to see which bead it was. When asked whether they knew the color of the bead, many 4-year-olds and even some 6-year-olds claimed to know. Rohwer et al. (2012) used objects of a different kind (e.g., a car and a ball) and contrasted the partial ignorance condition with total ignorance and knowledge conditions. Even 2- and 3-year-olds gave more than 80% correct answers in the knowledge and total ignorance conditions. In stark contrast, in the partial ignorance condition, a majority of children even in the group of 4-year-olds claimed to know which toy was in the bag. Only after 5 years of age (Experiment 2) or 6 years (Experiment 1) did children correctly deny any knowledge in more than 80% of trials. Moreover, the results were the same whether only 2 alternatives or up to 10 alternatives were used (Experiment 2), ruling out that children claim to know on the basis of the likelihood of making a correct guess.

Children’s failure to accurately assess their knowledge under partial exposure is also underlined by their inaccurate use of the concepts *know* and *guess*. For instance, when asked to indicate which of two (or more) boxes has been baited, children can only guess. However, when they guess correctly, they tend to claim that they knew where the bait was. Only when guessing incorrectly do they admit ignorance. So up to about 6 years of age children seem to identify *knowing* with *getting it right* (Johnson & Wellman, 1980; Miscione, Marvin, O’Brien, & Greenberg, 1978; Perner & Ruffman, 1995).

Children’s problems in expressing their lack of knowledge do not hinge on their deviant use of the words “to know.” Pillow (2002) asked 5-year-olds to express their uncertainty on a rating scale and found only a minimal difference in rating between the guess condition (77% certainty) and the informed knowledge condition (82%). One should note that although children are not asked explicitly about their knowledge at test, the instructions for how to use the rating scales refer to mental states like “uncertainty.” Lyons and Ghetti (2011; see also Ghetti, Hembacher, & Coughlin, 2013) used a rating scale depicting a child expressing certainty or uncertainty for 3-, 4-, and 5-year-olds to indicate how they felt

when they had problems in interpreting incomplete drawings. There was a minimal but significant rating difference between clear and unclear pictures even at 3 years of age. This seems to contradict [Pillow's \(2002\)](#) results. However, it seems that when one is unable to interpret a drawing, this is more similar to total ignorance than to the typical partial exposure tasks with clear and distinct alternatives.

Problems with partial ignorance also show when children are given ambiguous unclear instructions, for example, “Hand me the tall box!” when there are two tall boxes and one small box. They judge such instructions as “clear” or “adequate” (e.g., [Beal & Flavell, 1982](#); [Bearison & Levey, 1977](#); [Robinson & Robinson, 1977](#); [Singer & Flavell, 1981](#)), and they claim that such ambiguous referencing would be sufficient for a definite interpretation ([Robinson & Robinson, 1982](#); [Robinson & Whittaker, 1985](#)). Similarly, they have problems in distinguishing determinate from indeterminate evidence when, for example, deciding from which box a red bead could have been drawn. When encountering a box with red beads, they declare that this settles the issue even when there are unexplored alternatives that could also contain red beads (positive capture: [Fay & Klahr, 1996](#); [Klahr & Chen, 2003](#)). Similarly, children up to 6 years of age have difficulties with partial information in dual identity tasks (e.g., using dual objects such as a dice that is also an eraser; [Apperly & Robinson, 2001](#); [Perner, Huemer, & Leahy, 2015](#)).

Children's problems with ambiguous reference also show when they are asked to put a marker in all instances to which a statement could refer, for example, two tall boxes. They place a marker to only one of the boxes ([Robinson, Rowley, Beck, Carroll, & Apperly, 2006](#), Experiment 2; [Robinson & Whittaker, 1985](#)). Children also find it difficult to use an adaptive response for ambiguous situations, for example, delay the required response and ask for clarifying information ([Beck & Robinson, 2001](#), Experiment 3; [Beck, Robinson, & Freeth, 2008](#), Experiments 1 and 2; [Ironsmith & Whitehurst, 1978](#); [Sommerville, Hadkinson, & Greenberg, 1979](#)).

At this point, it seems amply clear that children fail basic meta-epistemic tasks of partial exposure in a variety of contexts until about 6 years of age. This indicates that they not only lack specific insights into their ignorance about a specific domain of knowledge but also have a more pervasive deficit. One task for us was to explain why this deficit affects assessment of their ignorance only under partial exposure, but not under total ignorance, or when acknowledging their knowledge when they do know. Before addressing this question, there is another puzzle in the literature; there is a set of studies in which children show much earlier sensitivity to their own partial ignorance.

Evidence for such early sensitivity comes from studies that offer children the possibility of natural pre-reflective exploration before committing themselves to a response. For instance, [Call and Carpenter \(2001, Experiment 3\)](#) tested 2- and 3-year-olds using two tubes, the content of which children could easily inspect by looking through the tubes. Children observed how one of the tubes was baited. In one condition, they saw which tube this was and, thus, had complete knowledge of where the bait was. In the other condition, they could not see which particular tube was being baited and, hence, remained partially ignorant of where the bait was; that is, they knew that it was in one of the tubes but did not know which one. Even at this young age, there was a clear difference of looking before deciding on a tube between conditions, with 75% looking under partial exposure and only 40% looking under full knowledge. In addition, [Balcomb and Gerken \(2008\)](#) found that 3½-year-olds skipped difficult items, of which they were uncertain, in a recognition test to minimize wrong responses.

[Robinson, Haigh, and Pendle \(2008\)](#) provided direct evidence for the importance of distinguishing unreflective information seeking responses and explicit reflection on the needed information. They modified the modality specificity test ([O'Neill, Astington, & Flavell, 1992](#)), where children need to explicitly answer a question about which sense modality is needed to determine an object's property (e.g., the eyes to tell its color, one's hand for whether it is soft or hard). Children up to 5 years of age found this to be difficult; for example, they might say that one should use one's hand to find out whether it was red or green. [Robinson et al. \(2008\)](#) showed 3- and 4-year-olds pairs of toys that differed in only one property. One pair of toys had different colors, and the other pair differed in how they felt—soft or hard. Then the experimenter mixed up all objects and selected one. In one condition, the experimenter put that toy on the table and asked children, “Which one is it?” Children were more likely to touch the toy before answering when the toy was either soft or hard than when the toy's distinctive feature was its color. They evidently had practical knowledge of how to find out the toy's distinctive feature. This result contrasts with children's performance in the other condition, where the

experimenter handed the toy to children so that they saw and felt the toy at the same time. After identifying the toy as, for example, “the hard one,” children were asked, “How did you know it was the hard one?” Although they had always identified it correctly as the hard one, only 37% correctly pointed out “because I could feel it.” In sum, although these children had good practical knowledge of using their hand to find out the toy’s qualities they had little explicit knowledge that it was the use of their hand that provided the information.

An earlier emergence of an implicit sign of partial ignorance before an explicit understanding is also indicated for ambiguous reference experiments. Children, who cannot point out whether an instruction they receive is ambiguous or has a determinate referent, nevertheless show different reactions (e.g., more frequent eye contact with the speaker, puzzled expressions, prolonged reaction times) when the instruction is ambiguous (e.g., Bearison & Levey, 1977; Flavell et al., 1981; Patterson, Cosgrove, & O’Brien, 1980; Plummert, 1996; Sekerina, Stromswold, & Hestvik, 2004).

The evidence for such an early implicit competence is, however, difficult to interpret because we do not know the features by which we could tell whether implicit or explicit knowledge is involved in a way that would discriminate between the tasks that are mastered early and those that are mastered later. For instance, while Balcomb and Gerken (2008) found that 3.5-year-olds skipped difficult items in a recognition memory task to avoid errors, Robinson and colleagues found that children were unable to use a question mark or to briefly defer a response to avoid errors in difficult hiding tasks until they were 6 or even 7 years old (Beck et al., 2008, Experiments 1 and 2; Robinson & Whittaker, 1985). Similarly, although 2.5-year-olds sought clarifying information in the finding game used by Call and Carpenter (2001), children did not do so in ambiguous referencing tasks before they were 6 or 7 years old (e.g., Beck & Robinson, 2001, Experiment 3).

However, apart from the far-reaching theoretical distinction between implicit and explicit processes, the crucial experimental factor that makes partial exposure tasks difficult for children may simply be the explicit reference to children’s knowledge state, as used by Beck, Robinson, and Rowley (2012, know condition) and Rohwer et al. (2012). This is supported by results from Beck et al. (2008, Experiment 2), where a picture was gradually revealed and children needed to stamp on the matching alternative once they had enough information to do so. Children were significantly better than they were in the know game, where they needed to answer a question like “Do you really know which one it is or don’t you really know?” However, the data from the delay game in their first experiment seem to speak against our hypothesis. Although their younger group of 6-year-olds found the delay game to be easier than the know game, these children’s performance of about 60% correct was not what one would expect from Balcomb and Gerken’s (2008) finding with 3-year-olds who skipped difficult trials successfully. Children in the delay game, however, had problems not only with the partial exposure trials but also with the knowledge trials. This indicates that they had general problems with the delay response and that the data might not speak to specific problems with partial exposure. So the studies in which children need to skip difficult trials provide an inconsistent picture.

To get a clearer picture of whether reference to mental states poses the critical source of difficulty, we modified the total ignorance and partial exposure tasks of Rohwer et al. (2012). Children could respond behaviorally without needing to answer a question about their knowledge. Neither did we opt for opting out (skipping difficult trials) as our dependent measure. Instead, children could respond with a compromise solution to partial exposure problems. Nevertheless, after their behavioral response, we asked children an explicit metacognitive question about their knowledge. This allowed us to replicate the findings of Rohwer and colleagues and nicely gauge the difficulty of the new behavioral measure. If it removes the difficulty of the metacognitive know question under partial ignorance, then performance should be significantly better than performance on answering the know question. If it does not remove this difficulty, then it should be significantly more difficult than performance on the know question under total ignorance.

Experiment 1

We used a hiding task (animal house task) with three houses. There was (a) a cathouse containing only cats and food, (b) a doghouse containing only dogs and food, and (c) an animal house containing

only food. The child's task was to bring an animal back home safely after it had run away. There were three choices: (a) bringing the animal back to its own home (e.g., a cat to the cathouse and a dog to the doghouse; this was the best option), (b) bringing it to the wrong home (i.e., dog to cathouse or cat to doghouse; this is the worst option because a fight between the animals is likely), or (c) bringing it to the neutral animal house (a kind of safe haven from which the animal can be transferred to its own home).

In the beginning, there were two training phases. In the first training phase, children learned to assign an animal to the correct house (i.e., cat to cathouse and dog to doghouse). The second training phase was similar to the first one, but now when the child attempted to bring the cat to the cathouse, the door was closed and the child needed to select either the doghouse or the neutral animal house. If the child understood that the animal house was a safe haven and brought the animal temporarily to this house, then the test phase began. Children who brought the animal to the wrong home were dropped from the experiment.

In the (critical) partial exposure task, an animal had run away and children knew that it was either a dog or a cat. The animal was caught by someone and put into an opaque cage. The main question was whether children would play it safe and bring the cage with the animal to the neutral animal house in order to avoid ("opting out from") the possible error of bringing the animal to the wrong house. After this indirect measure of awareness of own ignorance, children were also asked a direct metacognitive question: "Do you now know which animal is in the box or do you not know?"

To investigate whether children would be better able to acknowledge their own ignorance in a total ignorance task than in our partial exposure task, a total ignorance task was included. In this task, children were shown a box and told that an object (never shown) was going to be hidden in the box. Half of the children received the total ignorance task first, and the other half received the animal house task first. Given Rohwer et al. (2012) finding that even 97% of 3-year-olds admitted ignorance in the total ignorance task, but only about 30% of children under 6 years of age did so in the partial exposure task, we expected that children would have significantly more problems with the partial exposure task (on both measures) than with the total ignorance task. In contrast, an early competence view that ascribes the problems with the partial exposure task in Rohwer and colleagues' study to problems in understanding the meaning of "to know" would predict that children should perform better on the indirect/behavioral measure than on the direct/verbal measure of the partial exposure task.

Method

Participants

A total of 87 children participated in the study. Five children were eliminated from the sample after the training phase because they always put the box to one of the wrong houses. The final sample consisted of 82 children (44 boys and 38 girls). There were 12 3-year-olds (range = 37–46 months; $M = 43.33$ months, $SD = 2.60$), 17 4-year-olds (range = 49–59 months; $M = 54.65$ months, $SD = 3.37$), 18 5-year-olds (range = 62–70 months; $M = 66.17$ months, $SD = 2.68$), 13 6-year-olds (range = 72–81 months; $M = 74.46$ months, $SD = 2.88$), 12 7-year-olds (range = 84–95 months; $M = 89.25$ months, $SD = 3.82$), and 10 8- and 9-year-olds (range = 98–116 months; $M = 106.50$ months, $SD = 5.40$). Children were recruited from four different nurseries and two after-school care centers.

Materials

For the animal house task, three cardboard houses ($9 \times 8.5 \times 8.5$ cm) with brown doors, which could be opened, were used. There was a silver feeding bowl (diameter = 3 cm) on the right side of each house. As protagonists, two small plastic cats, two small plastic dogs, and a toy figure named the "animal catcher" were used. Animals of the same species differed from each other in terms of their fur color (e.g., one cat had red fur and the other one was gray). A small cardboard box ($5 \times 5 \times 8$ cm) with a lid was used as a trap box for the runaway animals. A big cardboard screen (33×33 cm), depicting a forest, was placed between the child and the experimenter so that the child could not see which animal was being trapped by the animal catcher. For the total ignorance task, an opaque box ($30 \times 18 \times 12$ cm) with a lid and a small toy were used.

Design and procedure

Two different tasks were used: a total ignorance task and an animal house task (partial exposure task). Each child received both tasks in one session. The sequence of tasks was counterbalanced between participants. In addition, in the animal house task, the position of the three houses at the beginning, the verbal presentation of the two response alternatives in the second training phase (see below), and the animal (dog or cat) that (in each training phase) was first put in the animal catcher's box were counterbalanced.

The animal house task consisted of two training phases and one partial exposure test phase. The training phases were administered to acquaint children with the basic task structure. Three houses were placed in a row in front of a cardboard wall ("forest"). One of the houses was called the "cathouse"; it was inhabited by two cats that were placed nearby. One house was called the "doghouse" and was inhabited by two dogs visible around the house. And one house was referred to as the "animal house"; no animal was around this house. All three houses had a silver feeding bowl at their right corner. The doors of all houses (except for the animal house in Training Phase 1) were open at the beginning of each phase.

The task started with Training Phase 1. The experimenter explained that each of the cats likes to live in the cathouse because there is plenty of food and other cats are around. In a similar way, the experimenter explained why dogs like to live in the doghouse. Finally, children were told that the animals like to run into the woods and that it was children's task to bring the animals back home safely. The experimenter then added that children should avoid bringing the cat to the doghouse because otherwise the cat would be beaten up by the dogs. In addition, children were advised not to bring the dog to the cathouse because otherwise the dog would get scratched by the cats.

After this basic instruction, the experimenter hid one cat and one dog behind the cardboard wall and said, "Look, a cat and a dog have gotten lost in the forest, but the animal catcher can only catch one of the two animals with his small box." Then, one of the animals (counterbalanced whether dog or cat first) was put into the animal catcher's box. The box was placed in front of the children so that they could see which animal was inside, and the experimenter asked, "Do you put the box with the cat/dog to this house?" while moving the box toward the nonmatching house (e.g., she moved the box with the cat to the doghouse). If children agreed, the experimenter showed how the hostile animals chased the caught animal and explained, "This was not good because now the poor cat/dog is in a really bad state!" If children disagreed, she asked, "Where would you put the box with the cat/dog then?" If children indicated the correct house, the experimenter said, "Yes, that's right, because now the cat/dog is very happy." For those children who did not place both animals correctly, the game started again. Some of these children had attempted to place the animal to the neutral animal house. In this case, these children were told that the door of the animal house was closed today. One child failed again after the restart and was dropped from the experiment.

In the second training phase, the experimenter explained, "If the animal catcher gets one of the animals, then you have to bring the animal back home. Sometimes, you may have problems figuring out to which house the animal in the box belongs. Then, you can bring the box to the animal house, and the animal catcher will bring the animal back to the right home later, so that nothing can go wrong. But don't forget: Although the animal is safe in the animal house and has plenty of food there, you should not bring the animal to this house if it is not really necessary because the animal will miss his/her friends." Then, the experimenter placed one cat and one dog behind the cardboard screen. One of the animals (cat or dog, counterbalanced) was put into the animal catcher's box. Subsequently, the box was placed with the lid open in front of the children, and the experimenter asked, "Where will you put the box with the cat/dog?" If children gave the animal to the house with the hostile animals, they were excluded from the experiment. If children responded correctly (i.e., dog to doghouse, cat to cathouse), the door of the respective house was closed and the experimenter said, "Oops, the door is locked today, and the cat/dog cannot get into his/her own home! But you could give the cat/dog either to this house [the experimenter pointed to the house with the hostile animals] or to the animal house." (The presentation of the two answer alternatives was counterbalanced.) Then, the critical test question followed: "Where will you put the box with the cat/dog?" If children put the animal to the hostile house, they were dropped from the experiment. If children brought the animal to the animal house, the experimenter said, "Well done. Now you have avoided making a mistake, that is, you have

avoided putting the cat/dog to the house with the dogs/cats.” As soon as one of the animals was correctly put to the animal house, the test phase began.

The procedure of the test phase was the same as for Training Phase 1, with the sole exception that after one of the animals had been hidden the box was placed with its lid *closed* in front of the children. Then, the experimenter asked, “Where will you put the box with this animal?” After children had placed the box to one of the three houses, the experimenter asked a follow-up question (before the lid was opened): “Do you know which animal is in the box or do you not know?” A single child answered affirmatively but did not immediately name an animal. In this case, the experimenter added, “Which animal is in the box?” Finally, all children were asked a second follow-up question: “Do you really know that or are you just guessing?” The order of the forced-choice questions (“Do you know which toy is inside or do you not know?” and “Do you really know that or are you just guessing?”) was not randomized because the reverse ordering is uncommon in everyday language.

In the total ignorance task, a toy (which children had not seen before) was hidden in a box. Then, the experimenter said, “Okay, now I have hidden a toy in the box. Do you know which toy is inside or do you not know?” Depending on children’s answer, different sequences of control questions followed. If children incorrectly claimed to know, the experimenter asked the following questions: (a) “Okay, then, tell me what toy is inside?”; (b) “Do you really know that or are you just guessing?”; and (c) “How do you know that there is an X [name of toy] inside?” If children correctly denied any knowledge, the experimenter asked, “Why don’t you know which toy is inside?”

Results

In the animal house task, children received a score of 1 in the partial exposure phase if they put the box with the unknown animal to the animal house. Children received a score of 0 if they overestimated their knowledge and put the box to the cathouse or doghouse. On the verbal follow-up question of the partial exposure task and on the test question of the total ignorance task (i.e., “Do you know which toy is inside or do you not know?”), children received a score of 1 if they verbally admitted ignorance. Children also received a score of 1 if they responded with a particular animal but then admitted to have just guessed on the subsequent “know/guess” question (“Do you really know that or are you just guessing?”). Children received a score of 0 if they claimed to know (either by answering with “yes” or by naming an animal) and still insisted to know on the subsequent know/guess question. Children’s responses on the ignorance justification question (“Why don’t you know which toy is inside?”) were scored as correct when children referred to the lack of informational access (e.g., “My eyes were closed!”; “I have not seen the hiding!”). All other answers were scored as incorrect (e.g., “I simply do not know that!”). To correct for multiple comparisons, alpha level was set at $p < .00625$ (Bonferroni adjustment for the eight individual tests).

Children’s performance on the two tasks differed markedly. Although nearly all children acknowledged their own ignorance on the total ignorance task ($M = 92.7\%$, $SD = .26$), only about half of the children did so on the partial exposure task (behaviorally: $M = 43.9\%$ correct, $SD = .50$; verbally: $M = 51.3\%$ correct, $SD = .50$). Accordingly, McNemar tests showed a significant difference between children’s responses on the total ignorance task and behavioral responses ($p < .001$), as well as verbal responses ($p < .001$), in the partial exposure task. There was no significant difference between children’s behavioral and verbal performance on the partial exposure task (McNemar: $p > .30$).

In addition, logistic regression analyses revealed some age-related changes on the tasks (see Fig. 1). In the total ignorance task, performance did not significantly increase with age (Wald statistic = 3.69, $p > .05$). The majority of children either promptly admitted ignorance on the test question ($n = 66$) or first claimed knowledge but then admitted that they had just guessed on the know/guess question ($n = 12$). These children ($n = 78$) subsequently received the ignorance justification question (“Why don’t you know which toy is inside?”).

Particularly children younger than 6 years had problems in justifying their own ignorance ($M = 30\%$ correct, $SD = .46$). But even 6- to 9-year-olds were not perfect ($M = 79.4\%$ correct, $SD = .41$). Children’s justifications improved significantly with age (Wald statistic = 13.13, $p < .001$), with 18% of the 3-year-olds, 46% of the 4-year-olds, 25% of the 5-year-olds, 69% of the 6-year-olds, 90% of the 7-year-olds, and 80% of the 8- and 9-year-olds giving correct justifications.

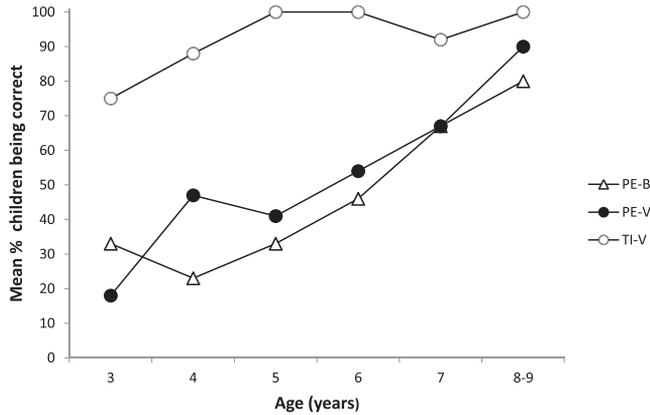


Fig. 1. Mean percentages of children being correct in the total ignorance task (TI-V), the verbal partial exposure task (PE-V), and the behavioral partial exposure task (PE-B) in the different age groups.

In the partial exposure task, children’s ability to *react adaptively* to their own uncertainty by placing the unknown animal to the animal house (“Where will you put the cat/dog?”) significantly improved with age (Wald statistic = 9.14, $p = .002$; PE-B in Fig. 1). In addition, children’s ability to *verbally acknowledge* their own ignorance in the partial exposure task (“Do you know what is in the box or do you not know?”) significantly improved with age (Wald statistic = 10.02, $p = .002$; PE-V in Fig. 1).

Children’s behavioral and verbal responses in the partial exposure task were highly correlated, $r = .63, p < .001$, even when controlling for age, $r(71) = .34, p = .003$ (see Table 1).

Discussion

To sum up, although even young children (at least from 4 years onward) were able to acknowledge their ignorance in the total ignorance task, only by around 6 years did children do so in the partial exposure task. This replicates Rohwer et al. (2012) as well as earlier experiments using verbal partial exposure (Sodian & Wimmer, 1987) or total ignorance tasks (e.g., Pratt & Bryant, 1990). Rohwer and colleagues argued that children overestimate their knowledge in partial exposure tasks due to a misleading feeling of competence (being able to produce something like a “relevant guess”).

Importantly, children also had difficulties with the behavioral measure of the partial exposure task. This indicates that it is not explicit verbal reflection that makes it difficult for children to admit their ignorance in the partial exposure task. This is in line with evidence that children do not show much

Table 1
Contingency between individual children’s behavioral and verbal responses on the partial exposure task.

Behavioral responses to question: “Where do you put the box with this animal?”	Verbal responses to knowledge test question: “Do you now know what is in the box or do you not know?”				Total
	“Yes I know”	Dog	Cat	“I do not know” ^a	
Doghouse	1 ^b	11	3	5	20
Cathouse	0	1	18	5	24
Animal house	0	3	2	31	36
Total	1	15	23	41	80 ^c

^a If children admitted to “guessing” after having given an affirmative response to the knowledge test question, they were classified under the category “I do not know”.

^b The single child answering with “Yes I know” answered with “dog” to the subsequent question “Which animal is in the box?”.

^c Two children did not give an answer to the knowledge test question.

sensitivity to their own uncertainty before 6 or even 7 years of age by using a question mark (e.g., Robinson & Whittaker, 1985), by deferring a response briefly (e.g., Beck et al., 2008, Experiments 1 and 2), or by providing two mats for the arrival of an object that could fall from one of two doors (Robinson et al., 2006).

On the other hand, 3- to 5-year-old children's reluctance to use a behavioral opt-out response (put box to animal house) seems to contradict the findings of Balcomb and Gerken (2008), who reported that even 3½-year-olds tended to opt out reliably in a memory recognition test when they could not remember the answer. This apparent discrepancy resolves when we assume that memory failure works like a total ignorance condition. In this condition, children cannot find the relevant answer (i.e., they have no "sense of knowing"); therefore, children admit ignorance (cf. Kloo & Rohwer, 2012; Rohwer et al., 2012). Thus, Balcomb and Gerken's (2008) data suggest that children are able to use an opt-out response when there is no sense of knowing. Note, however, that not only a complete memory retrieval failure may serve as a cue for ignorance; also serving as a cue may be a feeling of retrieval disfluency (i.e., a lack of ease in retrieving a plausible memory item) resulting from, for example, a conflict between to-be-remembered memory items (for a similar argument, see Kloo & Rohwer, 2012; Koriat, 1993; Koriat, 2007; Koriat, 2012; Rohwer et al., 2012).

However, this "sense of knowing" interpretation cannot explain other robust data (Call & Carpenter, 2001) suggesting that 2½-year-olds are able to respond adaptively to their own ignorance in partial exposure tasks when they are able to respond with nonverbal information-seeking behavior. Experiment 2 investigated this issue.

Experiment 2

Experiment 1 showed that although from 4 years of age onward children admit their ignorance in total ignorance tasks, they continue to overestimate their own competence in a partial exposure task until 6 or 7 years of age—even when they are allowed to express ignorance behaviorally. This difficulty has also been consistently reported in studies using ambiguous referencing tasks where preschool children fail to search or ask for clarifying information (e.g., Beck & Robinson, 2001, Experiment 3; Ironsmith & Whitehurst, 1978; Sommerville et al., 1979). However, in contrast to these findings, Call and Carpenter (2001) reported sensitivity to own ignorance in very young children when measuring visual exploratory information-seeking behavior in partial exposure tasks. This discrepancy might be due to the fact that visual exploratory information-seeking behavior is automatically triggered whenever children are in a *state of ignorance*. To investigate this discrepancy, we combined the methodology used by Call and Carpenter and that used in the ambiguous referencing tradition in a common task frame.

To this end, eight partial exposure tasks (PETs; see Table 2) were used in which children needed to find a star hidden in one of two (or three) cups. The eight tasks differed along three dimensions: (a) quality of information (uninformative, insufficient, or sufficient), (b) modality of information (visual or verbal), and (c) number of items (2 or 3).

Task 1 (PET-2) and Task 2 (PET-3) were partial exposure tasks in which only limited information about the star's location was given. Instead, children knew only that the star had been hidden in one of two (PET-2) or three (PET-3) white cups. Task 3 (PETvisual_3 → 2) was a partial exposure task in which visual information was given that was, however, insufficiently informative to be unique (for short: insufficient). In this task, the experimenter reduced the possible hiding locations from three to two (by lifting one of the empty cups). Task 4 (PETvisual_3 → 1) was a partial exposure task in which sufficient visual information was given—identifying the correct one of three white cups (i.e., the experimenter lifted the cup containing the star). Task 5 (PETverbal_2) and Task 6 (PETverbal_3) were partial exposure tasks in which redundant verbal information was given. The experimenter stated, "It is under the red," but this information was *uninformative* because there were either two (PETverbal_2) or three (PETverbal_3) red cups. Task 7 (PETverbal_3 → 2) was a partial exposure task in which insufficient verbal information ("It is under the red") was provided; this information reduced the possible hiding locations from three (two red and one green) to two cups. Task 8 (PETverbal_3 → 1) was a partial exposure task in which sufficient verbal information was given ("It is under the green").

Table 2
Task design.

Partial Exposure Tasks (PET)		Clue		Test: Find the star
1	PET-2	none		<u>△ △</u>
2	PET-3			<u>△ △ △</u>
3	PETvisual_3→2	visual	<u>△ △ △</u> △	<u>△ △ △</u>
4	PETvisual_3→1		△ ☆ △ △	<u>△ △ △</u>
5	PETverbal_2	verbal	“under the red ”	<u>△ △</u>
6	PETverbal_3		“under the red ”	<u>△ △ △</u>
7	PETverbal_3→2		“under the red ”	<u>△ △ △</u>
8	PETverbal_3→1		“under the green ”	<u>△ △ △</u>

Note. For interpretation of the references to and uses of color in this table, the reader is referred to the Web version of this article.

Based on the findings by Call and Carpenter (2001), we expected that even the youngest children should peek before answering in all conditions except in Task 4 (PETvisual_3 → 1) and Task 8 (PETverbal_3 → 1), where they know the exact hiding place. However, because children often consider (indirect) verbal information as unreliable (e.g., Mitchell, Robinson, Nye, & Isaacs, 1997; Perner & Davies, 1991) or as less certain than knowledge stemming from direct perceptual sources (e.g., Robinson, Mitchell, & Nye, 1995; Zaitchik, 1991), they might check more often after receiving unambiguous verbal information than after receiving unambiguous visual information.

Method

Participants

A total of 90 children (53 boys and 37 girls) participated. There were 22 3-year-olds (range = 41–47 months; $M = 44.68$ months, $SD = 2.36$), 15 4-year-olds (range = 49–59 months; $M = 55.40$ months, $SD = 3.11$), 28 5-year-olds (range = 61–71 months; $M = 66.25$ months, $SD = 3.47$), 15 6-year-olds (range = 72–82 months; $M = 74.33$ months, $SD = 2.41$), and 10 7-year-olds (range = 84–95 months; $M = 88.50$ months, $SD = 4.01$). Children were recruited from three different nurseries and two after-school care clubs.

Materials

A brown partition wall (45 × 3.5 × 42 cm) was used to conceal the hiding process. Seven plastic cups (three white, three red, and one green), which were opaque except for a small hole in their top, served as hiding places. A bonbon was used as a target object in the training trials, and eight yellow cardboard stars (3 × 3 cm) were used as target objects in the test trials. In addition, a white sheet displaying the black contours of eight stars was used; stars that had been found by children in the test phase were placed onto these contours so that children could track their progress.

Design and procedure

Two training tasks and eight different test tasks (see Table 2) were used. Each child received all tasks in one session. The sequence of the tasks was counterbalanced between participants, as was

the wording of the prompt used in the test trials (either “You can now either peek into all cups or you can lift the correct cup straightaway” or “You can now either lift the correct cup straightaway or you can peek into all cups”).

The experiment always started with two training trials, in which two white opaque cups were used as possible hiding locations for a bonbon. In the first training trial, the experimenter explained that a bonbon was going to be hidden under one cup and that it was children’s task to find the bonbon. After the bonbon had been covertly hidden, the experimenter said, “This time the bonbon can be under both cups; therefore, you have to peek through the small holes in the top of the cups before you can find the bonbon and lift the correct cup.” Children were told that peeking was allowed as often as they wished, whereas lifting was allowed only once, namely, for the cup containing the bonbon.

In the second training trial, children were allowed to watch the hiding. Then, the experimenter said, “This time you do not have to peek through the holes because you can lift the correct cup straightaway.” After children had successfully completed the second training trial, the bonbons were replaced with yellow stars. Children were told that they should always try to win as many stars as possible because stars could be exchanged for stickers. Before the test trials started, the experimenter said, “The game we are about to play now works in the same way as the previous game. Sometimes you have to peek into the cups if you cannot find the cup in which something is hidden straightaway, and sometimes you can lift the correct cup straightaway.”

Children were then given eight test tasks, which consisted of six uninformative (or insufficient information) tasks and two informative hiding tasks (see Table 2). In all tasks, children were confronted with a set of two or three opaque cups; in one of these cups, a star was hidden. Children were told that if they lifted the correct cup they would win a star; otherwise they would lose one. The star was won when children lifted the correct cup after having checked the content but also when children lifted the correct cup by sheer luck.

Results

The main question was whether children would discriminate between the six uninformative (or insufficient information) tasks and the two informative tasks by being more likely to seek clarifying information when it was necessary. Children received a peeking score of 0 or 1 for each task, depending on whether they checked (i.e., peeked into = 1) the cups or not (0). Table 3 displays the frequency of individual children’s response patterns and age-related changes (separately for visual and verbal tasks).

Of the 90 children, 32 (35.5%) showed the optimal response pattern in all eight tasks. That is, they peeked when insufficient information was given but lifted the correct cup straightaway in *both* informative tasks. Another 14 children (15.5%) peeked into the cups in at least four or five of the six tasks

Table 3
Individual children’s response patterns over the course of the eight subtasks.

Visual tasks				Age group (years)				Total
1	2	3	4	3	4	5	6–7	
peek ⁺	peek ⁺	peek ⁺	lift ⁺	6	14	19	18	57
peek ⁺	peek ⁺	peek ⁺	peek ⁻	6	1	1	1	9
lift ⁻	lift ⁻	lift ⁻	lift ⁺	4	0	1	1	6
peek ⁺	peek ⁺	lift ⁻	lift ⁺	2	0	2	3	7
	other pattern			4	0	5	2	11
Verbal tasks				Age group (years)				Total
5	6	7	8	3	4	5	6–7	
peek ⁺	peek ⁺	peek ⁺	lift ⁺	3	6	17	16	42
peek ⁺	peek ⁺	peek ⁺	peek ⁻	12	6	6	6	30
lift ⁻	lift ⁻	lift ⁻	lift ⁺	3	0	1	1	5
peek ⁺	peek ⁺	lift ⁻	lift ⁺	2	2	0	1	5
	other pattern			2	1	4	1	8

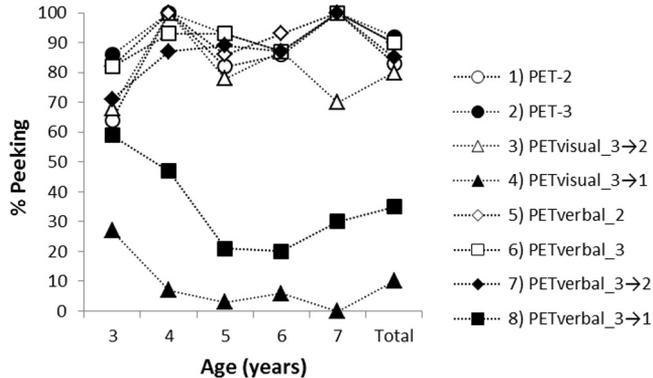


Fig. 2. Mean percentage of visual exploratory behavior (peeking responses) in the eight tasks of Experiment 2 in the different age groups as well as in the total sample.

with insufficient information but did not check the cups in *both* informative tasks. A further 19 children (21.1%) peeked into the cups in all six uninformative tasks but lifted a cup straightaway in only *one* of the two informative tasks. Finally, 7 children (7.7%) showed a *checking bias* (i.e., they always peeked before lifting a cup), whereas 3 children (3.3%) showed a *lifting bias* (i.e., they always lifted a cup straightaway). Interestingly, if we look separately at visual and verbal tasks, there was a particular strong checking bias in the verbal tasks ($n = 30$).

Fig. 2 shows children's performance in the eight different tasks in addition to age-related changes. First, we tested whether all six uninformative tasks were significantly interrelated. This was the case with r s ranging from .30 to .70, all p s < .01. Therefore, a total uninformative score was calculated per child (mean percentage of peeking responses across the six tasks). Then, to correct for multiple comparisons, we applied a Bonferroni adjustment for the six different tests (alpha level was set at $p < .00833$).

Wilcoxon tests showed significant differences between the PETverbal_3 → 1 task ($M = 35.56$, $SD = 48.14$) and the uninformative task ($M = 87.36$, $SD = 25.16$; $p < .001$) as well as between the PETvisual_3 → 1 task ($M = 10.00$, $SD = 30.17$) and the uninformative task ($p < .001$). In addition, children peeked significantly more often in the PETverbal_3 → 1 task than in the PETvisual_3 → 1 task (McNemar: $p < .001$).

Logistic regression analyses revealed no significant age-related changes on the PETverbal_3 → 1 task (Wald statistic = 6.77, $p = .009$) and on the PETvisual_3 → 1 task (Wald statistic = 5.59, $p = .018$). In addition, there was no significant effect of age on performance in the uninformative tasks according to a Kruskal–Wallis test ($p > .05$).

Discussion

Even the youngest children were sensitive to what they had seen in the PETvisual_3 → 1 task given that they did not check where the star was after the experimenter had lifted the cup with the star. This replicates previous findings by Call and Carpenter (2001, Experiment 3). In addition, in all age groups, some children had sensitivity to their knowledge originating from the verbal information in the PETverbal_3 → 1 task. However, in line with previous research showing that children often consider knowledge stemming from verbal information as being less certain than knowledge originating from visual sources (e.g., Robinson et al., 1995), children tended to check the cups more often in the PETverbal_3 → 1 task than in the PETvisual_3 → 1 task. This tendency became less pronounced with increasing age, implying either that children's sensitivity to their own knowledge increased with age or that older children regarded verbal messages as more reliable than younger children did.

Based on Call and Carpenter's (2001, Experiment 3) findings, we predicted that children would show different information-seeking behavior depending on whether they were knowledgeable or

ignorant. This prediction was largely confirmed; half of the 3-year-olds (11 of 22), the majority of the 4-year-olds (14 of 15), and the majority of the 5- to 7-year-olds (46 of 53) peeked when being ignorant (in the majority of the tasks with insufficient information) but lifted a cup straightaway in at least one of the two informative tasks.

Thus, contrary to the ambiguous referencing literature (e.g., Beck & Robinson, 2001, Experiment 3; Ironsmith & Whitehurst, 1978) showing that children up to 6 years of age do not seek clarifying information, participants did not overestimate their own knowledge after having received ambiguous (verbal) information in Experiment 2. In addition, in previous research young children have been found to look for information in partial exposure tasks when no information was given but committed themselves straightaway when either uninformative (redundant) or insufficiently informative (to be unique) information was given. However, in the current experiment, children did not lift a cup straightaway after having received redundant information.

To sum up, Experiment 2 showed that children look more often for clarifying information in uninformative (or insufficiently informative) partial exposure tasks than in informative tasks, although there was some general tendency to reassuringly check the cups in the informative task using verbal information. Given that young children typically fail to explicitly (and metacognitively) assess their own ignorance in partial exposure tasks (e.g., Rohwer et al., 2012), we argue that our findings indicate an implicit or pre-reflective access to own ignorance. Interestingly, this is in line with evidence that when young children are confronted with an ambiguous input, they typically fail in terms of explicit metacognitive judgments, but they often exhibit implicit signs of uncertainty such as showing puzzled expressions or prolonged response latencies (e.g., Bearison & Levey, 1977; Plummert, 1996). In addition, in a recent study, Kim, Paulus, Sodian, and Proust (2016) showed that 3- and 4-year-old children are sensitive to their own ignorance in a partial exposure task when they are asked to inform another person.

General discussion

Previous studies indicated that children acquire complete meta-epistemic competency relatively late during their childhood. That is, although children are able to correctly assess their own knowledge (e.g., Pratt & Bryant, 1990), they have problems in accurately gauging their own ignorance (e.g., Robinson et al., 2006; Sodian & Wimmer, 1987). We argue that these problems are due to a lack of metacognitive insight in their own lack of knowledge.

Typically, studies used a direct approach for assessing children's meta-epistemic insight (mainly by asking children directly about their own epistemic states); therefore, these studies may have underestimated children's actual understanding of their own ignorance. Indeed, children show some sensitivity to their own ignorance when being allowed to react indirectly (e.g., Balcomb & Gerken, 2008; Bearison & Levey, 1977; Call & Carpenter, 2001). But evidence for this early competence (or implicit access) view was often hard to interpret because other studies failed to show evidence for such an early sensitivity in very similar task settings (e.g., Balcomb & Gerken, 2008 vs. Call & Carpenter, 2001; Robinson & Whittaker, 1985 vs. Beck & Robinson, 2001, Experiment 3). Thus, we conducted two experiments to investigate this obvious discrepancy.

We obtained mixed evidence regarding children's early understanding of their own ignorance. In Experiment 1, even young preschoolers were able to explicitly assess their own ignorance in a total ignorance task, but there was no evidence for such an early understanding in a partial exposure task. This difficulty also existed even without questioning children explicitly about their knowledge when they were allowed to react adaptively by opting out (to avoid possible errors). This is in line with previous findings showing that children can neither use a question mark (e.g., Robinson & Whittaker, 1985) nor defer a response briefly (e.g., Beck et al., 2008) to avoid an error in ambiguous reference tasks.

In contrast, Experiment 2 provided evidence for such early adaptive behavior. Even young preschoolers sought clarifying information in partial exposure tasks in order to optimize performance. This is in line with Call and Carpenter (2001, Experiment 3; see also Kim et al., 2016). Four-year-olds showed this adaptive behavior even in response to ambiguous statements, which contrasts with the

ambiguous referencing literature showing that preschool children do not seek clarifying information before 6 or 7 years of age (e.g., Beck & Robinson, 2001, Experiment 3; Sommerville et al., 1979).

To explain these contrasting findings, we propose the following tentative explanation. We suggest that the relevant information-seeking responses in Experiment 2 (and similar studies) are early adaptive strategies to a lack of knowledge or uncertainty. These responses are automatically triggered whenever children are in a state of ignorance. For instance, when looking for an object knowing that it is in a room but not where in the room, one naturally goes to the room and then explores the room to spot the object. One does not need to reflect on one's ignorance about the object's precise location. One simply searches for it because one is ignorant without needing to think to oneself metacognitively, "I don't know where the object is; therefore, I need to look around."

Being in a state of ignorance or uncertainty has other typical consequences such as hesitation, a puzzled expression, and an elevated heartbeat. These effects are direct causal consequences of being ignorant and are not mediated by any metacognitive awareness of one's ignorance. One does not need to think, "Oh, I don't know which one he means, so I should look puzzled." So these reactions are implicit signs of ignorance and are typically not the result of a metacognitive reflection on, or explicit representation of, one's state of ignorance.

These natural reactions to ignorance will not help children in the animal house situation (Experiment 1). When being ignorant as to whether the animal in the box is a cat or a dog, children have no natural tendency to bring the animal to the animal house. They may well have a natural desire to look inside the box, but this was not an option. Hence, they needed to reason metacognitively: "I don't know whether the animal is a cat or a dog. So if I bring it to the dog kennel and it is a cat, it will be disastrous. The same for a dog delivered to the cats. So I have to play it safe and bring it to the animal house." The same metacognitive awareness is also needed for using a question mark to indicate one's ignorance (Robinson & Whittaker, 1985) and more complex information-seeking paradigms such as those in which children need to disambiguate verbal information by asking clarifying questions (Ironsmith & Whitehurst, 1978; Sommerville et al., 1979).

A further important assumption to explain children's problems with partial exposure tasks before 6 years of age is the following: When their natural tendency to look for more information is blocked and children must decide on some action, they think of one of the possibilities (e.g., the caged animal is a dog) and then treat this possibility as if it were established knowledge. In the total ignorance condition, it is difficult to think of a possible content of a box out of the blue. So children are not trapped into mistaking a possible content as the true content, and they correctly deny any knowledge. In partial ignorance tasks, possible content is fresh in the children's mind and they take one of them as if it were the real one. Even when explicitly asked whether they really know this or are just guessing, they insist on knowing (Rohwer et al., 2012). That children up to 6 or 7 years of age have this tendency to treat a possibility as real has also been documented in their understanding of possible physical outcomes. For instance, when an object is put into a chute that branches into two chutes so that the object can end up in either branch, children pick one of the branches and put a welcoming mat to that branch instead of putting a mat to each branch (Beck, McColgan, Robinson, & Rowley, 2011; Beck, Robinson, Carroll, & Apperly, 2006; Robinson et al., 2006).

Contrary to other views, we do not suppose that, in general, children are not able to represent more than one possibility because they can entertain only a single mental model due to general working memory constraints, as Robinson et al. (2006) suggested.

For, if this were the case, older preschoolers could, for instance, not pass standard theory of mind tasks, or corresponding counterfactual tasks (Riggs, Peterson, Robinson, & Mitchell, 1998), which require the representation of alternative models. Children's success on these tasks before 5 years of age is quite well established (Wellman, Cross, & Watson, 2001). To illustrate, in the standard false belief task a protagonist, such as "Max," puts his chocolate in Location 1 and then leaves the scene. In his absence, the chocolate is unexpectedly moved to Location 2. When Max returns, children are asked where he will look for his chocolate. At around 4 years of age, children understand that Max will search erroneously at Location 1 based on his false belief. In the counterfactual version, children are asked where the chocolate would be if it had not been moved.

The difference between the false belief or counterfactual task and partial exposure tasks has to do with the truth status of alternative models. In the false belief or counterfactual task (Wimmer &

Perner, 1983), children need to represent that the *chocolate is in Location 2* (reality model) but also a model for Max (or the counterfactual conclusion), which shows his *chocolate still in Location 1*. This model is false. Children's own model is true. In contrast, when children do not know which animal is in the box, they need to realize that the truth assignment to models is still open: Either "a cat is in the box" is true and "a dog is in the box" is false or the other way around. So in addition to understanding that there can be different models, one of which is correct and the other of which is wrong as in the false belief task, partial exposure tasks require the higher-order understanding that there can be different assumptions on which model is true and which is false.

This ability to consider different truth value assignments for a model is also tested in second-order mental state tasks, which children master at a similar age. In a study by Perner and Howes (1992), nearly all 4- to 6-year-old children correctly answered a first-order question about what mistaken Max would say when he is being asked where his chocolate was. However, most of these children answered incorrectly when asked how Max would respond to the question of whether he *knew* where his chocolate was. They thought that he would say that he does not know. They apparently failed to understand that Max thinks differently about the truth of his false belief: He thinks it is true when in fact it is false.

So we have zeroed in on a common denominator of children's difficulty with partial exposure tasks and second-order mental state attribution: Children lack the ability to consider the possibility that the truth of mental models is not fixed; it can be left undecided (partial exposure tasks) or thought to be different from what it actually is (second-order mental states). Assuming that this ability develops at around 6 years of age provides some explanation of why partial exposure tasks are mastered at around the same age as attribution of second-order mental states. Indeed, recent longitudinal evidence (Kloo, Kristen-Antonow, & Sodian, 2017) indicates that performance on second-order false belief tasks and partial exposure tasks is correlated even when verbal intelligence is partialled out. This explanation can also be extended to a range of other tasks that are mastered at around this age. In the physical uncertainty tasks (Beck et al., 2006; Robinson et al., 2006), children are faced with the same uncertainty about truth values as in the partial exposure tasks. Similarly, in ambiguous reference tasks (Robinson et al., 2006, Experiment 2; Robinson & Whittaker, 1985), children need to reflect on the fact that the ambiguous statement has two interpretations and it remains an open question as to which is the true/intended one.

To summarize, we arrived at the following developmental picture. When children are given the opportunity to search for more information, even the youngest 3-year-olds tend to do so in total ignorance as well as partial exposure tasks. They can do this because information search is a natural response to *being* ignorant without needing to be metacognitively aware of one's ignorance. When children are explicitly asked whether they know, these children can also correctly deny any knowledge but only in total ignorance tasks because in these tasks it is difficult to think of at least a possible answer. In partial exposure tasks, children up to about 6 years of age claim to know because they can easily think of a possible answer, fixate this possibility as definitive, and then think they know. This problem affects a range of tasks in which children need to keep more than one possibility in mind and, importantly, leave pending the decision of which possibility will be the real (true) one: partial exposure tasks with an explicit mental state question (Rohwer et al., 2012; see also the current Experiment 1) or with a behavioral response that requires reasoning (animal house in Experiment 1), physical uncertainty tasks (Robinson et al., 2006), or ambiguous reference tasks (Robinson & Whittaker, 1985; Robinson et al., 2006). Children's assumed problems with keeping the truth assignment for mental models pending can also explain why other tasks also are mastered at 6 years of age. In higher-order mental state tasks (e.g., where Max mistakenly thinks he knows), children also need to understand that Max has a different view on whether his belief is true or false than the children themselves have. It remains for future research to establish that it is not mere developmental coincidence that these tasks are mastered at around 6 years of age but that they also show robust correlations (e.g., Kloo et al., 2017).

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