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There is More to Mind Reading than having Theory of Mind Concepts: New Directions in Theory of Mind Research

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For more than 30 years, researchers have focused on the important transition that children undergo between the ages of 3 and 5, when they start to solve mind-reading problems that require reasoning about complex mental states, such as beliefs. The main question for debate has been whether, during that transition, children acquire new concepts about how the mind works (i.e. a more sophisticated 'theory of mind') or whether their more general cognitive abilities improve and help them deal with the general task demands. Recently, researchers have started to explore mind-reading abilities in individuals outside of the classic 3–5 age span, showing early theory of mind abilities in ever-younger children and infants, but also far from flawless performance in adults. In this article, we show how the results of these two new lines of research converge on the idea that there is more to mind reading than having theory of mind concepts: there are various processes required to efficiently implement theory of mind concepts in our reasoning, and there may be, in fact, multiple mind-reading routes available. We then highlight the emergent new directions for future research. Copyright © 2010 John Wiley & Sons, Ltd.

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For the last three decades there has been a continuous interest in humans' ability to impute mental states, such as desires, intentions or beliefs to themselves and others in order to predict or explain their behaviour. Such ability has been traditionally viewed as requiring a folk psychology or a 'theory of mind' (ToM),

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in other words a set of knowledge that allows one to understand unobservable mental states, such as belief, desire and knowledge (Premack & Woodruff, 1978). For many years, one of the predominant questions that has guided developmental psychologists has been *when* a child acquires a ToM. There is considerable consensus that children become increasingly proficient in ToM tasks during preschool age and that by the end of preschool age, they are able to reason correctly about most mental states including epistemic mental states, such as beliefs (Carpendale & Chandler, 1996; Doherty, 2008; Wellman, Cross, & Watson, 2001; Wimmer & Perner, 1983). There is still some scope for improvement during early school years when children start to correctly solve second-order belief reasoning tasks (Perner & Wimmer, 1985), when they understand the 'opacity' of mental states (Apperly & Robinson, 1998, 2003) and when they start to understand the hidden intention in some forms of social communication, such as in the case of irony and double bluff (Capelli, Nakagawa, & Madden, 1990). Indeed, it has long been proposed that conceptual change continues in ToM well into later childhood and adolescence (Chandler, Boyes, & Ball, 1990; Wellman, 1990). However, the popularity of belief reasoning tasks as indicators of the presence of a ToM alongside the scarcity of empirical work on ToM in older children led to the common assumption that the end point of ToM development is somewhere in early school age.

Two main theoretical positions have been advanced to explain what changes with development. On the one hand, some authors have claimed that the conceptual understanding of mental states is present all along during the child's development but that the child lacks sufficiently sophisticated general cognitive skills that are required to solve ToM tasks (Fodor, 1992; Leslie, 2005; Leslie & Thaiss, 1992). On this view, young preschool children fail ToM tasks not because they do not understand mental state concepts but because, for example, they cannot focus their attention on the task or they cannot remember the crucial information or they misunderstand the test question. This has been conceptualized as a competence/performance distinction, and the claim is that young children have the competence but fail to perform accordingly. On the other hand, other authors defended the idea that children's ToM competence, i.e. their understanding of mental states concepts *per se*, develops with age (the conceptual change hypothesis, Perner, 1991; Wellman, 1990). What has particularly attracted the attention of such researchers is the shift around the age of 4 when children progress from performance below chance to performance above chance when reasoning about representational mental states, especially false beliefs. The change observed at that age has been characterized in various ways but the common feature is that a qualitative change occurs in the way children reason about mental states and such change is enabled by more sophisticated understanding of mental states (Flavell, 1988; Perner, 1991; Wellman, 1990).

In more recent years, researchers started to investigate ToM in participants outside the traditional 3 to 5 years old age range, testing infants and also adults. This expansion of the age of interest occurred alongside important changes in the methodology used to test ToM. In order to be able to test very young children, researchers created simplified social scenarios and measured looking behaviour rather than recording explicit verbal or pointing responses. To test adults, researchers sought to avoid ceiling effects by using parametric measures (reaction time, error rate, probability estimates) over a series of trials, instead of the classic measurement of ToM with a pass/fail criterion on a few number of trials. The findings that emerged from these changes of methodology have been quite striking and controversial. Firstly, it appears that well before the age of 3, children

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are able to pass ToM tasks, even complex ones that apparently test an understanding of false beliefs (Onishi & Baillargeon, 2005; Southgate, Senju, & Csibra, 2007). Secondly, evidence suggests that adults are far from performing at ceiling in ToM tasks (Birch & Bloom, 2007; Keysar, Barr, Balin, & Brauner, 2000; Keysar, Lin, & Barr, 2003).

In recent reviews, we have discussed some of these findings in relation to what evidence from adults can tell us about the roles of language and executive function in the development of ToM (Apperly, Samson, & Humphreys, 2009), and in relation to a 'two systems' account of ToM (Apperly & Butterfill, 2009). In what follows, we will discuss the implications of the recent changes of methodology and the resulting findings for our understanding of ToM specifically in relation to egocentrism, and the difference between implicit versus explicit measures. We will then highlight some of the new directions in ToM research that seem to emerge.

FLAWLESS PERFORMANCE IS NOT THE END POINT OF ToM DEVELOPMENT

One of the most striking examples that the end point of ToM development is not a flawless or ceiling performance comes from a study by Keysar and collaborators conducted with adult participants (Keysar *et al.*, 2000). Participants were asked to move an object in a grid in response to the instructions given by a 'director'. The way the grid was constructed and the position of the director in the room meant that the director could not see some of the objects of the grid, whereas all the objects were in full view of the participants. On the critical test trials, the correct interpretation of the director's instruction required participants to take into account which objects the director could see and which ones he could not see. For example, among the objects placed in the grid, there could be a small candle, a medium size candle and a big candle, but the small candle was only visible to the participant. Hence, when the director requested to move the small candle, the participant should have moved the medium size candle as this was the smallest candle that could be seen from the director's perspective. Interestingly, participants' eye movements showed a significant tendency to fixate first on the object that was not in view of the director and which corresponded to an egocentric interpretation of the director's instruction. Subsequent fixations suggested that participants frequently corrected themselves but in around 20% of the cases, such correction did not take place and participants actually reached towards the object that could not be seen by the director. Importantly, the egocentric errors occurred although the participants were perfectly aware that some objects were not visible to the director. Indeed, participants were asked to switch role with the director before starting the task and they were even asked to help set up the occlusions in order to stress the discrepant perspectives. Thus, these results (and others obtained with a variety of paradigms, e.g. Back & Apperly, 2010; Birch & Bloom, 2007; Keysar *et al.*, 2003) show that it is not enough to have acquired a ToM to reason flawlessly about other people's mental states.

The difficulties that adults show in *using* their ToM and that are reported here have been attributed to cognitively costly processes required to resist interference from their own, egocentric, perspective (Birch & Bloom, 2007; Keysar *et al.*, 2000, 2003), an interpretation that has also been put forward when explaining children's failure in ToM tasks (Birch & Bloom, 2004; Moore *et al.*, 1995). It may be tempting to relate the distinction between having and using one's ToM to the

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competence/performance distinction referred to earlier on. However, such a comparison can overshadow an important point: being able to use one's ToM is as fundamental in reasoning about mental states as having a ToM. It is not just the case that the paradigm developed by Keysar *et al*. (2000) or other similar ones are posing artificially high cognitive demands; the demands are *inherently* part of the processes required to reason about other people's mental states. In many situations, indeed, other people hold a different perspective to ours and we need to be able to deal with this.

Evidence from neuropsychology suggests that the ability to resist interference from one's own perspective can be selectively impaired. This has been documented in the case of an adult patient, WBA, with acquired brain damage to the right frontal lobe (Samson, Apperly, Kathirgamanathan, & Humphreys, 2005). Patient WBA was presented with two belief-reasoning tasks, which varied in their demands of self-perspective inhibition. Both tasks were based on the classic false-belief task in which an agent is made aware of the location of an object, but is later unaware that the location of the object has changed. In one of the tasks, participants knew all along the actual location of the object and had thus to resist interference from that knowledge when inferring the agent's belief. In the other task, participants were not aware of the location of the object, but were aware that the location has changed. Hence, here, the agent's belief could be inferred without need to resist interference from one's own knowledge of the location of the object. Patient WBA had no difficulties inferring that the agent had a false belief in the latter task where the demands of self-perspective inhibition were reduced, but he was incapable of inferring that the agent had a false belief in the task where the demands of self-perspective inhibition were high. These results not only show that the mechanisms that allow us to resist interference from our own perspective can be selectively impaired, they also show that once these mechanisms are impaired in adulthood, it is not possible anymore to reason about another person's perspective if that perspective is different to ours. The success of WBA in the false-belief task where the demands in self-perspective inhibition were reduced shows that the patient meets the criteria of having ToM concepts. Yet clearly, having these concepts alone was not sufficient to impute a false belief to another person in some situations. Importantly, these situations in which WBA struggles to reason about beliefs are not contrived or artificial, but are the very common circumstances in which one's own perspective is both salient, and incompatible with the other person's perspective.

Being able to resist the interference from one's own perspective is not the only type of process required to use one's ToM. Indeed, one may know in principle how mental states arise (e.g. someone's belief about the location of an object derives from what the person has perceived or has been told in the past) and one may have successfully overcome egocentric biases, but that would still not be enough to infer the specific content of the other person's perspective. We also need to select, monitor and integrate the relevant cues in the specific situation at hand in order to provide the appropriate inputs for reasoning about the other person's mental state content (e.g. which are the relevant objects and persons to take into account, how far back in the past do we need to go?). There is some evidence that as adults we do not automatically engage in those selection/monitoring/integration processes (Apperly, Riggs, Simpson, Chiavarino, & Samson, 2006), suggesting indirectly that these processes may be cognitively demanding. There is also evidence that some of these processes can be selectively impaired in the case of brain damage, as documented in the case of an adult stroke patient, PF, with lesions to the temporal and parietal brain areas (Samson,

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Apperly, Chiavarino, & Humphreys, 2004; Samson, Apperly, & Humphreys, 2007). The errors patient PF made in belief-reasoning tasks were most often *not* egocentric errors, but errors which showed that she was easily misled by salient but irrelevant cues in the environment. It is only after a series of trial and errors that patient PF would finally find the relevant cues in the environment and reason correctly about the other person's mental state. Just as with the need to resist egocentrism, we suggest that this process, which is required to use one's ToM, is not incidental to experimental paradigms. One only needs to think about the complex multi-object and multi-agent environment in which we navigate in our daily life to realize that the selection/monitoring/integration of relevant cues probably often plays an important role when we reason about other people's mental states. Importantly, PF's successes in false belief tasks once she found out which cues to attend shows that, like WBA, PF meets the criteria of having ToM concepts. Yet, clearly again, having those concepts alone was not sufficient in some situations to impute a false belief to another person.

In sum, studies with healthy adults have used parametric measures, which show that reasoning about other people's mental state places cognitive demands even in adults who have reached the end point of ToM development. There is evidence for two distinct kinds of demand that make ToM 'hard' for adults: the need to resist interference from one's own egocentric perspective, and the need to ascertain what information is relevant for a particular ToM judgement. Those demands are not incidental to or artificially created by the experimental paradigms: they are ecologically valid, given the complex social environment in which we live. Evidence from neuropsychology further shows that the processing demands observed in healthy adults actually reflect the existence of a collection of processes that are *necessary* to efficiently use one's ToM (for a further discussion, see Samson, 2009). Altogether, this places a new emphasis on ToM as encompassing not only the passive possession of concepts but also their active implementation in reasoning.

EARLY MIND READING IN INFANTS: WHY ARE INFANTS NOT EGOCENTRIC?

At the same time as work has been progressing on ToM in adults, progress has also been made in the opposite direction by testing ever-younger children and infants. One of the first reports of what looks like very early competence in mind reading was provided by Onishi and Baillargeon (2005). In their study, 15-month-old infants first watched an adult putting an object in one of two boxes. On the false-belief trials, an occluder would then obstruct the view that the agent has of the boxes, while the object is moved from its original location to the other box. Finally, the occluder is removed and the agent reaches either to the original box (consistent with the agent's false belief about the location of the object) or to the new location of the object (inconsistent with the agent's false belief). Onishi and Baillargeon (2005) found that infants looked significantly longer at the display when the agent reached to the location inconsistent with his/her false belief. This study alongside other mounting evidence for early competence in mind reading (Sodian, Thoermer, & Metz, 2007; Song & Baillargeon, 2008; Song, Onishi, Baillargeon, & Fisher, 2008; Southgate *et al.*, 2007; Surian, Caldi, & Sperber, 2007) has sparked interesting controversies that mirror those that were raised in comparative psychology around the question as to whether chimpanzees have a ToM (Call & Tomasello, 2008; Povinelli & Vonk, 2003; Tomasello, Call, & Hare,

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2003). The main question for debate has been whether infants have ToM concepts. Several authors have argued that the data do suggest the presence of ToM concepts in infants, including concepts such as ignorance and false belief (Csibra & Southgate, 2006; Leslie, 2005; Onishi & Baillargeon, 2005; Southgate *et al*., 2007; Surian *et al*., 2007), while others argue that the data could be explained equally well in terms of infants making agent–object–location associations (Perner & Ruffman, 2005) or using rules about behaviour, such as 'agents return to objects where they looked at them' (Penn & Povinelli, 2007; Perner & Ruffman, 2005). This debate is very far from being resolved, and in our view, the debate's focus on concepts has obscured another important and potentially informative aspect of infants' performance on these tasks: their apparent absence of egocentrism.

Surely we should have expected infants to be egocentric. When preschool children make errors on ToM tasks, they do not err at random, but respond systematically from their own point of view. Indeed, as already mentioned, on some accounts, what changes in the preschool years is increasing availability of the executive processes necessary to overcome egocentric bias (Birch & Bloom, 2004; Moore *et al*., 1995). As it is generally assumed that infants have fewer executive resources at their disposal than older children and adults, we suppose that infants do not somehow overcome an egocentric bias that defeats older children on false-belief tasks. Rather we propose that (1) infants are not solving these tasks in the same way as older children and (2) however infants are solving these tasks, this processing is not subject to egocentric interference, and hence makes few or no demands on the executive control processes necessary for resisting such interference. A viable account of infants' abilities must explain how this is possible, and we argue, this also leads to testable predictions about analogous abilities in adults.

It is noteworthy that evidence of infants' sensitivity to the beliefs of others has come from tasks in which infants passively observe an agent's interaction with objects and from indirect measures such as looking time and anticipatory eye gaze. This contrasts with the 'standard' methods used with children and adults, in which participants are required to give explicit consideration to the other person's 'point of view'. Indeed, there is evidence of a dissociation between implicit and explicit measures within the same individuals. Clements and Perner (1994; see also Garnham & Perner, 2001) found that the eye gaze of 2- to 3-year olds may correctly anticipate the action of an agent with a false belief, yet the very same children answer incorrectly when explicitly asked to judge what the agent will do. The usual proposal is that both infants and older children have a ToM, but that in infants this ability is 'implicit' and so apparent only on indirect measures, whereas in older children development has rendered this understanding 'explicit', allowing it to support deliberate judgements in response to direct questions.

Our own work on the cognitive basis of ToM has led us to think about infants' abilities in a rather different way. For one thing, describing infants' abilities as 'implicit' does not, in itself, explain how these abilities are implemented in the cognitive system of infants. It tells us nothing about how infants manage to be sensitive to the mental states of others, despite having limited cognitive resources for memory and executive function, and in particular it tells us nothing about how they avoid egocentrism. It may indeed be appropriate to describe infants' abilities as 'implicit', but we are led to view this as the beginning, not the end, of the project of explaining infants' abilities. We have also been led to question the developmental relationship between the ToM abilities of infants and children. While it is possible that infants' implicit abilities are wholly subsumed into the

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explicit ToM abilities of older children and adults, it is also possible that they remain distinct abilities in older children and adults and might be detected via indirect measures. A small number of studies provide evidence suggesting that this may indeed be the case.

ADULTS RETAIN AN ALTERNATIVE ROUTE TO ToM JUDGEMENTS

Recent studies investigated adults' implicit ability to compute what someone else can and cannot see, i.e. the minimum type of processing required in many of the tasks that infants successfully pass. In one such study (Samson, Apperly, Braithwaite, Andrews, & Bodley Scott, in press), adults were presented with pictures of a room and were asked to judge how many red discs were displayed on the walls. An agent, irrelevant to the task, was positioned in the room so that on some trials he/she would see the same discs that participants could see whereas on other trials he/she would only see a subset or none of the discs visible to participants. Participants were instructed to ignore the agent and simply judge how many discs they themselves could see in the room. Interestingly, participants' self-perspective judgements were slower and more error prone when the agent had a different perspective to theirs. Participants were given feedback about their accuracy and would have thus noticed the interference created by the agent; yet this did not help them avoid taking into account the agent's perspective. We suggest that these results reflect automatic computation of what the agent saw. Consistent with this hypothesis, the interference of what the agent saw on self-perspective judgements was found to be maintained even while adults were performing a cognitively demanding secondary task, indicating that computing what the agent saw was not cognitively effortful (Qureshi, Apperly, & Samson, submitted). If it could be further demonstrated that adults not only automatically track what an agent sees, but also what he/she *has seen*, such abilities would go a long way to explaining the precocious performance of infants on false-belief tasks.

Thus, from infancy to adulthood, there seems evidence that humans implicitly and efficiently process someone else's visual experience, even when they themselves have a different view.

HOW IS IMPLICIT PROCESSING OF PERSPECTIVE COGNITIVELY EFFICIENT?

For adults, as for infants, evidence of implicit processing of perspective does not, in itself, explain how such processing is cognitively efficient. Our working hypothesis is that efficiency is gained by circumventing the two key demands that seem to make ToM 'hard' for adults: overcoming egocentrism and identifying relevant information for ToM inferences. We deal with these in turn.

Egocentrism and Task Construal in ToM Problems

As just noted, the main evidence that adults compute the perspectives of others quickly, and without disruption from a secondary task, comes from the indirect effect of this information on adults' ability to make explicit judgements about *their own* perspective. Importantly, on the more direct measure—when

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participants were required to make explicit judgements about the agent's perspective—adults were not totally immune from egocentric biases (Samson *et al.*, in press). That is to say, although participants were relatively fast and accurate at judging the agent's perspective, explicit judgements of the agent's perspective were slower and more error prone when participants held a different view to the agent compared with situations where they held the same view, and indeed, this interference is exaggerated under dual-task conditions (Qureshi *et al.*, submitted). Why do adults still show egocentric biases despite other evidence that they process the agent's visual experience efficiently? The key to answer this question may lie in how a ToM problem is construed.

When measuring the implicit computation of what someone else can see (or has seen) in infants, children or adults, nothing in the task required participants to see the other person as someone with a distinct 'perspective' to theirs: infants passively watched an agent and adults were simply asked to judge how many discs they saw in the room. In contrast, in situations where egocentric biases have been shown, participants were more explicitly asked about the other person's perspective (e.g. what does the other person see or think? What will the other person do?). Explicitly referring to the other person in the question invites participants to consider the other person as a person distinct from themselves. It could be specifically under those conditions where the world around us is explicitly construed in terms self and other that egocentric biases would occur. When the task does not require explicit perspective judgements, we suggest that information about the perspectives of others is not represented as alternatives to one's own perspective (which would make it vulnerable to egocentric interference), but rather as independent information about others' exposure to objects or situations. This would not afford reflection on the relationship between alternative perspectives, and for some theorists, this would mean that perspectives are not being represented *as such* (Perner, 1991). But critically, information about the perspectives of others could exert useful influence on other cognitive processes (such as forming expectations about what they would do or say) without the need to resist interference from one's own perspective.

Task Complexity and Identifying Relevant Information for ToM Inferences

In the light of evidence of efficient implicit processing of someone else's visual experience, why do adults find it hard to take into account someone else's mental states even in tasks that do not explicitly instruct participants to take someone else's perspective, such as in the case of Keysar *et al.*'s task (2000) described earlier? Contrasting the type of display used in that task with the ones presented to adults in the simplified visual perspective taking paradigms described earlier (Samson *et al.*, in press), one difference that stands out is the number of objects presented in the displays. For example, in the latter tasks, the number of objects was smaller than 4, and object sets of this small size can be processed very efficiently (Trick & Pylyshyn, 1994). In contrast, in the studies by Keysar *et al.*, the number of objects exceeded 5. Interestingly, two studies—one carried out with school children (Nadig & Sedivy, 2002), the other with adults (Hanna, Tanenhaus, & Trueswell, 2003)—used a paradigm very similar to the one used by Keysar *et al.* (2000), but with a display that contained less than 5 objects and with only one occluded object. In those circumstances, both children and adults did take into account from the onset what was seen by the other person when interacting with the other person. Thus, our specific suggestion in this case is that visual perspective-taking manages to be cognitively efficient, and may be achieved

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implicitly, when the cues to what someone can see are simple (in this case, a difference in line of sight leads different objects being observed by self and other) and when the amount of information to be processed falls within the capacity of other efficient processing systems (in this case, the capacity to track small sets of objects). Our general suggestion is that this illustrates a guiding principle for how cognitive efficiency is achieved in ToM: efficiency comes by limiting the range of cues that are ever considered as potentially relevant for inferring mental states. In turn, this means that the mental states that can be ascribed efficiently and implicitly will be likewise limited. Understanding the nature of these limits is an important project for understanding the implicit abilities of adults and infants alike, a small subset of those that can be ascribed via more effortful, explicit processing.

Thus, we would like to suggest that it is the absence of explicit perspective taking instructions *combined with* the simplified cues and mental state contents, which allows infants and adults to ascribe efficiently other people's mental states. One of the two conditions alone does not seem to be sufficient to reach the same level of efficiency. As illustrated above, despite the simplified displays used in Samson *et al*. (in press), when explicit perspective instructions are given to participants, egocentric biases are still present. Likewise, even when the instructions do not necessarily invite to take someone else's perspective as in the case of Keysar *et al*. (2000), the complexity of the scene and/or lack of salience of the relevant cues may prevent the efficient use of implicit mind-reading processes.

CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

In the past three decades, there has been a lot of emphasis on the development of ToM concepts. However, many recent studies now converge to the idea that there is much more to mind reading than having such concepts.

Firstly, having ToM concepts is not sufficient to efficiently read someone else's mind. In the complex social world that we navigate, processes are required to correctly implement ToM concepts in our reasoning. Observations that adults who have acquired ToM concepts do not necessarily show a flawless performance in solving ToM problems suggests that the processes by which we use our ToM concepts are cognitively demanding (Birch & Bloom, 2007; Keysar *et al*., 2000, 2003). Unravelling the specific nature of these processes is a scientific programme that has only just begun. One type of process we have highlighted is the one needed to resist interference from one's own perspective (Samson *et al*., 2007, 2005). Although the existence of such process has been known for a long while (Leslie & Thaiss, 1992; Moore *et al*., 1995), its specific nature and developmental trajectory only just started to be investigated. For example, a recent study suggested that the ability to overcome egocentric biases continues to improve from childhood into late adolescence (Dumontheil, Apperly, & Blakemore, 2010), which may contribute to explaining continuing developmental change in social abilities. Another type of process necessary to use ToM concepts is the ability to select/monitor/integrate the relevant information from the environment in each unique situation, where we ascribe mental states to others (Samson, 2009; Samson *et al*., 2007). Far less is known about the nature and developmental trajectory of the collection of processes referred to in that latter case. The success of future studies that will investigate these processes for *ToM use* will depend on the use of adequate and more sensitive measures, whose aim is not simply to test for the presence or absence of an ability but rather to test the efficiency and

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flexibility of that ability. In the ever-changing complex environment in which we live, it is not only the accuracy but also the speed with which we can use our ToM concepts which is likely to make a significant contribution to the success of our interactions with other people around us. Such shift in assessing ToM may also provide a fruitful avenue to investigate the origin of social impairments in developmental disorders, where the question may not only be whether these children have ToM concepts but also whether they can use them efficiently enough for them to be useful in online social interaction and communication.

The second reason why there is more to mind reading than having ToM concepts comes from evidence of efficient computation of mental states from infancy to adulthood in certain specific circumstances at least (Onishi & Baillargeon, 2005; Qureshi *et al.*, submitted; Samson *et al.*, in press; Sodian *et al.*, 2007; Southgate *et al.*, 2007; Surian *et al.*, 2007). This efficient computation contrasts with the more effortful perspective taking processes that have been studied in the past 30 years of ToM research and suggests that there may be different ways available to us to read someone else's mind, some more sophisticated than others. The specific nature of these alternative mind-reading routes has yet to be investigated (for a discussion, see Apperly & Butterfill, 2009), but one emergent idea is that their efficiency comes at the cost of lower flexibility. Identifying the limits in their flexibility will thus provide valuable information about the underlying computation. An interesting first study in this direction was conducted by Sodian and Thoermer (2008), who showed that 16-month-old infants did not expect an agent to search for an object in a specific location when that agent was absent from the scene at the time the object was hidden, consistent with their tracking the agent's lack of knowledge. However, in another condition where the agent also left the scene, but was present at the critical time when the object was hidden, infants likewise did not expect the agent to look in a specific location, suggesting that they also *incorrectly* ascribed ignorance in this scenario. This study suggests that when scenarios are made slightly more difficult, infants overgeneralize the relevance of certain cues (the absence of the agent) irrespective of the impact this cue has on the agent's true mental state. Investigating the limits of these efficient computation routes across life span may also provide a valuable source of information to study their underlying nature. For example, are the limits of these computations the same for infants and adults, or is there scope for improving the efficiency of these processes with age?

Finally, the apparent absence of egocentric biases in infants who show signs of early ToM competence leads us to think that infants may be solving ToM problems without construing the other person as having a perspective as such. As we have suggested, the implicit versus explicit perspective taking distinction may be the critical factor determining whether egocentric biases will occur. Such hypothesis will need to be put to empirical test.

In sum, recent ToM research has started to look at humans' ability to ascribe mental states to others well beyond the traditional ages of 3- to 5-year-old children. Measuring ToM in adults and infants came with the challenge of creating new and appropriate tasks. Interestingly, the changes in methodology provided totally new insights into mind-reading abilities. Far from seeing ToM as a unitary ability, mounting evidence now forces us to consider the multiple pathways and processes available to humans to read other people's mind. Whether or not all these different mind-reading routes require ToM concepts still remains to be determined. However, even if it turns out that some routes reflect the use of alternative processes, the fact that these are useful in a variety of tasks suggests that these processes may be useful in everyday life situation as well. The

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question is thus not only how ToM concepts develop but how the collection of mind-reading processes develop across life span and what kind of mind-reading routes are available in different situations.

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