British Journal of Developmental Psychology (2012), 30, 75–86

The British Psychological Society

www.wileyonlinelibrary.com

Direct and indirect measures of Level-2 perspective-taking in children and adults

Andrew D. R. Surtees[1]*, Stephen A. Butterfill[2] and Ian A. Apperly[1]

[1]University of Birmingham, UK
[2]University of Warwick, UK

Studies with infants show divergence between performance on theory of mind tasks depending on whether *direct* or *indirect* measures are used. It has been suggested that direct measures assess a flexible but cognitively demanding ability to reason about the minds of others, whereas indirect measures assess distinct processes which afford more efficient but less flexible theory of mind abilities (Apperly & Butterfill, 2009). This leads to the prediction that performance on indirect measures should be subject to *signature limits*. The current study tested whether the Level-1/Level-2 distinction might constitute one such limit. The study adapted a task that has shown evidence of Level-1 perspective-taking on both direct and indirect measures (Samson, Apperly, Braithwaite, Andrews, & Bodley-Scott, 2010). The aim was to test Level-2 perspective-taking in a sample of 6- to 11-year-olds ($N = 80$) and adults ($N = 20$). Participants were able to make Level-2 judgements on the direct measure. In contrast with the findings from Level-1 perspective-taking, there was no evidence of automatic processing of Level-2 perspectives on the indirect measure. This finding is consistent with the view that theory of mind abilities assessed by indirect measures are subject to signature limits. The Level-1/Level-2 distinction, suitably refined, marks one way in which efficient but inflexible theory of mind abilities are limited.

Perspective-taking most commonly refers to being sensitive to another's mental states. These mental states can be beliefs, desires, intentions, or perceptions. Another's non-mental states, such being to the left or right of an object, are also sometimes considered within the notion. Perspective-taking can be tested in two very different ways. On *direct* measures participants have to respond in a way that provides a 'correct' answer or an appropriate behaviour; classic examples of this include Piaget's three mountains task (Piaget & Inhelder, 1956), in which children are asked how an array of three mountains would appear to someone from a different viewpoint. *Indirect* measures, on the other hand, test participants' spontaneous sensitivity to differences in conditions: these most regularly involve measures of spontaneous behaviours such as the looking

*Correspondence should be addressed to Andrew D. R. Surtees, School of Psychology, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK (e-mail: a.surtees@bham.ac.uk).

DOI:10.1111/j.2044-835X.2011.02063.x

behaviour of infants (Clements & Perner, 1994; Luo & Baillargeon, 2007; Onishi & Baillargeon, 2005) and non-human animals (Emery & Clayton, 2004), but can also include incidental measures gained when adults are not explicitly asked to perform a given behaviour (Cohen & German, 2009; Kovacs, Teglas, & Endress, 2010; Samson *et al.*, 2010). Using direct measures, perspective-taking seems to be relatively effortful. Children fail most tasks directly measuring perspective-taking and theory of mind up till around 4 years of age (Flavell, Everett, Croft, & Flavell, 1981; Wellman, Cross, & Watson, 2001), performance correlates with abilities in executive function (Carlson & Moses, 2001) and even adults seem to be limited in how they can perform under time pressure (Keysar, Lin, & Barr, 2003). Using indirect measures, perspectives seem to be calculated relatively efficiently. Infants and non-human animals (with sparse processing resources) show sensitivity to what others have seen (Emery & Clayton, 2004; Luo & Baillargeon, 2007; Onishi & Baillargeon, 2005) and adults have been shown to calculate the perspectives of others somewhat automatically (Kovacs *et al.*, 2010; Samson *et al.*, 2010). In the current paper, we investigate whether direct and indirect measures reflect the performance of independent cognitive systems or a single system performing differently under differing task demands. In the discussion, we will also consider the related question of whether efficient mechanisms for perspective-taking in adults might be responsible for precocious performance in infancy.

Apperly and Butterfill (2009) hypothesize that conflicting needs for efficiency and flexibility on theory of mind may be reconciled by the operation of independent cognitive systems. More effortful systems should gain flexibility at the expense of speed. Efficient systems should gain speed at the expense of flexibility and, by doing so, may allow for success of infants and non-human animals. If this hypothesis is correct, then efficient perspective-taking abilities should show distinct limitations, and such limits may provide a 'signature' for the operation of that ability. Such signature limits should prescribe the performance of participant groups through development (ontogenetic and phylogenetic) and when independent task demands differ, much in the way that three to four items is the limit to precocious performance of infants and chimpanzees sensitivity to number (Feigenson, Dehane, & Spelke, 2004) and adults' spontaneous and efficient enumeration (or subitizing; Trick & Pylysyn, 1994). In the case of number, such limits provide converging evidence for the existence of a cognitive system for number cognition that is independent of other, more flexible, capacities for thinking about number. Here, we examine whether the distinction between Level-1 and Level-2 perspective-taking is a signature limit on theory of mind. If so, we should expect to find that Level-1, but not Level-2, perspective-taking can be accomplished automatically in older children and adults.

The distinction between Level-1 and Level-2 perspective-taking has long been suggested by developmental researchers (Flavell, Everret *et al.*, 1981; Flavell, Flavell, Green, & Wilcox 1981; Lempers, Flavell, & Flavell, 1977; Masangkay *et al.*, 1974). Level-1 perspective-taking requires the ability to understand that objects visible to oneself are not necessarily visible to another person (Flavell, Everett *et al.*, 1981). Level-2 perspective-taking has been defined as understanding that 'an object simultaneously visible to both the self and the other person may nonetheless give rise to different visual impressions or experiences in the two if their viewing circumstances differ' (Flavell, Everett *et al.*, 1981, p. 1).

The Level-1/Level-2 distinction distinguishes between a set of tasks that seem to be passed prior to the age of four (Moll & Tomasello, 2006, Flavell, Everett *et al.*, 1981), characterized as Level-1, and those tasks which children younger than the age of four consistently seem to fail (Flavell, Everett *et al*., 1981; Masangkay *et al*., 1974). Notably, while recent research has suggested that infants as young as 12.5 months may show evidence of Level-1 perspective-taking on indirect measures such as looking time (Luo & Baillargeon, 2007; Sodian, Thoermer, & Metz, 2007), no such evidence has so far been forthcoming for Level-2 perspective-taking.

Two recent studies have examined adults' Level-1 perspective-taking using both direct and indirect measures. Samson *et al*. (Qureshi, Apperly, & Samson, 2010; Samson *et al*., 2010) had adults complete a computerized task in which they viewed stimuli showing an avatar in a room. A number of red circles were located within the room, each of which was either visible to the avatar or not. On some trials ('Other' trials), participants were required to make a direct judgement about the avatar's perspective. On this, direct, measure of perspective-taking participants found it harder to judge another's perspective when it differed from their own, and moreover, this egocentric interference was increased when participants simultaneously performed a task that taxed executive function (Qureshi *et al*., 2010). These findings suggest that adopting others' perspectives remains cognitively effortful, even for adults (Epley, Morewedge, & Keysar, 2004).

The indirect test of perspective-taking came from 'Self' trials, in which the presence of the avatar was irrelevant and participants simply reported their own perspective. On these trials, adults were slower and more error-prone in judging their own perspective when the avatar happened to have a different perspective than when his perspective was the same as theirs. This interference provides an indirect measure of perspective-taking because it suggests that participants were processing the avatar's perspective even though this was not required for their explicit judgement of 'Self' perspective. This interference was not a simple carry-over from the requirement to take perspectives on 'Other' trials, because Samson *et al*. found similar interference even when participants made 'Self' judgements throughout the entire study. Moreover, in contrast to findings from the direct measure, Qureshi *et al*. (2010) found that this automatic processing of Level-1 perspectives was not disrupted when adults simultaneously performed a task that taxed executive function. Altogether, results from this indirect measure suggest that participants are processing the avatar's perspective in a manner that is both relatively automatic and cognitively efficient. Importantly, there need be no contradiction between findings of cognitively efficient perspective processing on the indirect measure and egocentrism on the direct measure; Qureshi *et al*. (2010) suggest that even though participants calculate the Level-1 perspectives of others efficiently, selection of either self or other perspectives for a response requires effortful control, particularly when the perspectives are conflicting.

These findings from indirect versus direct measures find some correspondence in the developmental literature, where indirect measures have revealed infants to show earlier sensitivities to the Level-1 perspectives of others, as well as other aspects of ToM, suggesting that these are somehow 'easier' to process. But of course, all such observations raise the same basic question: What does it mean if the 'difficulty' of a task depends on whether performance is assessed directly or indirectly? Apperly and Butterfill's (2009) conjecture is that direct and indirect measures reflect the activity of distinct processing systems that make complementary trade-offs between flexibility and efficiency. It follows that the cognitively efficient system that drives effects observed on indirect measures should be limited to relatively simple cases. The current study tests the hypothesis that it is limited to Level-1 and not Level-2 perspectives.

We adapted Samson *et al*.'s task so that instead of Level-1 judgements about how many dots an avatar could see, child and adult participants made Level-2 judgements

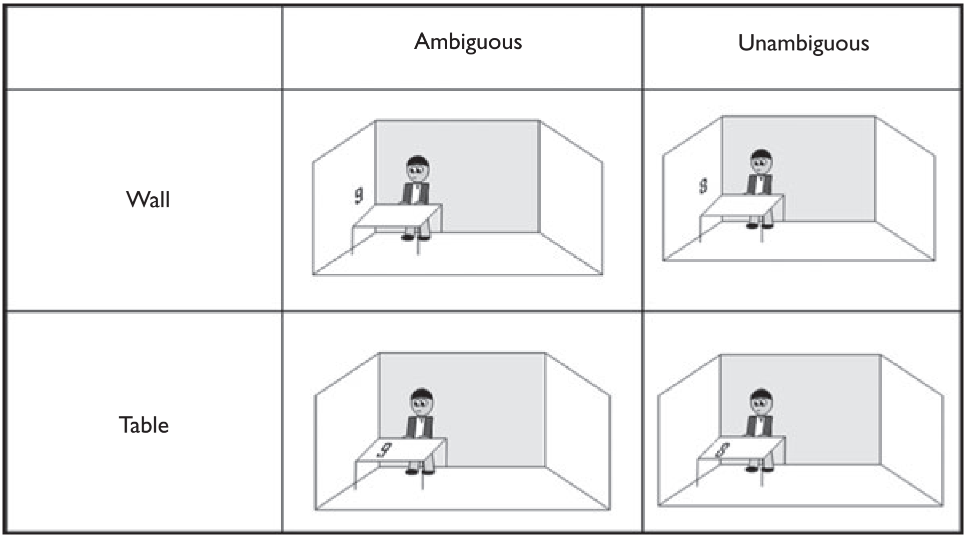

Figure 1. Examples of stimuli used. Ambiguous stimuli appear different if inverted, unambiguous stimuli appear the same. Wall stimuli appear the same to Self and Other, Table Stimuli are viewed inverted. Only on Ambiguous-Table trials are Self and Other perspective content different.

about the appearance of numerals, such as 6 and 9, that appear different depending on one's viewing position. On 'Other' trials (the direct measure of perspective-taking), participants explicitly judged what the cartoon avatar saw. The existing literature predicts that we should observe egocentric interference (worse performance when the avatar's perspective was different from the participants') at all ages. On 'Self' trials (from which we take the indirect measure of perspective-taking), participants explicitly judged their own perspective. On the basis of previous findings from a Level-1 version of the task (Qureshi *et al.*, 2010; Samson *et al.*, 2010; Surtees & Apperly, in press), it might be expected that participants would experience interference from automatic processing of the avatar's perspective. However, if automatic perspective processing is limited to Level-1 perspectives (Apperly & Butterfill, 2009) then such interference should not be observed.

Method

On every trial, participants viewed a cartoon picture of an avatar standing on the other side of a table (see Figure 1). A single numeral (0, 6, 8, or 9) was placed either on the wall, or on the table. On 'Self' trials, participants judged the numeral as it appeared to themselves. On 'Other' trials, participants judged how the numeral appeared to the avatar in the scene. On Stimulus–Ambiguous trials, the numeral used was a 6 or a 9 (numerals that look different if inverted). On Stimulus–Unambiguous trials, the numeral used was a 0 or an 8 (numerals that looked the same if inverted). On Location–Wall trials, the numeral was placed on the wall (so that it always appeared the same to the participant and the cartoon avatar). On Location–Table trials, the numeral was placed on the table so that the avatar's position in the room meant that he saw Ambiguous stimuli as a different number (but the Unambiguous stimuli as the same). Involuntary taking of an irrelevant perspective would be evidenced by an interaction between Stimulus and Location: any effect of Location should be greater when the stimulus is Ambiguous (as this is the only time perspectives diverge).

Participants

Adult participants were students from the University of Birmingham (N = 20, mean age = 20.4 years, 18 female). Child participants attended a school in a lower middle class area of Wolverhampton. Children between the ages of 6 and 11 were tested (mean age = 9.67, N = 80, 41 female). A median split based on age was performed to create a group of younger children (age range: 6.6–9.2, mean age = 8.38, 24 female) and a group of older children (age range = 9.2–11.6, mean age = 10.95, 17 female).

Design and procedure

Child participants completed the experiment in a room adjacent to their normal classroom. Adult participants used a testing cubicle. Instructions included a detailed description of the procedure and an instruction to respond as quickly and accurately as possible. Practice trials were completed on paper until the participant had successfully answered examples from each condition.

On each trial, participants viewed successive fixation stimuli (a smiling face [600 ms] and a fixation cross [600 ms]) followed by a 1,800 ms auditory stimulus (either 'He sees a Y' or 'You see a Y', where Y was either 0, 6, 8, or 9) and then the test picture. Participants pressed one of two coloured keys to indicate whether or not the auditory stimulus correctly described the picture. Response time (RT) was measured from the onset of the picture. Child participants completed four practice trials, followed by 60 test trials (split evenly between Self and Other and presented in pseudo-random order). We mixed Self and Other trials within blocks because previous studies show this design to yield the largest effect sizes, and so this design would be most likely to detect any signs of automatic Level-2 perspective-taking. Adults completed 60 test trials organized to the same criteria, and also a further 60 trials aimed to test variance in participants responses with practice (these data are not analysed here). The experiment was presented using E-prime 2.0 (Psychology Software Tools, Inc.) on a laptop computer (Schneider, Eschmann, & Zuccolotto, 2002).

Results

Other perspective-taking provided a 'Direct' measure of voluntary perspective-taking. Self perspective-taking allowed for the calculation of an 'Indirect' measure of any involuntary perspective-taking which may have taken place. Data from these Self and Other perspectives were analysed together so that any interference effects could be statistically compared. Main effects of Stimulus examined whether there was any extra difficulty in processing Ambiguous stimuli (containing 6s or 9s) rather than Unambiguous stimuli (containing 8s or 0s). Main effects of Location examined whether presentation of the digit on the wall or table affected performance, whether or not this location resulted in a perspective difference between self and other. The critical effects for our hypotheses concerned the interaction between Stimulus and Location. This investigated interference between contents of self and other perspectives, because only in Ambiguous–Table trials does the perspective content of the character differ from that of the participant.

For Other perspective trials, an interaction between Ambiguity and Location would be the result of egocentric interference from self on to other. For Self trials, an equivalent Ambiguity by Location interaction would provide evidence for interference from the perspective of other when making judgements about the self. Only trials in which participants responded that the probe was correct were analysed (following Samson *et al.*, 2010). Trials with incorrect probes were not analysed as for these there was a systematic difference between Ambiguous–Table trials and all other trials: for this condition, the number to be rejected matched the alternative perspective content and thus was a correct answer for a different condition (whilst in *all* other conditions, the number to be rejected was not an alternative perspective and so would always be linked to an incorrect response).

Response times

Data that were two and a half standard deviations from the mean were omitted from the analysis of RTs (accounting for between 1% and 3% of data for each age group) as were data from incorrect responses.

An ANOVA with Perspective (Self, Other), Stimulus (Ambiguous, Unambiguous), and Location (Wall, Table) as within-subjects factors, and Age group as a between-subjects factor revealed a main effect of age group ($F(2, 99) = 32.86$; $p < .001$; Older < Younger). There was a main effect of Perspective ($F(1, 99) = 54.43$; $p < .001$; $\eta_p^2 = .364$; Self < Other), a main effect of Location ($F(1, 99) = 126.47$; $p < .001$; $\eta_p^2 = .571$; Wall < Table) and a main effect of Stimulus ($F(1, 99) = 74.28$; $p < .001$; $\eta_p^2 = .439$; Unambiguous < Ambiguous). There were significant two-way interactions between Perspective and Stimulus ($F(1, 99) = 18.81$; $p < .001$; $\eta_p^2 = .165$), Perspective and Location ($F(1, 99) = 11.02$; $p = .001$; $\eta_p^2 = .104$), and between Stimulus and Location ($F(1, 99) = 17.12$; $p < .001$; $\eta_p^2 = .153$). There was also a significant three-way interaction between Perspective, Stimulus, and Location ($F(1, 99) = 9.02$; $p = .003$; $\eta_p^2 = .571$). There were no other significant interactions ($F(1, 99) < .183$; $p > .166$; $\eta_p^2 < .037$).

The three-way interaction suggested that the critical interaction between Location and Stimulus was different for our Self and Other perspective-taking conditions. To investigate this further we completed two 2-way ANOVAs for Self and Other perspective-taking with Stimulus and Location as within-subjects factors. For Other perspective taking, there was a main effect of Stimulus ($F(1, 99) = 92.67$: $p < .001$; $\eta_p^2 = .486$), a main effect of Location ($F(1, 99) = 115.35$; $p < .001$; $\eta_p^2 = .181$), and an interaction between Stimulus and Location ($F(1, 99) = 21.65$; $p < .001$; $\eta_p^2 = .181$). Follow-up *t*-tests revealed the effect of Location to be significant for Unambiguous stimuli ($t(99) = 4.64$, $p < .01$), but greater for Ambiguous trials ($t(99) = 10.22$, $p < .001$) (see Figure 2). For Self perspective-taking, whilst there was again a main effect of Stimulus ($F(1, 99) = 33.02$; $p < .001$; $\eta_p^2 = .252$) and a main effect of Location ($F(1, 99) = 66.22$; $p < .001$; $\eta_p^2 = .403$), there was no interaction between the two factors ($F(1, 99) = 1.362$; $p = .246$; $\eta_p^2 = .014$).

Errors

An equivalent ANOVA on errors revealed no main effect of age ($F(2, 99) = .407$; $p = .667$; $\eta_p^2 = .008$). There was no main effect of Perspective ($F(1, 99) = 1.881$; $p = .173$; $\eta_p^2 = .018$). There were, however, main effects of Location ($F(1, 99) = 9.193$; $p = .003$, $\eta_p^2 = .087$; Wall < Table) and of Stimulus ($F(1, 99) = 11.436$; $p < .001$;

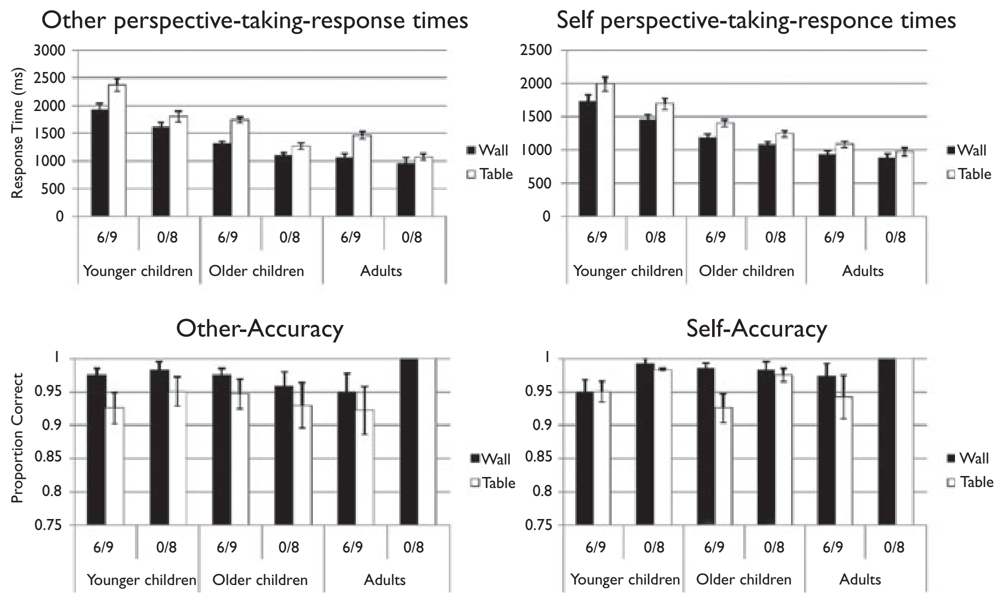

Figure 2. Response times and accuracy for all age groups. Error bars represent standard error of the mean.

$\eta_p^2 = .105$; Unambiguous < Ambiguous). There were no significant interactions. Most notably, unlike for RTs, there was no significant three-way interaction between Perspective, Location, and Stimulus ($F(1, 99) = .122$; $p = .728$; $\eta_p^2 = .001$) and no significant two-way interaction between Stimulus and Location ($F(1, 99) = 1.635$; $p = .204$; $\eta_p^2 = .017$), suggesting that any interference effects did not result in errors.

Results from our analysis of RTs suggested that we had indeed identified interference between perspectives. That this interference was different for self and other perspective-taking ruled out the possibility that such an effect could be caused by switching between tasks. Follow-up analysis revealed that this interference was only present on Other perspective-taking trials, and not on Self trials. In a previous study, Surtees and Apperly (in press) found an equivalent measure to be equally sensitive at measuring interference effects on self and other Level-1 perspective-taking. This suggests that the difference identified here truly reflects a difference between self and other perspective-taking for Level-2 judgements, not a difference in sensitivity in measurement between Self and Other conditions.

Discussion

In contrast to previous findings with Level-1 perspectives (Samson *et al.*, 2010; Surtees & Apperly, in press), the current study found evidence of Level-2 perspective processing only on a direct measure, not on an indirect measure. On 'Other' trials, participants were largely accurate at directly judging another's perspective, though they were slower and more error-prone when the avatar's perspective was different from their own. A significantly different pattern was observed on Self trials, where there was no distinctive pattern of interference in cases where the avatar's irrelevant perspective was different from the participants'. We discuss the implications of these findings from direct and indirect measures in turn.

Egocentrism in direct perspective judgements

Egocentrism – the interference from one's own perspective when taking that of another – is a feature of perspective-taking in young children (Flavell, Everett *et al.*, 1981; Light & Nix, 1983; Piaget & Inhelder, 1956): when young children make errors on perspective-taking tasks, they most commonly make errors in line with their own perspective, not at random. More recently, evidence from adults has suggested that it is not only children who suffer egocentric effects (Bernstein, Atance, Loftus, & Meltzoff, 2004; Birch & Bloom, 2004; Epley *et al.*, 2004; Keysar *et al.*, 2003; Nickerson, 1999; Royzman, Cassidy, & Baron, 2003). Adults rarely make egocentric errors in optimal conditions, but when they have to make estimates (Bernstein *et al.*, 2004) or perform tasks quickly (Keysar *et al.*, 2003; Samson *et al.*, 2010), they do show egocentric biases. One interpretation of this is that children's egocentric errors and adults' egocentric biases are largely unrelated: tasks with adults often involve much more complex information and reasoning. Alternatively, these effects may in fact be symptoms of the very same problem: it may be more difficult to process perspectives of others if they differ from one's own and this processing cost may lead to errors in young children, but merely biases in older children and adults who have more cognitive resources available.

One way to distinguish between these two interpretations is to test older children and adults on the very same tasks that young children fail. Our results suggest that egocentric errors in young children's Level-2 perspective-taking are the result of the very same processing problem that affects older children and adults. In our Level-2 perspective-taking task, children from the age of 6 showed egocentric interference effects very similar to those of adults. It is always difficult to ignore how one sees an object, and this may cause young children to make mistakes, and adults to perform more slowly, or less accurately under time pressure.

Limits on perspective-taking on indirect measures

Exciting and controversial recent research suggests that human infants and some non-human species may be capable of perspective-taking and that these abilities are most likely to be observed on indirect measures, such as looking time or spontaneous behaviour (e.g., Call & Tomasello, 2008; Emery & Clayton, 2004; Onishi & Baillargeon, 2005; Santos, Nissen, & Ferrugia, 2006; Sodian *et al.*, 2007; Song & Baillargeon, 2008; Southgate, Senju, & Csibra, 2006; but note that there is also some evidence of perspective taking on more direct measures, e.g., Buttelmann, Carpenter, & Tomasello, 2009). It is striking that when children are directly asked about what another person sees, knows, or believes, they generally perform significantly less well (e.g., Flavell, Everett *et al.*, 1981; Wellman *et al.*, 2001), and indeed, it is possible for the very same individual to be simultaneously 'incorrect' and 'correct', depending on whether their ability is measured directly or indirectly (e.g., Clements & Perner, 1994). Samson *et al.* (2010) likewise used both direct and indirect measures to assess Level-1 perspective-taking in older children and adults (see further Qureshi *et al.*, 2010; Surtees & Apperly, in press). Findings from the direct measure fit with a large literature suggesting that explicit perspective judgements are relatively effortful and prone to egocentric interference. Findings from the indirect measure suggested that Level-1 perspectives can be processed relatively automatically and with little cognitive effort. However, one problem with interpreting these findings – and the reason why the findings from infants and non-human animals have proved so controversial – is that it is just not clear whether direct and indirect measures are simply alternative ways of assessing the same underlying ability or whether they are in fact tapping quite different cognitive processes.

Apperly and Butterfill (2009) propose that one way of explaining the pattern of results is to suppose that humans have multiple systems for theory of mind, some of which trade flexibility to gain efficiency and others which do the reverse. The efficient systems might be common to adults, infants, and perhaps also some non-human animals, and might not necessarily be available for explicit report on direct measures. Importantly, this provides a theoretically motivated prediction that can assist with interpreting the findings from direct and indirect tests: if it is the case that indirect measures are tapping a cognitive process that has gained efficiency at the expense of flexibility, then there really must be limits to the problems that it can handle. Apperly and Butterfill (2009) offered the Level-1/Level-2 distinction as a candidate for one such signature limit.

The current findings support this prediction by showing that older children and adults, who succeed on direct tests of Level-2 perspective-taking, show no evidence of Level-2 perspective-taking on our indirect measure. Absence of evidence does not, of course, constitute evidence of absence, but we should be interested when absence of evidence repeatedly converges on the same conclusion across multiple studies and multiple participant groups. This is the case in the literature on number cognition, where there is evidence that human adults, human infants, and non-human animals are all capable of precise enumeration, and convergence on the conclusion that this ability is limited to sets of no more than three or four items (e.g., Feigenson *et al.*, 2004). It is noteworthy, therefore, that in addition to the absence of evidence from adults reported here, there is no evidence that either infants or non-human animals are capable of Level-2 perspective-taking. We suggest that this convergence should make us take seriously the proposition that indirect measures in studies of non-human animals and human infants, children, and adults are tapping a cognitively efficient capacity for perspective-taking that is limited to process Level-1 perspective problems.

Another interesting finding in our study was that, although participants did not show evidence of calculating the Level-2 perspectives of others automatically, they were slower at calculating their own perspective when the avatar viewed the stimulus upside down. While this may reflect an artefact of the placement of the stimuli, further research may investigate whether, alternatively, this reflects a form of interference caused by another viewing an object from upside down (regardless of whether they actually perceive the object to be different).

Clarifying the distinction between Level-1 and Level-2 perspective-taking

In the current paper, we have followed the literature in supposing that the Level-1/Level-2 distinction marks a straightforward difference between different kinds of perspective-taking. In fact, however, the distinction between Level-1 and Level-2 perspective-taking has been defined in at least two different ways. Distinguishing between them is important for generating informative hypotheses for future research on efficient versus effortful perspective-taking. In one canonical formulation, Level-1 perspective-taking involves being able to infer 'what another person does and does not see', whereas Level-2 perspective-taking involves knowing that 'an object simultaneously visible to both the self and the other person may nonetheless give rise to different visual impressions or experiences' (Flavell, Everett *et al*., 1981, p. 1). So understood, Level-2 perspective-taking requires understanding that objects give rise to experiences. However, elsewhere Level-2 perspective taking is defined in terms of the appearances of objects (Flavell, 2000, p. 19; Masangkay *et al.*, 1974, p. 360). It is important to distinguish *the experiences of subjects* (invoked in the first definition) from *the appearances of objects* (invoked in the second definition). Someone might know that two perceivers' experiences of a single object differ without supposing that this is related to any of the object's appearances, as when (for example) only one of the perceivers has blurred vision (Smith, 2007). Conversely, it is possible to recognize that an object has multiple appearance properties that are accessible under different conditions without construing appearances as involving facts about perceivers' experiences of the object (Nudds, 2010). To illustrate, consider Flavell *et al*.'s stimulus, a rabbit that appears yellow when viewed from one angle and green when viewed from another. These appearances are not properties of any particular perceiver; they can be enjoyed by any observer with normal colour vision who is appropriately located and oriented.

So being able to distinguish among an object's various appearances does not logically entail being able to make corresponding distinctions among subjects' different experiences of that object; and the converse entailment fails too. The experiments presented here like those of Flavell *et al*. (1981) involve tasks on which success could in principle be achieved either by representing appearances or by representing experiences. Our current evidence therefore suggests that neither function is supported by efficient perspective processing. It remains an open question whether children's later-acquired capacity to reason about perspectives is best characterized as a single, all-or-nothing ability, 'Level-2' perspective-taking. Alternatively, empirical evidence may show 'Level-2 perspective-taking' to be more clearly understood as piecemeal abilities to discern objects, their appearances, and people's experience of them.

References

Apperly, I. A., & Butterfill, S. A. (2009). Do humans have two systems to track beliefs and belief-like states? *Psychological Review*, *116*, 953–970.

Bernstein, D. M., Atance, C., Loftus, G. R., & Meltzoff, A. (2004). We saw it all along – Visual hindsight bias in children and adults. *Psychological Science*, *15*, 264–267.

Birch, S. A. J., & Bloom, P. (2004). Understanding children's and adults' limitations in mental state reasoning. *Trends in Cognitive Sciences*, *8*, 255–260.

Buttelmann, D., Carpenter, M., & Tomasello, M. (2009). Eighteen-month-old infants show false belief understanding in an active helping paradigm. *Cognition*, *112*(2), 337–342.

Call, J., & Tomasello, M. (2008). Does the chimpanzee have a theory of mind? 30 years later. *Trends in Cognitive Sciences*, *12*, 187–192.

Carlson, S. M., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development*, *72*, 1032–1053.

Clements, W. A., & Perner, J. (1994). Implicit Understanding of belief. *Cognitive Development*, *9*, 377–395.

Cohen, A. S., & German, T. C. (2009). Encoding of others' beliefs without overt instruction. *Cognition*, *111*, 356–363.

Emery, N. J., & Clayton, N. S. (2004). The mentality of crows: Convergent evolution of intelligence in corvids and apes. *Science*, *306*, 1903–1907.

Epley, N., Morewedge, C. K., & Keysar, B. (2004). Perspective taking in children and adults: Equivalent egocentrism but differential correction. *Journal of Experimental Social Psychology*, *40*, 760–768.

Feigenson, L., Dehaene, S., & Spelke, E. (2004). Core systems of number. *Trends in Cognitive Sciences*, *8*, 307–314.

Flavell, J. H. (2000). Development of children's knowledge about the mental world. *International Journal of Behavioral Development*, *24*(1), 15–23.

Flavell, J. H., Everett, B. A., Croft, K., & Flavell, E. R. (1981). Young children's knowledge about visual-perception – ff. *Developmental Psychology*, *17*, 99–103.

Flavell, J. H., Flavell, E. R., Green, F. L., & Wilcox, S. A. (1981). The development of 3 spatial perspective-taking rules. *Child Development*, *52*, 356–358.

Keysar, B., Lin, S. H., & Barr, D. J. (2003). Limits on theory of mind use in adults. *Cognition*, *89*, 25–41.

Kovacs, A. M., Teglas, E., & Endress, A. D. (2010). The social sense: Susceptibility to others' beliefs in human infants and adults. *Science*, *330*, 1830–1834.

Lempers, J. D., Flavell, E. R., & Flavell, J. H. (1977). Development in very young-children of tacit knowledge concerning visual-perception. *Genetic Psychology Monographs*, *95*, 3–53.

Light, P., & Nix, C. (1983). Own view versus good view in a perspective-taking task. *Child Development*, *54*, 480–483.

Luo, Y., & Baillargeon, R. (2007). Do 12.5-month-old infants consider what objects others can see when interpreting their actions? *Cognition*, *105*, 489–512.

Masangkay, Z. S., McCluskey, K. A., McIntyre, C. W., Sims-Knight, J., Vaughn, B. E., & Flavell, J. H. (1974). Early development of inferences about visual percepts of others. *Child Development*, *45*, 357–366.

Moll, H., & Tomasello, M. (2006). Level I perspective-taking at 24 months of age. *British Journal of Developmental Psychology*, *24*, 603–613.

Nickerson, R. S. (1999). How we know – and sometimes misjudge – What others know: Imputing one's own knowledge to others. *Psychological Bulletin*, *125*, 737–759.

Nudds, M. (2010). Appearance-reality and perspective-taking tasks, forthcoming. In N. Eilan, H. Lerman, & J. Roessler (Eds.), *Perception, causation and objectivity*. Oxford, UK: Oxford University Press.

Onishi, K. H., & Bailargeon, R. (2005). Do 15-month-old infants understand false beliefs? *Science*, *308*, 255–258.

Piaget, J., & Inhelder, B. (1956). *The child's conception of space*. London: Routledge & Kegan Paul.

Qureshi, A. W., Apperly, I. A., & Samson, D. (2010). Executive function is necessary for perspective selection, not Level-1 visual perspective calculation: Evidence from a dual-task study of adults. *Cognition*, *117*, 230–236.

Royzman, E. B., Cassidy, K. W., & Baron, J. (2003). "I know, you know": Epistemic egocentrism in children and adults. *Review of General Psychology*, *7*, 38–65.

Samson, D., Apperly, I. A., Braithwaite, J. J., Andrews, B. J., & Scott, S. E. B. (2010). Seeing it their way: Evidence for rapid and involuntary computation of what other people see. *Journal of Experimental Psychology-Human Perception and Performance*, *36*, 1255–1266.

Santos, L. R., Nissen, A. G., & Ferrugia, J. A. (2006). Rhesus monkeys, Macaca mulatta, know what others can and cannot hear. *Animal Behaviour*, *71*, 1175–1181.

Schneider, W., Eschmann, A., & Zuccolotto, A. (2002). *E-Prime user's guide*. Pittsburgh, PA: Psychology Software Tools.

Smith, A. D. (2007). Translucent experiences. *Philosophical Studies*, *140*(2), 197–212.

Sodian, B., Thoermer, C., & Metz, U. (2007). Now I see it but you don't: 14-month-olds can represent another person's visual perspective. *Developmental Science*, *10*, 199–204.

Song, H. J., & Baillargeon, R. (2008). Infants' Reasoning about others' false perceptions. *Developmental Psychology*, *44*, 1789–1795.

Southgate, V., Senju, A., & Csibra, G. (2007). Action anticipation through attribution of false belief by 2-year-olds. *Psychological Science*, *18*, 587–592.

Surtees, A. D. R., & Apperly, I. A. (in press). Egocentrism and automatic perspective-taking in children and adults. *Child Development*.

Trick, L. M., & Pylyshyn, Z. W. (1994). Why Are small and large numbers enumerated differently – A limited-capacity preattentive stage in vision. *Psychological Review*, *101*, 80–102.
Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory-of-mind development: The truth about false belief. *Child Development*, *72*, 655–684.

Received 1 December 2010; revised version received 1 September 2011