UNIVERSITY OF BIRMINGHAM

University of Birmingham Research at Birmingham

Unintentional perspective-taking calculates whether something is seen, but not how it is seen

Surtees, Andrew; Samson, Dana; Apperly, Ian

DOI:
10.1016/j.cognition.2015.12.010

License:
Creative Commons: Attribution-NonCommercial-NoDerivs (CC BY-NC-ND)

Document Version
Peer reviewed version

Citation for published version (Harvard):
Surtees, A, Samson, D & Apperly, I 2016, 'Unintentional perspective-taking calculates whether something is seen, but not how it is seen', *Cognition*, vol. 148, pp. 97-105. https://doi.org/10.1016/j.cognition.2015.12.010

Link to publication on Research at Birmingham portal

Publisher Rights Statement:
Checked for eligibility: 27/03/2018
https://doi.org/10.1016/j.cognition.2015.12.010

General rights
Unless a licence is specified above, all rights (including copyright and moral rights) in this document are retained by the authors and/or the copyright holders. The express permission of the copyright holder must be obtained for any use of this material other than for purposes permitted by law.

•Users may freely distribute the URL that is used to identify this publication.
•Users may download and/or print one copy of the publication from the University of Birmingham research portal for the purpose of private study or non-commercial research.
•User may use extracts from the document in line with the concept of 'fair dealing' under the Copyright, Designs and Patents Act 1988 (?)
•Users may not further distribute the material nor use it for the purposes of commercial gain.

Where a licence is displayed above, please note the terms and conditions of the licence govern your use of this document.

When citing, please reference the published version.

Take down policy
While the University of Birmingham exercises care and attention in making items available there are rare occasions when an item has been uploaded in error or has been deemed to be commercially or otherwise sensitive.

If you believe that this is the case for this document, please contact UBIRA@lists.bham.ac.uk providing details and we will remove access to the work immediately and investigate.

Download date: 10. Dec. 2024

Unintentional perspective-taking calculates whether something is seen, but not how it is seen.

Andrew Surtees[1,2], Dana Samson[1] and Ian Apperly[2]

[1] University catholique de Louvain, Belgium. [2]University of Birmingham, UK

Key words: Perspective-taking, Theory of Mind, Visual Perspective-taking

Word Count: 5710

Address for correspondence: Andrew Surtees, School of Psychology, University of Birmingham, Edgbaston, Birmingham, B15 2TT

Abstract

A long established distinction exists in developmental psychology between young children's ability to judge *whether* objects are seen by another, known as "level-1" perspective-taking, and judging *how* the other sees those objects, known as "level-2" perspective-taking (Flavell et al., 1981). Samson et al. (2010) provided evidence that there are two routes available to adults for level-1 perspective-taking: one which is triggered relatively automatically and the other requiring cognitive control. We tested whether both these routes were available for adults' level-2 perspective-taking. Explicit judgements of both level-1 and level-2 perspectives were subject to egocentric interference, suggesting a need for cognitive control. Evidence of unintentional perspective-taking was limited to level-1 judgements.

In order to predict and explain the behaviour of others in even simple social environments it is often necessary to take into account their perspective on the world. People's actions are dictated by their goals and intentions, which in turn are dictated by beliefs and desires, any of which may diverge from our own. Cooperating and competing with others regularly requires representation of these perspectives. One case where such situations arise is in taking visual perspectives. Developmental psychologists have argued that perspective-taking is fundamentally different at two levels (Flavell et al., 1981). Young children successfully understand *whether* someone sees something or not (a level-1 perspective) before they understand *how* something looks to them (a level-2 perspective). In the current paper we test whether the cognitive characteristics of adults' perspective-taking are similarly divergent and discuss the implications for how we understand the impressive performance of infants on some perspective-taking and theory of mind tasks (Luo & Baillargeon, 2007; Onishi & Baillergeon, 2005).

The traditional method for testing perspective-taking involves using *direct measures*. Participants (often children) are asked to assess the perspectives of others and either report this perspective or make judgements about what a character will do given that they hold a specific perspective. For example, Piaget and Inhelder (1956) asked children to report how an array of three mountains would appear to an experimenter and Masangkay et al. (1974) asked children to judge whether someone sat opposite them would see a picture of a turtle as being the right way up, or upside down. Although tasks vary in difficulty, these direct measures all suggest that perspective-taking is relatively taxing for young children. Interestingly, children's errors are "egocentric", reflecting over-application of their own perspective (Flavell et al, 1981; Piaget & Inhelder, 1956). Overcoming this egocentrism is thought to be crucial in the development of perspective-taking (Piaget & Inhelder, 1956) and continues to be taxing, even for adults (Epley et al., 2004; Keysar et al, 2003; Kessler & Thomson, 2010; Michelon & Zacks, 2005; Nickerson, 1999). Taken together, these findings support a view of perspective-taking as an effortful process.

Recent research in infant (Onishi & Baillargeon, 2005; Sodian, Theormer & Metz, 2007; Southgate, Senju & Csibra, 2007) and comparative (Clayton & Emery, 2007; Hare, Call &Tomasello, 2001, Santos, Nissan & Feruggia, 2006) psychology has suggested that, under certain circumstances, perspective-taking might not be so difficult after all. *Indirect* measures, monitoring eye gaze and other spontaneous behaviours, seem to show that infants and non-human animals with rather limited cognitive resources can track perspectives. One interpretation of such results is that researchers have finally been able to find measures sensitive enough to show how easy perspective-taking really is (Baillargeon, Scott & He, 2010; Onishi & Baillargeon, 2005). Others are more sceptical about whether such evidence counts as genuine perspective-taking or "theory of mind" (Heyes, 2014, in press; Perner & Ruffman, 2005; Ruffman & Perner, 2005; Ruffman, Taumoepeau & Perkins, 2012). In contrast to these polarised positions, it will be our working hypothesis that direct measures and indirect measures of perspective-taking can both reveal interesting features about the cognitive profile of perspective-taking.

Samson et al. (2010) identified both a direct and an indirect measure of perspective-taking using a single paradigm, requiring adults to judge the number of dots that could be seen on the walls of a room (a level-1 perspective-taking task). On separate trials, adults took either their own perspective (Self trials) or that of a cartoon avatar present in the room (Other trials). On Other trials (a direct measure of perspective-taking), participants were slower and more error-prone at judging the avatar's perspective when their own perspective was different, demonstrating egocentric interference. Importantly, an analogous effect was also observed on Self trials, when participants were also slower and more error prone at judging their own perspective when the irrelevant perspective of the avatar happened to be different from their own (which they dubbed altercentric interference). This novel observation suggested that participants calculated the avatar's perspective, even though they had no reason to do so, leading to "altercentric" interference on judgements of their own perspective (see Kovacs et al. 2010 for a related phenomenon). The authors suggested that this altercentric interference provided an indirect measure of the operation of a process of visual perspective-taking that had been triggered relatively automatically.

Researchers in the cognitive sciences have long argued over the most appropriate definition of automaticity. Bargh (1994) described the automaticity of a processes as the degree to which it displays four features: Operation outside of cognitive control, efficiency, lack of awareness and lack of intentionality. For our purposes, it is clear that the automaticity of perspective-taking is potentially interesting in the degree to which it is efficient and can operate without cognitive control, as both of these factors may make such a process available to infants and non-human animals with limited cognitive resources. There is evidence to suggest that level-1 perspectives may be processed both outside of cognitive control, and efficiently. Samson et al. (2010; see also Santiesteban, Catmur, Coughlan Hopkins, Bird, & Heyes, 2014) showed that the altercentric intrusions occurred when participants repeatedly judged their own perspective across a same block or even across the entire experiment, suggesting that they could not voluntarily ignore the irrelevant perspective of the avatar. Qureshi and colleagues found that adults computed perspectives when they did not need to, even when also completing a secondary task that loaded executive function (Qureshi et al, 2010). To just this extent we conclude that level-1 perspectives may be calculated in a relatively automatic manner, and that the consequences of this may be observed on indirect measures, such as interference from an avatar's irrelevant perspective when judging one's own “Self” perspective. This perspective calculation is not enough to drive explicit perspective judgements, for which effortful selection is required especially when “Self” and “Other” perspectives diverge.

Our key concern in the current work is whether Samson et al’s (2010) altercentric effect would also be present for level-2 perspectives. There are two reasons to hypothesise that level-2 perspectives will not be calculated automatically. Firstly, if the abilities demonstrated on indirect measures reflect cognitively efficient processes, then there are strong theoretical reasons for supposing that this efficiency will come at the cost of inflexibility about the kinds of perspectives that can be processed (Apperly & Butterfill, 2009; Apperly, 2010; Butterfill & Apperly, 2013). Recent evidence testing predictions from this account has suggested that children’s and adults’ predictive gaze (an “indirect measure”) anticipates the behaviour of an agent with a false belief about an object’s location, but no such effect was seen when the agent’s behaviour is based upon a false belief about the object’s identity (Low & Watts, 2013). A related prediction is that level-2 perspectives will not be processed automatically. Secondly, there are good empirical reasons for supposing that some kinds of perspective-taking are significantly more demanding than others. As well as traditional findings from direct measures of visual perspective-taking showing that children pass level-1 tasks around the age of 2-years (Moll &Tomasello, 2006), but do not pass similar level-2 tasks till around the age of 4 or 5 (Flavell et al, 1981, Masangkay et al., 1974), the level-1/level-2 distinction also captures current limits on evidence of precocious abilities shown by infants and non-human animals (Apperly & Butterfill, 2009; Clayton & Emery, 2007; Hare, Call & Tomasello, 2006; Song & Baillargeon, 2008). Many of these new tasks either test or imply level-1 perspective-taking, but as yet there is no positive evidence of the equivalent level-2 ability.

Surtees, Butterfill & Apperly (2012) adapted Samson et al.’s perspective-taking ability to allow for level-2 judgments. In this study, children and adults were asked to make self and other judgments about the appearance of a numeral, making use of the fact that some numbers (6 and 9 for example) look different if viewed upside down, whilst others (e.g. 0 and 8) look the same. Across trials there was variation in the type of number used and whether the participant and the avatar looked at them from the same angle. When participants made judgements about what number the avatar saw, they found this most difficult in cases where their perspective was different from that of the avatar. Analogous to Samson et al.’s (2010) egocentrism effect, it was hardest to judge that the avatar saw a 6 when the participant saw a 9. However, no “altercentric” effect was found for level-2 judgements, as observed from the fact that there was not a specific difficulty for participants in judging that they saw a 6 when the avatar saw a 9. It was concluded from this that level-2 perspective-taking was not automatic: There was no evidence of efficiency, nor of operation outside of cognitive control. There were, however, two clear limitations to Surtees et al.'s findings. Firstly, there was no direct comparison between level-1 and level-2 perspective-taking. Secondly, to be appropriate for children, participants did relatively few trials (only 60), thus limiting power to detect signs of automaticity.

To examine the processes involved in adults' visual perspective-taking, we therefore adapted Samson et al.'s and Surtees et al.'s tasks so that we could elicit level-2 as well as level-1 judgements using very similar stimuli. We tested two aspects of automaticity, both whether adults *could* calculate the avatar's perspective rapidly enough to interfere with their given task and whether they *would* do so outside of cognitive control. To this end, we varied whether participants completed trials in separate blocks of self and other perspective or mixed blocks. Separate blocks provide more opportunity to strategically ignore the other perspective, thus providing a test of whether perspective-taking would operate outside of intentionality and cognitive control. Mixed blocks provide less opportunity to strategically ignore the other perspective, thus giving the greatest opportunity to observe whether rapid calculation would ever occur. On trials requiring explicit judgements of the "other's" perspective we follow Samson et al. (2010) and Surtees et al (2012) in predicting evidence of egocentrism. We expected participants to calculate their own perspective relatively automatically and to suffer a cost of ignoring this. On trials requiring explicit judgements of "self" perspective, we predicted altercentric effects (interference from the avatar's perspective) on both of our level-1 conditions, since Samson et al. (2010) showed participants to be influenced by the avatar's level-1 perspective, regardless of opportunities for cognitive control. In contrast, we predicted that altercentric interference from the avatar's level-2 perspective would depend on the level of strategic control available to participants. We expected no evidence of interference in the separate block condition, in which participants have more opportunity for strategically processing just their own perspective. Our mixed block condition, provided the opportunity for the first systematic assessment of whether level-2 perspective could be calculated rapidly enough to yield altercentric interference under the right conditions.

EXPERIMENT 1

Method

Adult participants judged their own perspective or that of a cartoon avatar in a picture stimulus. Level-1 judgements involved judging how many balloons could be seen, whilst level-2 involved identifying a numeral from its appearance (see figure 1). Consistency between Self and Other perspectives was varied. An effect of Consistency on Other trials would be evidence of *egocentrism*, an extra cost due to ignoring one's own perspective. An effect of Consistency on Self trials would be evidence of *altercentrism*, an extra cost due to having to ignore the avatar's perspective, which has been processed unnecessarily.

Participants

Participants were 64 undergraduate students from the University catholique de Louvain, Belgium (Mean age: 19.4; 54 female). All participated in exchange of course credit or a small honorarium.

Stimuli

All picture stimuli showed a cartoon avatar next to a table in a room (Figure 1). For level-1 stimuli one to three balloons were placed either in front of or behind the avatar. For Consistent stimuli all of the balloons were found in front of the avatar. For Inconsistent stimuli one or more were behind him. Samson et al. (2010) showed that varying the position of objects in this way did not disrupt processing of self perspective except in the presence of an avatar. For level-2 stimuli a numeral (either a 6 or a 9) was placed on the table. The numeral was seen either laid flat or stood upright. This crucial design feature of the stimuli meant that if a stimulus contained an upright numeral, perspectives were consistent and if the stimulus contained a flat-lying numeral, perspectives were inconsistent. The novelty of these stimuli, compared with those for the level-1 task meant that we conducted a pre-test to establish that the orientation of the number did not affect judgements of Self perspective in the absence of an avatar (see figure 2).

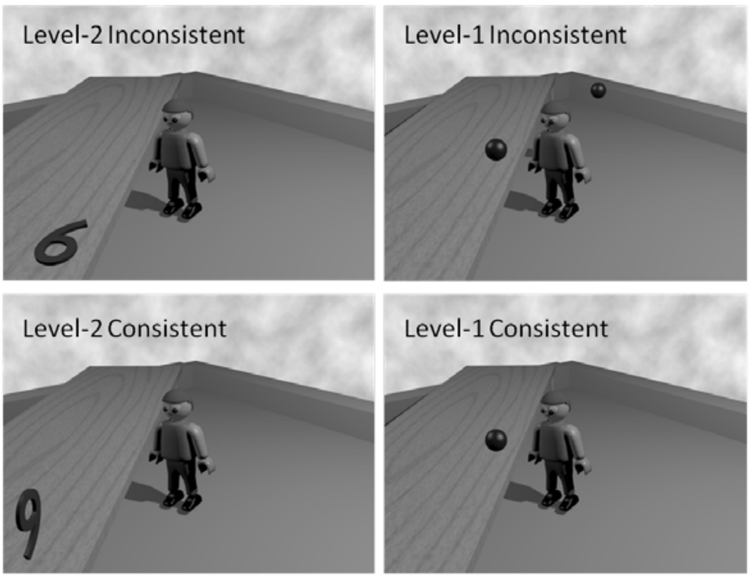

Figure 1, Example of stimuli used. For level-1 perspective-taking, perspectives are inconsistent when 1 or more balloons are unseen by the avatar. For level-2 perspective-taking, perspectives are inconsistent when the numeral lies flat on the table. Here the avatar sees the numeral in a different orientation.

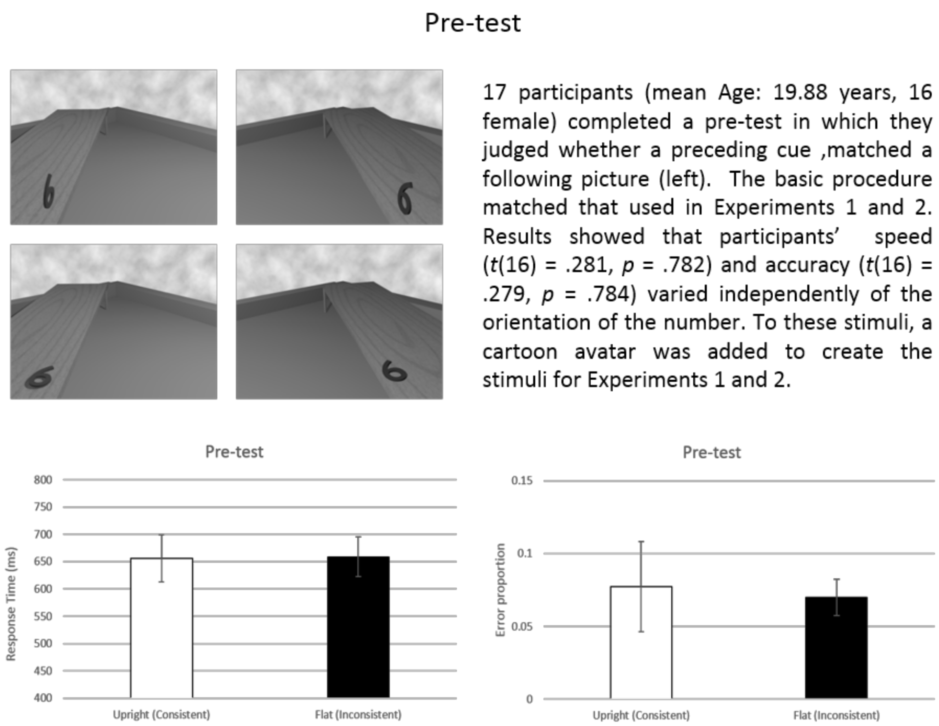

Figure 2. Information on a pre-test performed to test for variation in performance based on the nature of level-2 stimuli.

Procedure

Participants were evenly split into four groups: Level-1 Blocked, Level-1 Mixed, Level-2 Blocked and Level-2 Mixed, and presented with 208 trials in the Level-1 conditions or 192 trials in the Level-2 conditions. The greater number for Level-1 reflects the fact that the Level-1 conditions contained 16 filler trials, included in order to make each probe as likely to be combined with a "yes" response (see Samson et al., 2010, for details). On each trial (see figure 3) participants saw a fixation cross, followed by a cue as to whose perspective to take. Following this a number was presented, for Level-1 perspective-taking, zero, one, two or three; for level-2 perspective-taking, six or nine. Finally, participants saw the picture stimulus. On half of trials, the cues matched the content of the picture stimulus, on the other half they did not. Participants responded on a keyboard as to whether the cues matched the picture.

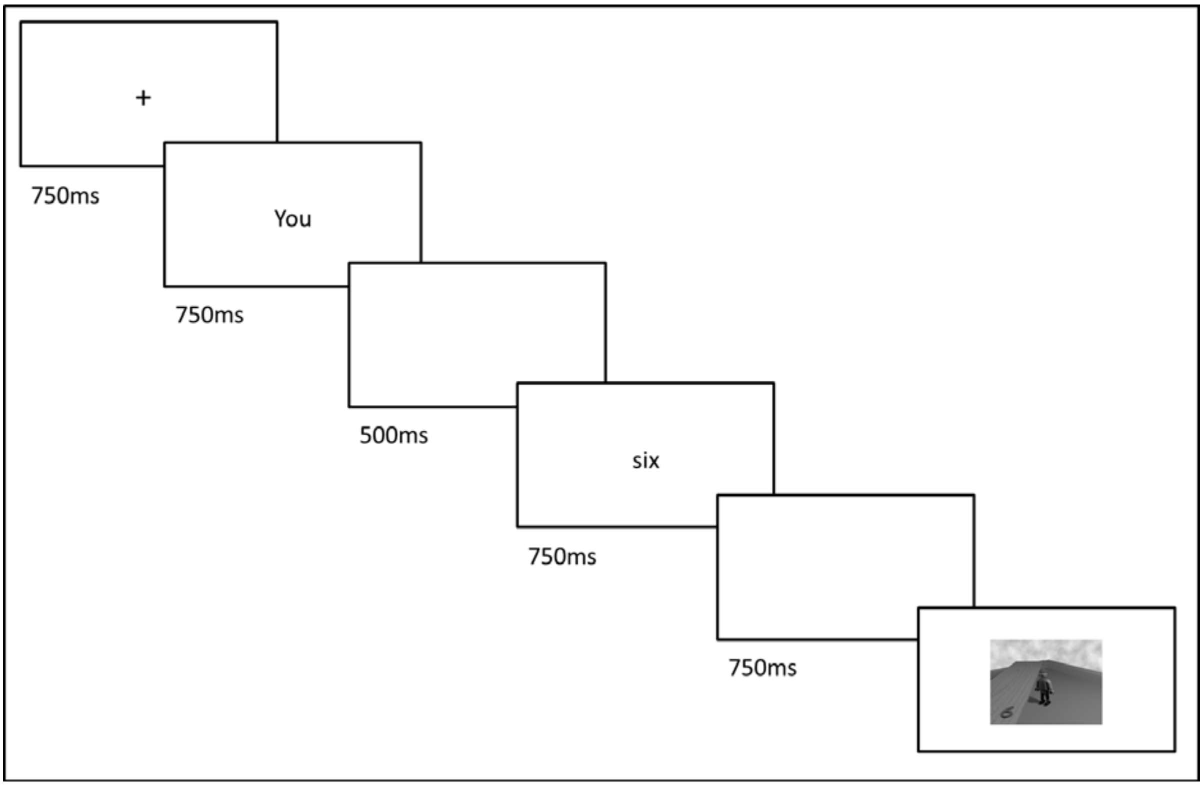

Figure 3. Example event sequence. Participants were cued with the relevant perspective, either you or him (“vous” or “lui” in French). This was followed by the number to verify, for level-1 perspective-taking either zero, one, two or three (“zéro", “un”, “deux” or “trois”), for level-2 perspective-taking either six or nine (“six” or “neuf”). Participants responded as to the validity of the cue. In the example above, the cues correctly match the picture.

Results and Discussion

Only responses in which the cues and the picture matched were analysed. Two participants who failed to perform above chance were excluded. Outliers were excluded from the analysis of Response Times on the basis of being 2.5 standard deviations away from the mean response time (between 2.3% and 2.9% of data across the four groups), as were incorrect responses. For both Response Times and errors, we completed a 2x2x2 repeated measures ANOVA with Level of perspective-taking (Level-1, Level-2) and Blocking (Mixed, Blocked) as between subjects factors and Consistency as a within-subjects factor.

For Self perspective-taking, our crucial hypothesis of the altercentric effect being limited to level-1 perspective-taking rests on the interaction between Level, Blocking and Consistency. For level-1 perspective-taking, we predicted an effect of Consistency that is apparent irrespective of whether the trials were presented in mixed blocks, suggesting that level-1 other perspective taking is triggered by the mere presentation of the avatar (Samson et al., 2010). If level-2 perspective-taking is as rapid and unintentional as level-1 perspective taking, then we should find a consistency effect both in the separate and mixed block design. However, if level-2 perspective taking is not operating outside of cognitive control, we predict no effect in the separate block design.

For the mixed block design, a Consistency effect would demonstrate that people could take the avatar's effect rapidly. For Other perspective-taking, we predicted that the effect of Consistency would be present across all conditions. It has been regularly found that even adults suffer a cost to evaluating another person's discrepant perspective (Keysar et al., 2003), regardless of whether this is a relatively simple level-1 judgement (Samson et al., 2010), or a more complicated level-2 judgement (Surtees et al., 2012).

Self perspective judgements (altercentrism)

Response Times. We identified a main effect of Consistency (see figure 4), $F(1, 60) = 22.45$, $p < .001$, $\eta p^2 = .272$; Consistent < Inconsistent, of Level, $F(1, 60) = 25.16$, $p < .001$, $\eta p^2 = .295$; Level-1 < Level-2, and of Blocking, $F(1, 60) = 10.19$, $p = .002$, $\eta p^2 = .145$. The interaction between Consistency and Blocking was significant, $F(1, 60) = 7.18$, $p = .009$, $\eta p^2 = .107$, as was that between Consistency and Level, $F(1, 60) = 6.01$, $p = .017$, $\eta p^2 = .091$, and there was a trend for an interaction between Consistency, Level and Blocking, $F(1, 60) = 3.37$, $p = .073$, $\eta p^2 = .053$. Since one of our predictions concerned this three-way interaction we investigated this trend further.

For Level-1 perspective-taking, there was a main effect of Consistency, $F(1, 30) = 9.47$, $p = .004$, $\eta p^2 = .24$, Consistent < Inconsistent, a main effect of Blocking $F(1, 30) = 6.06$, $p = .02$, $\eta p^2 = .168$, Blocked < Mixed, but no interaction between Blocking and Consistency, $F(1, 30) = 1.33$, $p = .258$, $\eta p^2 = .042$.

For Level-2 perspective-taking, there was a main effect of Consistency, $F(1, 30) = 14.99$, $p = .001$, $\eta p^2 = .16$, Consistent < Inconsistent, a main effect of Blocking $F(1, 30) = 4.60$, $p = .04$, $\eta p^2 = .133$, Blocked < Mixed, and an interaction between Blocking and Consistency, $F(1, 30) = 5.83$, $p = .022$, $\eta p^2 = .164$. This interaction demonstrated that the effect of Consistency was significant for mixed blocks of level-2 perspective-taking, $t(15) = 3.58$, $p = .003$, Consistent < Inconsistent, but not for separate blocks, $t(15) = 1.52$, $p = .150$.

Errors. Overall the error rate was very low (4.5%). There was a main effect of Consistency on error rate, $F(1, 60) = 7.35$, $p = .009$, $\eta p^2 = .109$; Consistent < Inconsistent, no effect of Level, $F(1, 60) = .296$, $p = .589$, $\eta p^2 = .005$, and no effect of Blocking, $F(1, 60) = 1.06$, $p = .307$, $\eta p^2 = .017$. The only significant interaction was between Consistency, Blocking and Level, $F(1, 60) = 9.37$, $p = .003$, $\eta p^2 = .135$.

For Level-1 perspective-taking, there was a main effect of Consistency, $F(1, 30) = 4.30$, $p = .047$, $\eta p^2 = .125$, Consistent < Inconsistent, no main effect of Blocking $F(1, 30) = 2.24$, $p = .145$, $\eta p^2 = .069$, and no interaction between Blocking and Consistency, $F(1, 30) = 2.20$, $p = .149$, $\eta p^2 = .068$.

For Level-2 perspective-taking, there was a trend for an effect of Consistency, $F(1, 30) = 3.40$, $p = .075$, $\eta p^2 = .102$, Consistent < Inconsistent, no main effect of Blocking $F(1, 30) = .10$, $p = .75$, $\eta p^2 = .003$, Blocked < Mixed, and an interaction between Blocking and Consistency, $F(1, 30) = 7.34$, $p = .011$, $\eta p^2 = .197$. This interaction demonstrated that the effect of Consistency was significant for mixed blocks of level-2 perspective-taking, $t(15) = 3.78$, $p = .002$, Consistent < Inconsistent, but not for separate blocks, $t(15) = .542$, $p = .596$.

Other perspective judgements (egocentrism)

Response Times. We identified a main effect of Consistency, $F(1, 60) = 66.80$, $p < .001$, $\eta p^2 = .527$; Consistent < Inconsistent, of Level, $F(1, 60) = 44.27$, $p < .001$, $\eta p^2 = .425$; Level-1 < Level-2, and a trend for an effect of Blocking, $F(1, 60) = 3.617$, $p = .062$, $\eta p^2 = .007$. There was a two-way interaction between Consistency and Blocking , $F(1, 60) = 12.011$, $p = .001$, $\eta p^2 = .167$, and a three-way interaction between Consistency, Level and Blocking, $F(1, 60) = 4.58$, $p = .036$, $\eta p^2 = .071$. The interaction between Consistency and Level was not significant, $F(1, 60) = 1.14$, $p = .29$, $\eta p^2 = .019$.

For Level-1 perspective-taking, there was a main effect of Consistency, $F(1, 30) = 138.94$, $p < .001$, $\eta p^2 = .822$, Consistent < Inconsistent, no main effect of Blocking $F(1, 30) = 1.188$, $p = .284$, $\eta p^2 = .038$, and an interaction between Blocking and Consistency, $F(1, 30) = 4.842$, $p = .036$, $\eta p^2 = .139$. Though the Consistency effect varied in magnitude, it was significant for both blocked $t(15) = 6.69$, p < .001, and mixed blocked, $t(15) = 10.06$, p < .001, conditions.

For Level-2 perspective-taking, there was a main effect of Consistency, $F(1, 30) = 138.94$, $p < .001$, $\eta p^2 = .822$, Consistent < Inconsistent, no main effect of Blocking $F(1, 30) = 2.43$, $p = .130$, $\eta p^2 = .075$, Blocked < Mixed, and an interaction between Blocking and Consistency, $F(1, 30) = 8.64$, $p = .006$, $\eta p^2 = .224$. Though the Consistency effect varied in magnitude, it was significant for both blocked $t(15) = 2.68$, p = .017, and mixed blocked, $t(15) = 4.16$, p < .001, conditions.

Errors. Again, error rates were quite low (3.9%). A main effect of Consistency, $F(1, 60) = 40.58$, $p < .001$, $\eta p^2 = .403$; Consistent < Inconsistent, and of Level, $F(1, 60) = 7.17$, $p = .001$, $\eta p^2 = .107$; Level-1 < Level-2, but no effect of Blocking, $F(1, 60) = .304$, $p = .584$, $\eta p^2 = .005$. The only significant interaction was between Consistency and Level, $F(1, 60) = 25.23$, $p < .001$, $\eta p^2 = .296$. This demonstrated that for Level 1 there was an effect of Consistency, $t(15) = 7.08$, $p < .001$, Consistent < Inconsistent, that was not apparent for Level 2, $t(15)$

= 1.13, *p* = .266. Thus, the pattern of results in the error analyses was consistent with that found in the RT analyses.

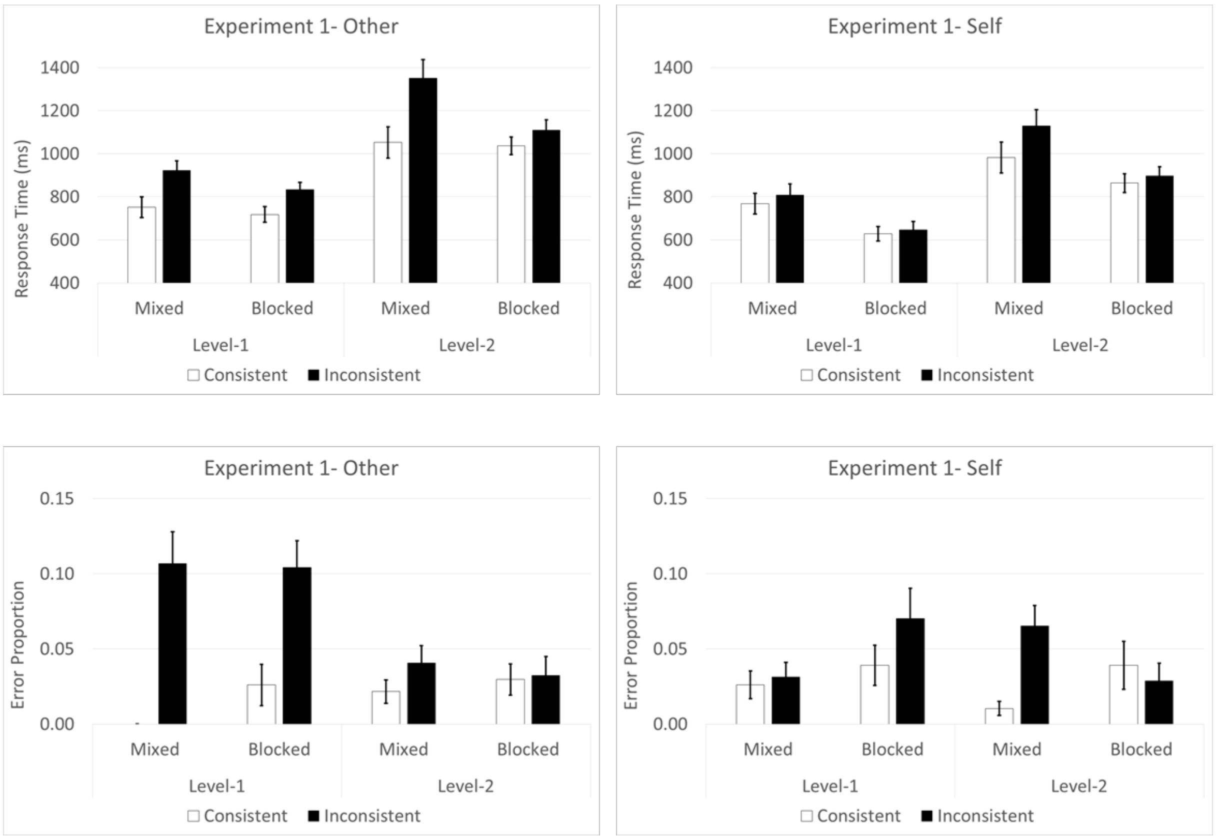

Figure 4. Results of Experiment 1. Error bars represent the standard error of the mean.

When participants explicitly took the avatar's perspective, our results demonstrated egocentrism. Participants in all conditions were slower when the avatar's perspective was different from their own and this was observed for reaction times and error proportion. This effect varied in size with level and with blocking, but was always significant. When participants took their own perspective, we saw a different pattern of results for level-1 and level-2 perspective-taking (see Figure 4), with the effect most marked when taking into account the error proportion. For level-1 perspective-taking, consistency always affected performance, regardless of whether trials were in mixed or separate blocks. For level-2 perspective-taking, consistency only had a significant impact in the mixed block condition. This suggests that the involuntary computation of the other perspective was limited to the level-1 task.

EXPERIMENT 2

Experiment 1 showed that there was a difference between level-1 and level-2 perspective-taking in the degree to which other perspective-taking was triggered rapidly and unintentionally. One thing that differed, however, between the two conditions was the number of possible cues to which the participants had to attend, leading to the possibility that there was a higher cognitive load in the level-1 than in the level-2 task. For level-2 perspective-taking, only the numbers 6 and 9 were used, raising the possibility that participants were able to resist interference from the avatar's perspective because the stimulus set was so small. For level-1 perspective-taking, by contrast, the fact that participants had to consider a larger set of stimuli, ranging from 0-3, may have led to a greater cognitive load that led to altercentric interference in both blocked and mixed conditions. To investigate this possibility, we repeated the level-2 conditions from Experiment 1, with the additional inclusion of stimuli involving 1 and 8, which look the same if viewed from another angle. This means that the set size for level-2 conditions in Experiment 2 was the same as for the level-1 conditions in Experiment 1. A *set-size hypothesis* would predict that this manipulation should raise the cognitive load, leading to altercentric interference in both mixed and blocked conditions; a *level-1/ level-2 distinction hypothesis* would predict findings similar to those in Experiment 1, whereby level-2 perspective-taking is not triggered rapidly or unintentionally.

Method

Participants

Participants were 32 undergraduate students from the University catholique de Louvain, Belgium (Mean age: 20.33, 22 female). All participated in exchange of course credit or a small honorarium.

Design and Procedure

Participants were divided into two groups: Mixed and Blocked. The basic procedure matched that of the level-2 condition of Experiment 1 (see figure 3). Participants in the mixed condition completed 192 trials (96 Self, 96 Other), on half of trials they judged their own perspective of the identity of a number and on the other half they judged the perspective of the avatar. In the Blocked condition, these self and other trials were completed in two separate blocks. As in Experiment 1, on half of trials self and other perspectives were consistent and on the other they were inconsistent. The crucial point of difference from Experiment 1 was that on this occasion, we included a larger range of stimuli. As well as being cued with the numbers "six" and "nine", participants were equally likely to be cued with the numbers "one" and "eight". Similarly, in addition to the four basic picture stimuli (figure 1), an additional set of filler trials were included with the numbers 1 and 8 displayed in the upright and flat positions.

Results and Discussion

Self perspective taking (altercentrism)

Response Times. A 2x2 repeated measures ANOVA with Blocking (Mixed, Blocked) as a between subjects factor and Consistency (Consistent, Inconsistent) as a within-subjects factor revealed a main effect of Consistency (see figure 5), $F(1, 30) = 12.56$, $p = .001$, $\eta p^2 = .296$; Consistent < Inconsistent, and an effect of Blocking, $F(1, 30) = .5.84$, $p = .022$, $\eta p^2 = .163$; Blocked < Mixed. The interaction between Consistency and Blocking was also significant, $F(1, 30) = 4.434$, $p = .044$, $\eta p^2 = .129$. Follow up t-tests evidenced better performance for Consistent (than Inconsistent) trials for the Mixed block condition, $t(15) = 3.21$, $p = .006$, but not for the Blocked condition, $t(15) = 1.52$, $p = .149$.

Errors. Overall error rate was quite low (6.6%). There was a main effect of Consistency, $F(1, 30) = 4.86$, $p = .035$, $\eta p^2 = .139$; Consistent < Inconsistent, but no effect of Blocking, $F(1, 30) = .016$, $p = .901$, $\eta p^2 = .001$. The interaction between Consistency and Blocking was not significant, $F(1, 30) = 1.75$, $p = .196$, $\eta p^2 = .055$. However, the pattern of errors was not suggestive of the RT analyses results being caused by a speed accuracy trade-off, since, consistently with the RT results, there was no effect of consistency in the blocked condition, $t(15) = .676$, p = .509 while there was in the mixed condition $t(15) = 2.324$, p = .035.

Other perspective taking (egocentrism)

Response Times. A 2x2 repeated measures ANOVA with Blocking (Mixed, Blocked) as a between subjects factor and Consistency (Consistent, Inconsistent) as a within-subjects factor revealed a main effect of Consistency, $F(1, 30) = 62.69$, $p < .001$, $\eta p^2 = .676$; Consistent < Inconsistent, but no effect of Blocking, $F(1, 30) = .386$, $p = .539$, $\eta p^2 = .013$. The interaction between Consistency and Blocking was not significant, $F(1, 30) = .803$, $p = .377$, $\eta p^2 = .026$.

Errors. Overall error rates were quite low (6.3%) and were again mainly explored to rule out that the RT results reflected a speed-accuracy trade-off. There was a main effect of Consistency, $F(1, 30) = 5.95$, $p = .021$, $\eta p^2 = .166$; Consistent < Inconsistent, but no effect of Blocking, $F(1, 30) = .236$, $p = .630$, $\eta p^2 = .008$. The interaction between Consistency and Blocking was not significant, $F(1, 30) = .238$, $p = .629$, $\eta p^2 = .008$. Thus the results of the error analyses were consistent with those observed in the RT analyses.

In summary, increasing set size did not alter the key findings seen in Experiment 1. For other perspective-taking, we again found evidence of egocentrism, it was harder to judge that the avatar saw a 6 if you saw a 9, this effect was apparent regardless of whether the trials were presented in separate or mixed blocks. For self perspective-taking, we again found evidence of interference from the avatar's perspective, but again only in our mixed block condition. Experiment 2 favours the *level-1/ level-2 hypothesis,* that the altercentric effect is driven by the type of perspective-taking involved and not by the size of the stimulus set.

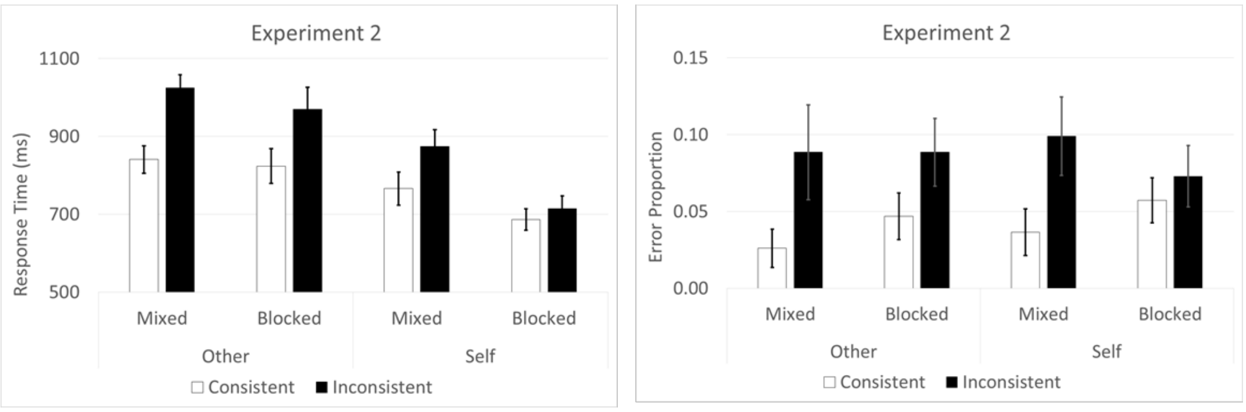

Figure 5. Results of Experiment 2. Error bars represent the standard error of the mean.

General Discussion

We deployed direct and indirect measures across two kinds of perspective-taking problem: level-1 (judging *whether* someone sees an object) and level-2 (judging *how* they see it). Our findings suggest that direct and indirect measures tap distinct processes for perspective-taking. While it was clear that participants processed and correctly judged both level-1 and level-2 perspectives when directly asked to do so, the indirect measure indicated that only level-1 perspective-taking was triggered outside of cognitive control.

Directly measuring perspective-taking.

When participants had to judge the perspective of an avatar explicitly (in other-perspective trials), they always found this harder if their own perspective was different. The egocentrism identified fits with previous reports that adults show egocentric biases (Nickerson, 1999). Egocentric biases are consistent with at least two perspective-taking strategies. Firstly, participants could be using a strategy of egocentric anchoring and adjustment (Epley et al, 2004), initially representing a self-perspective and making a series of adjustments away from this. An egocentrism and adjustment hypothesis would suggest that consistent trials are processed more easily because self-perspective already represents an appropriate estimate for other-perspective, so effortful adjustments are not required. Another alternative is that participants do immediately begin processing the other's perspective, but suffer interference as their own perspective is a salient distracter.

Evidence of egocentrism across both level-1 and level-2 perspective-taking still allows that the two tasks are achieved by distinct processes. Explicit judgements of other people's perspectives may require rotation or line of sight calculation (Michelon & Zacks, 2005), may be embodied, or not (Kessler & Thomson, 2010) and, of course may show a different developmental course (Flavell et al., 1981). A recent study (Surtees, Apperly & Samson, 2013), found that whilst explicit judgements of level-2 visual perspectives were sensitive to angular disparity between self and other, explicit judgements of level-1 visual perspectives were not. Effortful perspective-taking affords flexibility of strategy in how we solve perspective-taking problems (Apperly & Butterfill, 2009). This comes at a cost to efficiency and is subject to egocentrism, either from making sufficient adjustments to calculate another person's perspective or through selecting between competing self and other perspective contents.

Indirectly measuring perspective-taking

Not all perspective-taking is undertaken in response to an explicit requirement to judge the content of someone else's perspective. Evidence from the indirect measure of perspective-taking in the current study converges with evidence from Samson et al. (2010) showing that level-1 perspectives may be calculated rapidly and unintentionally and extends the evidence base for this effect. Firstly, the current evidence suggests that these effects generalise to avatars that are oriented towards the participant, whereas previous findings have all used an avatar whose perspective is perpendicular to the viewer. Secondly, the current evidence allows direct comparison of blocked and mixed block designs and finds equivalent effects in these cases.

The altercentric interference we observed suggests that the calculation of level-1 perspectives is triggered by the presentation of an avatar. An open question remains as to whether the richness of information about perspectives contained when generated in this way is equivalent to that generated through explicit processing. One alternative is that a rich spatial representation has been made of the spatial location of the avatar and all objects that form part of his perspective. Alternatively, the presence of an avatar in a visual scene may trigger the generation of two separate sets based on object properties, firstly the set {Objects seen by self} and secondly the set {Objects seen by avatar}. By this second alternative, we may be slower on inconsistent trials due to a post-recognition conflict. To this way of thinking, inconsistent trials are more difficult as {Objects seen by self} ≠ {Objects seen by avatar}, rather than because of a qualitative difference between visuo-spatial representations. Whilst it may be debated whether this alternative actually means that we have *taken* the avatar's perspective (e.g., Santiesteban et al., 2014), it is apparent that such a distinction based on object properties would be enough to drive recent indirect measures of false belief reasoning (Onishi & Bailergeon, 2005) and solve many everyday problems (e.g., Heyes, 2014b).

We also found evidence of altercentrism in level-2 perspective taking in our mixed block design, suggesting that perspective-taking had taken place rapidly in this context, despite the fact that it was irrelevant within trials in which participants judged their own perspective. This finding is consistent with other evidence that specific cues and specific conditions can influence the degree to which another's perspective is processed without explicit instructions to do so (Back &Apperly, 2010; German & Cohen, 2012; Surtees, Noordzij & Apperly, 2012). It is also informative that this effect shows that level-2 perspectives can, in principle, be calculated with sufficient speed to interfere with a fast judgement of one's own perspective. It might have been thought that calculating the avatar's perspective on the numeral stimuli used in the present study was intrinsically slow because it required mental rotation (e.g., Carruthers, 2013). Other research shows that, under some circumstances, level-2 perspective taking does indeed require mental rotation (e.g., Surtees et al., 2013), but the present findings from mixed blocks of trials show that this can sometimes be performed sufficiently quickly to generate altercentric interference for level-2 perspectives.

In light of the presence of altercentric inference from a level-2 perspective in mixed blocks of trials, the absence of this effect when trials were presented in separate blocks is particularly informative. If interference effects on self judgements observed by Samson et al. (2010) were due to rapid and unintentional calculation of the avatar's perspective, then we provide evidence here that under such circumstances this process does not calculate level-2 perspectives. The existence of a process (or set of processes) that is triggered rapidly (Samson et al., 2010) and is cognitively efficient (Qureshi et al., 2010) helps to explain how adults meet the perspective-taking demands everyday social interaction and communication without placing an onerous burden on general processing resources. The fact that unintentional perspective-taking appears limited to level-1 perspectives helps explain why more effortful theory of mind processes remain necessary in some cases. Such limitations also cast light on converging evidence from different participant groups on different paradigms, which indicates that participants with limited cognitive resources may be able to take level-1 perspectives, but not level-2 perspectives. Tasks using preferential looking or violation of expectation have demonstrated level-1 abilities in infancy, but so far there is no evidence of level-2 abilities (Onishi & Baillargeon, 2005, Sodian et al, 2007, Southgate et al, 2007). Children from 2-years of age, but not 18 months, have made explicit solutions requiring level-1 perspective-taking (Moll & Tomasello, 2006), but again there is no evidence of such success in a level-2 paradigm until around the age of four (Flavell et al. 1981). Of course, the present findings do not preclude the existence of alternative efficient processes that calculate level-2 perspectives automatically. For example, we would certainly suppose that specific cases could be automatized through sufficient practice Importantly, our findings gain strength from their convergence with other evidence showing related signature limits on efficient theory of mind processes across different ages (Low & Watts, 2013; Surtees et al., 2012; Wang et al., 2015), cultures (Wang et al., 2015) and experimental paradigms (Low & Watts, 2013). For this reason, we follow Apperly and Butterfill (2009) in suggesting that as a general rule level-2 perspectives, in contrast to level-1 perspectives, are not calculated outside of cognitive control.

Acknowledgements:

This research was funded by a FSR (Fonds spéciaux de recherche) / Marie Curie Actions of the European Commission post-doctoral fellowship awarded by the Université catholique de Louvain to AS. The authors would like to thank several anonymous reviewers for comments on an earlier draft.

References

Apperly, I.A. (2010). *Mindreaders: the cognitive basis of "theory of mind"*. Hove: Psychology Press / Taylor & Francis Group.

Apperly, I. A. & Butterfill, S. A. (2009). Do Humans Have Two Systems to Track Beliefs and Belief-Like States? *Psychological Review, 116,* 953-970.

Back, E., & Apperly, I.A. (2010). Two sources of evidence on the non-automaticity of true and false belief ascription. *Cognition,115(1),* 54-70.

Baillargeon, R., Scott, R. M., & He, Z. J. (2010). False-belief understanding in infants. *Trends in Cognitive Sciences, 14,* 110-118.

Bargh, J. A. (1994). The four horsemen of automaticity: Intention, awareness, efficiency, and control as separate issues.

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.

Butterfill, S. & Apperly I.A. (2013). How to construct a minimal theory of mind. *Mind & Language, 28(2)* 606-637.

Clayton, N. S., & Emery, N. J. (2007). The social life of corvids. *Current Biology*, *17*(16), R652-R656.

Epley, N., Keysar, B., Van Boven, L., & Gilovich, T. (2004a). Perspective taking as egocentric anchoring and adjustment. *Journal of Personality and Social Psychology, 87,* 327-339.

Epley, N., Morewedge, C. K., & Keysar, B. (2004b). 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., Everett, B. A., Croft, K., & Flavell, E. R. (1981a). Young Childrens Knowledge About Visual-Perception - Further Evidence for the Level 1-Level 2 Distinction. *Developmental Psychology, 17,* 99-103.

Flavell, J. H., Flavell, E. R., Green, F. L., & Wilcox, S. A. (1981b). The Development of 3 Spatial Perspective-Taking Rules. *Child Development, 52,* 356-358.

Gopnik, A. & Astington, J. W. (1988). Childrens Understanding of Representational Change and Its Relation to the Understanding of False Belief and the Appearance-Reality Distinction. *Child Development, 59*, 26-37.

Hare, B., Call, J., & Tomasello, M. (2001). Do chimpanzees know what conspecifics know? *Animal Behaviour, 61,* 139-151.

Heyes, C. M. (2014a) False belief in infancy: a fresh look. Developmental Science. Supporting Information DOI: 10.1111/desc.12148

Heyes, C. M. (2014b) Submentalizing: I'm not really reading your mind. *Perspectives on Psychological Science, 9,* 131-143

Heyes, C. M. (in press) Animal mindreading: What's the problem? Psychonomic Bulletin and Review.

Kessler, K. & Thomson, L. A. (2010). The embodied nature of spatial perspective taking: Embodied transformation versus sensorimotor interference. *Cognition, 114,* 72-88.

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

Kozhevnikov, M. & Hegarty, M. (2001). A dissociation between object manipulation spatial ability and spatial orientation ability. *Memory & Cognition, 29,* 745-756.

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.

Low, J., & Watts, J. (2013). Attributing false beliefs about object identity reveals a signature blind spot in humans' efficient mind-reading system. *Psychological Science*, *24*(3), 305-311.

Luo, Y., & Baillargeon, R. (2007). Do 12.5-month-old infants consider what objects others can see when interpreting their actions? *Cognition, 105(3),* 489-512.

Masangka, Z. S., Mccluske, K. A., Mcintyre, C. W., Simsknig, J., Vaughn, B. E., & Flavell, J. H. (1974). Early Development of Inferences About Visual Percepts of Others. *Child Development, 45,* 357-366.

Michelon, P. & Zacks, J. M. (2006). Two kinds of visual perspective taking. *Perception & Psychophysics, 68,* 327-337.

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.

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

Perner, J. & Leekam, S. (2008). The curious incident of the photo that was accused of being false: Issues of domain specificity in development, autism, and brain imaging. *Quarterly Journal of Experimental Psychology, 61,* 76-89.

Perner, J. & Ruffman, T. (2005). Infants' insight into the mind: How deep? *Science, 308,* 214-216.

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

Qureshi, A., 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

Ruffman, T. & Perner, J. (2005). Do infants really understand false belief? *Trends in Cognitive Sciences, 9,* 462-463.

Ruffman, T., Taumoepeau, M., & Perkins, C. (2012). Statistical learning as a basis for social understanding in children. *British Journal of Developmental Psychology, 30(1),* 87-104.

Samson, D., Apperly, I. A., Braithwaite, J. J., Andrews, B. J., & Bodley Scott, S. E. (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(5),* 1255.

Santiesteban, I., Catmur, C., Coughlan Hopkins, S., Bird, G., & Heyes, C. (2014). Avatars and arrows: Implicit mentalizing or domain-general processing? *Journal of Experimental Psychology: Human Perception and Performance, Vol 40(3)*, 929-937.

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.

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.

Surian, L., Caldi, S., & Sperber, D. (2007). Attribution of beliefs by 13-month-old infants. *Psychological Science, 18,* 580-586.

Surtees, A. D., & Apperly, I. A. (2012). Egocentrism and automatic perspective taking in children and adults. *Child Development, 83(2),* 452-460.

Surtees, A. D., Butterfill, S. A., & Apperly, I. A. (2012). Direct and indirect measures of level-2 perspective-taking in children and adults. *British Journal of Developmental Psychology, 30(1),* 75-86.

Wang, B., Hadi, N. S. A., & Low, J. (2015). Limits on efficient human mindreading: Convergence across Chinese adults and Semai children. *British Journal of Psychology*. 106, 724–740