


Knowing minds: Linking early perspective taking and later metacognitive insight

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Recent metacognitive research using a partial knowledge task indicates that a firm understanding of ‘knowing about knowing’ develops surprisingly late, at around 6 years of age. To reveal the mechanisms subserving this development, the partial knowledge task was used in a longitudinal study with 67 children (33 girls) as an outcome measure at 5;9 (years:months). In addition, first- and second-order false belief was assessed at 4;2, 5;0, and 5;9. At 2;6, perspective taking and executive abilities were evaluated. Metacognition at 5;9 was correlated with earlier theory of mind and perspective taking – even when verbal intelligence and executive abilities were partialled out. This highlights the importance of perspective taking for the development of an understanding of one’s own mind.

Statement of contribution

What is already known on this subject?

- Metacognition is crucial (e.g.) for learning, thinking, social cognition, and general success in school.
- There is some evidence that earlier theory of mind predicts later metacognition.

What the present study adds?

- Earlier theory of mind and perspective taking are related to later metacognitive knowing.
- Perspective understanding is important for understanding one’s own and other people’s mind.
- Executive functions play a role, but cannot fully explain the relation between theory of mind and metacognition.

Background

In 1979, John Flavell called for a new area of cognitive–developmental inquiry focusing on metacognition and cognitive monitoring. He broadly defined metacognition as ‘knowledge and cognition about cognitive phenomena’ and also highlighted the practical importance of monitoring our cognitive enterprises (p. 906). Indeed, there is evidence that children’s ability to assess and monitor their own epistemic states is important in a large variety of contexts including learning, thinking, eyewitness memory and

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suggestibility, social cognition, and general success in school (e.g. Fisher, 1998; Hacker, Dunlosky, & Graesser, 2009; Lockl & Schneider, 2007; Roebbers, 2002).

‘Metacognition’ is an umbrella term including a number of different skills and abilities. According to Kuhn (2000a, p. 178), metacognition can be defined as ‘cognition that reflects on, monitors, or regulates first-order cognition’. Within the realm of metacognition, researchers have drawn a distinction between different sub-components. We can distinguish between ‘metacognitive knowing’ as declarative metacognition (knowing that) and ‘meta-strategic knowing’ as procedural metacognition (knowing how; see, e.g. Kuhn, 2000a, 2000b; Schneider, 2008).

While metacognitive knowing entails abilities like understanding of mental states (beliefs, desires, emotions, consciousness) and corresponding mental verbs, meta-strategic knowing can be conceptualized as our knowledge about memory processes (metamemory; Flavell & Wellman, 1977). Within metamemory, declarative metamemory denotes knowledge about person, task, and strategy variables for memory performance, and procedural metamemory encompasses processes of monitoring (e.g. feeling-of-knowing) and control (e.g. allocation of study time; e.g. Kuhn, 2000a). Nelson and Narens (1990) argue that control means that the meta-level modifies the object-level (e.g. by initiating or terminating and action), while monitoring means that the meta-level is informed by the object-level (leading to changes in the meta-level’s model of the situation).

Another area of research, which (similar to the concept of ‘metacognitive knowing’) investigates children’s understanding of mental states, is ‘theory of mind’, that is, our ability to ascribe mental states such as beliefs, desires, and emotions to oneself and to others (Doherty, 2009; Perner, 1991). At around 4 years of age, children understand that someone may hold a false belief. In the Maxi task (Wimmer & Perner, 1983), children witness Maxi putting chocolate in location A. In his absence, the chocolate is transferred to a second location B. Then, Maxi returns, and children are asked where he will look for the chocolate. At around 4, children understand that Maxi holds a false belief (‘the chocolate is in Location A’), whereas they themselves have a true belief (‘the chocolate is in Location B’).

Around 2 years later, children also master so-called second-order false belief tasks. In these tasks, they have to realize that someone may have a false belief about someone else’s belief (e.g. Miller, 2009; Perner & Wimmer, 1985; Sullivan, Zaitchik, & Tager-Flusberg, 1994). For example, in the Birthday Puppy story (Sullivan *et al.*, 1994), children have to understand that Peter’s mom has a false belief about Peter’s belief. Peter’s mom thinks that Peter thinks that he will get a toy for his birthday, but he already knows that he will get a puppy from his mom.

As can be seen, in a general sense, research on both, theory of mind and metacognition, has the same objective, namely ‘exploring children’s knowledge about and understanding of mental phenomena’. (Schneider, 2008, p. 115) While thus conceptually related, metacognitive research mainly investigates children’s understanding of their own mental states, whereas theory of mind research puts emphasis on children’s understanding of other persons’ mental states. Kuhn (2000a) proposed that metacognition begins to develop at around 3 years of age closely linked to theory of mind understanding and then follows an extended and protracted developmental course. In particular, theory of mind and metacognition may be interrelated in development, because understanding the importance of informational access for knowledge formation is related to children’s understanding of the mental world and the concept of representation (e.g. Perner, 1991; Schneider, 2008).

Nevertheless, research on theory of mind and metacognition has been relatively unconnected (for a discussion, see Lockl & Schneider, 2006), and empirical research on the developmental relation between metacognition and theory of mind is sparse. There is some longitudinal evidence (Lockl & Schneider, 2007; see also Lockl & Schneider, 2006) showing that early theory of mind abilities are a precursor of subsequent metamemory. Lockl and Schneider (2006) found that theory of mind and understanding of metacognitive verbs (e.g. know, guess, remember) at 4–5 years of age predicted declarative metamemory (e.g. knowledge about memory-relevant variables like ‘study time’ or ‘number of items to be remembered’) at 5–6 years of age. Similarly, Lockl and Schneider (2007) found that metamemory (indicated by knowledge about memory-relevant variables) at 5 years of age was significantly associated with first- and second-order theory of mind as well as with language skills (both at the same time and 1 or 2 years earlier). The relation between theory of mind and metamemory at 5 years of age remained significant even when language ability was partialled out. Furthermore, both theory of mind and language at 3 and 4 years of age made independent predictive contributions to metamemory at 5 years of age.

Lecce, Demicheli, Zocchi, and Palladino (2015) corroborated these findings in two studies. In Study 1 with 106 preschoolers, they showed that at 4 years of age cognitive (e.g. perspective taking and false belief understanding) but not affective (measured by emotion comprehension) theory of mind tasks was related to declarative metamemory (knowledge about memory-relevant variables and memory strategies) when controlling for verbal as well as non-verbal ability and working memory. In Study 2 with 83 children, using a longitudinal design, they found that first-order theory of mind understanding at around 4.6 years predicted later declarative metamemory at around 5.2 years, independent of children’s verbal ability, but this longitudinal relationship was not significant for early metamemory at 4.6 years and later theory of mind at 5.2 years. Also, Lecce, Caputi, and Pagnin (2015) found that theory of mind understanding at 5 years predicted children’s beliefs about learning at 8 years.

To sum up, first evidence has indicated that early theory of mind predicts later metastrategic knowing (metamemory) suggesting that there is a link between metamemory and theory of mind. There has been less research on the relation between metacognitive knowledge and theory of mind. Yet, theoretically, there is even stronger overlap between theory of mind and metacognitive knowing. Consequently, one would also expect a longitudinal relation between theory of mind and metacognitive knowing. Therefore, based on theoretical views on a close interconnection between theory of mind and metacognitive development (e.g. Carruthers, 2009; Perner, 1991; Schneider, 2008), we hypothesized that there would be a correlation between children’s theory of mind understanding and metacognitive knowing. For example, it has been argued by Carruthers (2009, p. 123) that ‘metacognition is merely the result of us turning our mindreading capacities upon ourselves’.

Metacognitive knowing follows a protracted course of development. One of the first steps in metacognitive knowing occurs by age 3, when children begin to use metacognitive verbs like know and think (Olson & Astington, 1986) and comprehend the importance of informative experience for knowledge formation. They understand that they know what is ‘hidden’ inside a container, if they have previously looked inside. In addition, between 3 and 4 years, they become able to infer another person’s state of knowledge and also to acknowledge their own ignorance, when they are totally ignorant about the content of a box (Pratt & Bryant, 1990; Tardif, Wellman, Fung, Liu, & Fang, 2005; Wellman & Liu, 2004; Wimmer, Hogrefe, & Perner, 1988).

However, while there is a bulk of evidence indicating that at around 4 years of age children understand that ‘they do not know’ when they are totally ignorant about possible contents, more recent research using a partial knowledge paradigm indicates that a firm understanding of ‘knowing about knowing’, or meta-knowing, develops not until around the age of 6 years (Kloo, Rohwer, & Perner, 2017; Rohwer, Kloo, & Perner, 2012). In their partial knowledge task, Rohwer *et al.* (2012) presented 3- to 7-year-old children with a set of possible objects ahead of hiding one of these objects, that is, children knew a set of different possible contents, but they did not know which particular object had been hidden. Interestingly, when children were asked, ‘Do you know now which toy is inside or do you not know?’, more than 60% claimed to ‘know’ (denying their ignorance) up to 5 years of age. Even when they were subsequently asked a know-guess control question (‘Do you really know that or are you just guessing?’), around 90% of these children still insisted to know. In order to explain this response pattern, it has been argued that children’s difficulties in the partial knowledge task may be due to a misleading ‘feeling of competence’, because they are able to come up with a ‘relevant guess’ (Rohwer *et al.*, 2012).

More specifically, the partial knowledge task may be difficult, because it requires Level 3 perspective taking – children have to take a second-order perspective in order to know that they do not know (see also Kloo *et al.*, 2017). First-order false belief understanding like in the Maxi task requires only Level 2 perspective taking (see also, Flavell, Everett, Croft, & Flavell, 1981); children have to understand that there can be different perspectives or mental models about a real object or a situation. However, in Level 3 perspective taking tasks, children have to understand that there can be different perspectives on mental models of reality. For example, in the partial knowledge task, children have to understand that they possess different mental models of the content of the box (Level 2 perspective taking) and that the truth assignment to these models is still open; each of the possible models could be either true or false (Level 3 perspective taking). In line with this, children also have difficulties with referential ambiguities until about 6 years (e.g. Beck & Robinson, 2001), a context also requiring a second-order evaluation of one’s perspective. Therefore, Kloo *et al.* (2017) argued that the partial knowledge task and second-order false belief tests may be related, because both tasks require Level 3 perspective taking.

Even earlier signs of perspective understanding are evident through research on Level 1 understanding of visual perspectives (Flavell, Shipstead, & Croft, 1978; see also McGuigan & Doherty, 2002). In Level 1 tasks, children have to understand what another person sees or does not see. Flavell *et al.* gave 48 children between 29 and 48 months of age an object-hiding task using a toy doll and a cardboard screen. They found that even most of the 30-month-olds were able to hide an object by placing it on the correct side of the screen (so the experimenter could not see it); however, the youngest children had difficulty when instructed to hide the object by placing the screen between the object and the other person (move screen). This suggests that Level 1 perspective understanding (understanding what another person can or cannot see/know) develops at around 3 years of age (see also Pillow, 1989).

That is, at 30 months of age, children understand *what* another person sees or does not see (Level 1 perspective taking; cf. Sodian, 2016). In contrast, (explicit) false belief understanding, which emerges at around 4 years of age, requires an awareness of different perspectives, that is, an understanding of *how* oneself or another person represents an object or situation (Level 2 perspective taking). In turn, second-order false belief and partial knowledge involves an additional level of reflection (Level 3 perspective

taking; see also Kloo *et al.*, 2017), namely that there can be different perspectives about someone else's or one's own perspective.

The present study

Most research relating metacognitive and theory of mind development investigated the relation between theory of mind and meta-strategic knowing (task-related mental activities, for example, memory strategies; Lecce, Caputi, *et al.*, 2015; Lecce, Demicheli, *et al.*, 2015; Lockl & Schneider, 2007). In the present paper, however, we will focus on the relation between theory of mind and the development of meta-knowing, the ability to reflect on one's own state of knowledge, which should be intrinsically related to theory of mind development. We employed a longitudinal design and used different measures of theory of mind – Level 1 perspective taking as well as first- and second-order false belief tasks – as possible precursors and concurrently associated abilities of meta-knowing in a partial knowledge setting. In order to control for the effects of executive control, we administered an executive function task (Fruit Stroop) at the time point when children were given the first (Level 1) perspective taking task, because executive functioning has been associated with theory of mind (see Devine & Hughes, 2014, for a review) and metacognition (e.g. Roebbers, 2017; Roebbers, Cimeli, Röhlsberger, & Neuenschwander, 2012). Also, as both theory of mind understanding (for a meta-analysis, see Milligan, Astington, & Dack, 2007) and metacognition (e.g. Lockl & Schneider, 2007) are closely related to children's language abilities, we added a measure of children's verbal abilities (WPPSI-III; Petermann, 2009).

In line with theoretical frameworks on the emergence of metacognitive abilities (e.g. Carruthers, 2009; Kuhn, 2000a), we hypothesize that theory of mind is related to metacognitive knowing. Based on a model of different levels of perspective taking, we argue that second-order false belief understanding (Level 3 perspective taking) should be strongly related to metacognitive knowing as required in the partial knowledge task. However, as different levels of perspective taking are related in development, we also expect developmental relations between earlier Level 1 perspective taking as well as first-order false belief (Level 2 perspective taking) and later metacognition. If claims of a genuine relation between theory of mind and metacognition (Carruthers, 2009; Kuhn, 2000) are true, we expect that these relations should be independent of language and other cognitive abilities. We, therefore, controlled for these factors.

Method

Participants

The final sample receiving the partial knowledge task at around 6 years of age consisted of 67 children aged 5;9 (years;months, $SD = 16$ days; 33 girls). Children came from predominantly white middle-class families in an urban area of Germany. The present sample is part of a larger longitudinal study on the development of social and cognitive abilities (e.g. Kloo & Sodian, 2017; Sodian & Kristen-Antonow, 2015; Sodian *et al.*, 2016; Thoermer, Sodian, Vuori, Perst, & Kristen, 2012). Most of the 67 children also participated at earlier points in their development in the longitudinal study. Ages and number of participants for earlier measurement points were as follows: 2;6 ($SD = 12$ days; $n = 66$), 4;2 ($SD = 24$ days, $n = 65$), and 5;0 ($SD = 22$ days, $n = 66$).

Procedure

At each time point, children were tested individually in a child-friendly University laboratory by a trained experimenter. Addresses were obtained through local birth records. Participation was voluntary. Parents received full information about the study, and informed parental consent was obtained for all children who participated. Families received a travel reimbursement and a small age-appropriate gift at each measurement point. The study was approved by the ethics committee of Ludwig-Maximilian-University Munich to the project 'Longitudinal effects of preschool children's theory of mind on cognitive and social competencies in primary school'.

Measures

Our outcome measure was a metacognition task (*partial knowledge task*) based on Rohwer *et al.* (2012), which children received at the age of 5;9. In addition, *first- and second-order false belief understanding* was assessed at ages 4;2, 5;0, and 5;9. Furthermore, at the age of 2;6, children's understanding of *perspective differences* and their *executive abilities* (specifically inhibition) were evaluated. A measure of *verbal intelligence* was given at 4;0.

Metacognition task (5;9)

In this task based on Rohwer *et al.* (2012), children sat at a table opposite to the experimenter. They received three different conditions: ignorance, partial knowledge, and full knowledge – with two trials per condition in a fixed random order (full knowledge, ignorance, partial knowledge, partial knowledge, ignorance, full knowledge).

In the *ignorance condition*, children were first shown an empty, black box (28 × 20 × 11.5 cm). Then, they were told (without presenting any objects) that a game would be played, in which a toy would be hidden in the box behind a screen (45 × 4.5 × 32 cm). In the *partial knowledge* condition, children were presented with two different toys. Then, one of the toys was hidden. In the *full knowledge* condition, children were shown a toy and then watched the experimenter putting the toy in the box. In each task, after the toy had been hidden, the experimenter said, 'Okay, now, I have hidden a toy in the box. Do you know which toy is inside the box or do you not know?' If children said that they did know, the experimenter asked, (1) 'Okay, then, tell me which toy is inside?' and (2) 'Do you really know or are you just guessing?'

On each ignorance and partial knowledge trial, children received a score of 0 or 1, resulting in a sum score of 0 to 2 in each condition (ignorance vs. partial knowledge). If children spontaneously admitted ignorance on the first test question ('Do you know which toy is inside the box or do you not know?'), they received 1 point. Furthermore, some children claimed knowledge on the first test question but then correctly admitted that they were guessing on the subsequent '*know-guess*' question ('Do you really know or are you just guessing?'); these children also received 1 point. On each full knowledge trial, all 67 children answered correctly on the first test question. Therefore, only children's performance on the ignorance and partial knowledge conditions will be analysed.

First-order false belief (4;2, 5;0, 5;9)

First-order false belief understanding was measured with two tasks from the German version of the ToM Scale (Kristen, Thoermer, Hofer, Aschersleben, & Sodian, 2006; Wellman & Liu, 2004; see Hofer & Aschersleben, 2007, for the full German version). In the *contents false belief* task, children were shown a Smarties box and were asked, 'What do you think is inside the Smarties box?' After the expected answer ('Smarties'), the experimenter opened the box, revealed that the box actually contained a toy pig and then put the toy pig back in the box. Then, a Playmobil figure called Lukas was introduced, and children were asked, 'So, what does Lukas think is in the box?'

In the *location false belief* task, children were told a story about Paul, who wants to find his mittens. Children were given the following test question, 'Really, Paul's mittens are in his backpack. But Paul thinks that his mittens are in the closet. So, where will Paul look for his mittens?'

At each time point, children were given both tasks. One point was given for each correct answer yielding a total score between 0 and 2 at each time point.

Second-order false belief (5;0 and 5;9)

Second-order false belief understanding was investigated using the '*Birthday Puppy*' story about a boy called Peter whose mom wants to surprise him with a puppy on his birthday (Sullivan *et al.*, 1994). Peter's mom has hidden the puppy in the basement. Peter says, 'Mom, I really hope to get a puppy for my birthday'. Children were reminded, 'Remember, Peter's mom wants to surprise him. So she tells him that he will get a great toy instead of a puppy'. By accident, Peter finds the birthday puppy in the basement. He says to himself, 'Wow, Mom didn't get me a toy, I will really get a puppy for my birthday'.

After two control questions ('Does Peter know that he will get a puppy for his birthday?'; 'Does his mom know that Peter found the puppy in the basement?'), the story was continued, 'The telephone rings. Peter's grandmother calls to find out what time the birthday party starts. Grandma asks Peter's mom, "Does Peter know what you really got him for his birthday?"' Now, children were asked a *second-order ignorance question* ('What does Peter's mom say to Grandma?'; correct answer: 'No, he doesn't know'). Then, they were told that Grandma says to Peter's mom, 'What does Peter think you got him for his birthday?' followed by the *second-order false belief test question* ('What does Peter's mom say to Grandma?'; correct answer: 'He thinks he will get some toy'). At each time point, children received a score between 0 and 2 based on the number of test questions (second-order ignorance question and false belief test question) answered correctly.

Understanding perspective differences (2;6)

In this task based on McGuigan and Doherty (2002; see also Flavell *et al.*, 1978), children were asked to hide a toy from the experimenter (hiding task) and to judge whether the experimenter or the child him/herself can see the toy (judgement task). We did not include a move screen condition due to possible floor effects at that age.

The *object-hiding task* consisted of four trials. On the first trial (180°), the experimenter sat directly opposite the child across a small table. A cardboard screen (18 cm high × 23 cm wide) was placed on the table with the broad side turned towards the experimenter. Children were handed a Winnie the Pooh toy doll (10 × 5 × 3 cm) and were told, 'Put the bear somewhere on the table, so I can't see him'. Three more

hiding trials of this kind followed, with the experimenter sitting 90° to the child's right, 90° to his/her left, and then next to the child (at the same side of the table). On all four trials, the cardboard screen was placed broadside to the experimenter. Children received one point for each correct response resulting in a score from 0 to 4.

In the *perspective judgement* task, again, the experimenter sat opposite the child across the table (180°). The cardboard screen was placed on the table broadside to the experimenter. First, Winnie the Pooh was placed so that the toy was in clear sight of the experimenter, but blocked from the child's view. Children were asked two questions, (1) 'Can I see the bear now?' and (2) 'Can you see the bear now?'. Then, the bear was placed so that the toy was in clear sight of the child, but blocked from the experimenter's view. Again, children were asked, (1) 'Can I see the bear now?' and (2) 'Can you see the bear now?'. Children received one point for each correct response resulting in a maximum score of 4.

Finally, each child received a combined perspective understanding score representing the percentage of correct responses on the eight test trials.

Fruit Stroop (2;6)

This Stroop-like task was based on Kochanska, Murray, and Harlan (2000). First, children were shown six coloured line drawings (big and little apples, oranges, and bananas). They were asked to point to each (e.g. 'Show me the apple'). If children could correctly identify all three fruits, three test trials were given. The experimenter replaced the six cards with three cards showing a little fruit nested in a different large fruit (e.g. a little apple in a big banana). Children were required to point to each of the little fruits (e.g. 'Show me the *little* apple'); that is, children had to inhibit the tendency to point to the more salient large depiction of a specific fruit. Children received a score from 0 to 3 based on the number of correct test trials.

Verbal IQ estimate at 4;0 (WPPSI-III; Petermann, 2009)

At 4;0, verbal IQ was assessed using two subtests (*Similarities* and *Information*) of the German version of the Wechsler Preschool and Primary Scale of Intelligence-III (WPPSI-III; Petermann, 2009). Based on the raw values of each subtest, normalized scores for the given age group were assigned. In order to calculate a normalized score estimate for the verbal scale with only two (instead of three) subtests, the sum of the normalized values of the two administered tests was divided by two and multiplied by three. Based on this, estimated verbal IQ scores were assigned.

Results

First, we present an overview of children's performance on the individual tasks. Then, interrelations between tasks are investigated. Descriptive statistics of children's task performance at the five measurement points are shown in Table 1. First, we inspected children's performance on the relevant outcome measure, the metacognition task. Children performed significantly better on the ignorance condition ($M = 1.86$, $SD = 0.42$) than on the partial knowledge condition ($M = 1.24$, $SD = 0.80$) according to a Wilcoxon test ($Z = 4.39$, $p < .001$). Also, performance on the ignorance and partial knowledge condition was correlated, $r = .68$, $p < .001$. In order to avoid ceiling effects, we will use the partial knowledge condition for further analysis.

Table 1. Descriptive statistics of performance on all measures

Measure	<i>M</i> (<i>SD</i>)	Range	<i>n</i> (task)
Partial knowledge 5;9	1.63 (0.67)	0–2	67
Verbal IQ 4;0	107.02 (13.65)	67–137	61
Fruit Stroop 2;6	2.43 (0.76)	0–3	61
Understanding perspective 2;6	59.0 (19.39)	0–100	58
First-order false belief 4;2	0.72 (0.74)	0–2	60
First-order false belief 5;0	1.45 (0.71)	0–2	65
First-order false belief 5;9	1.72 (0.57)	0–2	67
Second-order false belief 5;0	0.65 (0.75)	0–2	66
Second-order false belief 5;9	1.27 (0.71)	0–2	67

Note. *M* = mean value; *n* = number of participants; *SD* = standard deviation.

Table 2. Zero-order and partial correlations controlling for IQ and inhibition (below the main diagonal)

Measure	2.	3.	4.	5.	6.	7.	8.	9.
1. Verbal IQ 48 months	.38**		.13	.35**	.29*	.17	.35**	.12
2. Fruit Stroop 30 months	—	.25 [†]	.25 [†]	.28*	.24 [†]	.11	.17	.12
3. Partial knowledge 69 months		—	.35**	.24 [†]	.28*	.19	.35**	.09
4. Understanding perspective 30 months		.31*	—	.15	.20	.20	.18	.11
5. First-order FB 50 months		.15	.07	—	.22 [†]	.23 [†]	.18	.36**
6. First-order FB 60 months		.21 [†]	.15	.12	—	.15	.37**	.14
7. First-order FB 69 months		.15	.17	.18	.10	—	.12	.19
8. Second-order FB 60 months		.29*	.14	.05	.30*	.06	—	.21 [†]
9. Second-order FB 69 months		.04	.08	.33**	.10	.17	.17	—

Note. * $p < .05$; ** $p < .01$; [†] $p < .10$; FB = false belief.

For first- and second-order false belief understanding, there was a clear developmental trend across the different measurement points. First-order false belief understanding improved significantly according to a Friedman test, $\chi^2(2, n = 58) = 55.30, p < .001$. At 4;2, children received 0.72 ($SD = 0.74$) out of two points. At 5;0 of age, children scored at 1.45 out of two ($SD = 0.71$). And at 5;9, they were almost perfect, reaching 1.72 ($SD = 0.57$) out of two. There was also a significant increase on the second-order false belief task given at 5;0 ($M = 0.65$ out of 2 correct, $SD = 0.75$) and 5;9 ($M = 1.27$ out of 2 correct, $SD = 0.71$) according to a Wilcoxon test, $Z = -4.47, p < .001$.

Zero-order correlations (two-tailed) and partial correlations (one-tailed) controlling for verbal ability and inhibition (Fruit Stroop) are shown in Table 2. As expected, we found a predictive relationship between early theory of mind understanding and later metacognitive knowledge: metacognition at 5;9 was significantly related to understanding perspective differences at 2;6 ($r = .35, p = .006$) and to first-order false belief understanding ($r = .28, p = .023$) and second-order false belief reasoning ($r = .35, p = .004$) at 5;0. Also, replicating previous research, inhibition as measured with performance on the Fruit Stroop task was related to first-order false belief understanding at 4;2 ($r = .28, p = .041$). Furthermore, first-order false belief reasoning at 4;2 was significantly associated with second-order false belief understanding at 5;9 ($r = .36,$

$p = .005$). And first-order false belief at 5;0 correlated significantly with second-order false belief at 5;0 ($r = .37, p = .002$).

When verbal IQ at 4;0 and inhibition (Fruit Stroop at 2;6) were partialled out, metacognition remained significantly related to perspective understanding at 2;6 ($r = .31, p = .014$) and second-order false belief reasoning at 5;0 ($r = .29, p = .018$); the relation between metacognition and first-order false belief at 5;0 failed to reach significance ($r = .21; p = .066$). Also, first-order false belief at 4;2 correlated with second-order false belief at 5;9 ($r = .33, p = .008$). Furthermore, at 5;0 first-order and second-order false belief understanding were interrelated ($r = .30, p = .013$). See Figure 1 for an illustration of these relations.

Discussion

While there are longitudinal studies showing that early theory of mind is related to later meta-strategic knowing, to the best of our knowledge, this is the first longitudinal study demonstrating a relation between early theory of mind and later metacognitive knowing ('knowing about knowing'). As expected, all three levels of perspective taking were related to later metacognitive knowing. Perhaps most interesting, Level 1 perspective understanding at 2;6 was significantly related to metacognition two and a half years later. Also, metacognition at 5;9 was significantly linked to Level 2 and Level 3 perspective understanding (first- and second-order false belief) at 5;0 – but not at the other time points (perhaps due to test sensitivity because of task variance or repetition effects). Furthermore, when inhibitory control and language competency were partialled out, the correlations between Level 1 and Level 3 perspective taking with metacognitive

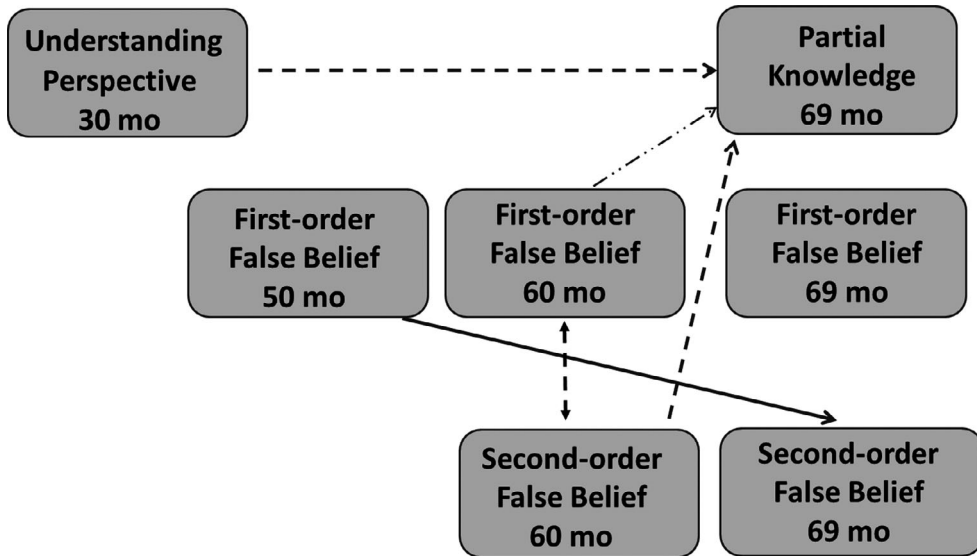


Figure 1. Longitudinal correlations between perspective understanding, first- and second-order false belief, and partial knowledge between 30 and 69 months of age. --- $p < .10$; -.- $p < .05$; — $p < .01$.

knowing remained significant supporting theories that claim a close relation between theory of mind and metacognitive development.

In general, our results fit with the argument that meta-knowing is rooted in early theory of mind and perspective understanding (Carruthers, 2009; Kuhn, 2000). In addition, the present finding confirms and extends previous research showing that early theory of mind predicts later metacognition, in particular, metamemory performance (Lecce, Demicheli, *et al.*, 2015; Lockl & Schneider, 2007), through focusing on another area of metacognition, namely children's understanding of 'knowing about knowing'. That is, early theory of mind understanding may allow children to reflect on, evaluate, and understand their cognitive processes in tasks requiring metamemory and metacognitive knowing.

We argue that the present results highlight the importance of perspective understanding for the development of an understanding of one's own mind. When children are able to engage in Level 2 perspective taking around 4 years of age, they are also able to understand ignorance in themselves or others. However, only when they are able to engage in Level 3 perspective taking around 6 years of age, they are able to acknowledge their ignorance in a partial knowledge task. In the partial knowledge task, the truth-value of one's own perspective is left undecided (each one of the two possible perspectives can be true or false), requiring a second-order evaluation of one's perspective. Such a reflective understanding of one's own cognition, like in the partial knowledge task, may be a consequence of applying a theory of mind on one's own mind.

Interestingly, a link between understanding oneself and understanding others has also been proposed in adults. For example, Dimaggio, Lysaker, Carcione, Nicolò, and Semerari (2008) describe evidence indicating that self-reflection improves mindreading. Furthermore, it has been shown that first-hand experience of monitoring one's own learning influences judgments of another person's learning in a corresponding task (Paulus, Tsalas, Proust, & Sodian, 2014). Furthermore, similar brain regions are activated when reasoning about oneself or others (e.g. Lombardo *et al.*, 2010). These results speak in favour of a bidirectional relation between metacognition and theory of mind.

A recent neuroimaging study with 24 5- and 6-year-olds (Filevich *et al.*, 2020) showed that children who succeeded in the partial knowledge task had greater cortical thickness in the left medial orbitofrontal cortex, a region that has previously been related to metacognitive abilities. Furthermore, resting state analyses revealed that this region of the medial orbitofrontal cortex was connected to regions belonging to the default mode network, a network that is involved in introspection and self-referential thinking. This supports the claim that the partial ignorance task measures introspective awareness of one's state of knowledge. However, Filevich *et al.* found no overlap between this region in the left medial orbitofrontal cortex and prefrontal regions typically associated with theory of mind processing in adults; that is, theory of mind understanding and metacognitive knowing may be linked to neighbouring but distinct regions of the prefrontal cortex.

However, clearly, in order to gain more insight into the developmental relation between these two important abilities, longitudinal studies using measures of both metacognition and theory of mind at each time point are needed. Furthermore, future research should also include implicit measures of metacognition. For example, Kim, Paulus, Sodian, and Proust (2016) demonstrated an earlier implicit understanding of uncertainty in the partial knowledge task. They found that 3- to 4-year-old children are sensitive to their own ignorance when informing an ignorant third person and they also show gestures of uncertainty reflecting their level of (partial) informational access.

It should also be noted that Lecce, Demicheli, *et al.* (2015) found that early false belief understanding (Level 2 perspective taking), but not pre-false-belief abilities like Level 1

perspective taking or understanding ignorance, is crucial for later metacognition/metamemory. This contrasts with the present results indicating that Level 1 perspective taking is significantly related to later metacognitive performance. One possible explanation for these contradicting results is that in the Lecce *et al.* study, children's performance on this earlier theory of mind abilities (perspective taking and understanding ignorance) was close to ceiling.

To conclude, the present study yielded evidence that perspective taking is important for understanding others' but also for understanding one's own inner world. In particular, our human capacity to be self-reflexive seems to be rooted in our ability to take different perspectives. We found that metacognitive knowing at 5;9 years of age was related to children's development of perspective taking abilities assessed with Level 1, 2, and 3 perspective taking tasks. That is, children's growing understanding of perspectives – from understanding *what* another person sees (Level 1) to understanding *how* objects are represented (Level 2) to taking different perspectives on one's own or another person's perspective (Level 3) – seems to be intrinsically related to a growing understanding of one's own thought processes. We propose that Level 3 perspective taking is necessary in order to be able to purposefully reflect on one's own cognitive processes, an ability that is crucial for children's academic success, because it facilitates and enhances learning in school.

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Conflicts of interest

All authors declare no conflict of interest.

Author contributions

Daniela Kloo (Conceptualization; Data curation; Formal analysis; Writing – original draft; Writing – review & editing) Beate Sodian (Conceptualization; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Writing – review & editing) Susanne Kristen-Antonow (Conceptualization; Data curation; Investigation; Methodology) Sunae Kim (Investigation; Writing – review & editing) Markus Paulus (Conceptualization; Formal analysis; Methodology; Writing – review & editing).

Data availability statement

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

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