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Altercentric interference in level-1 visual perspective-taking reflects the ascription of mental states, not sub-mentalising.

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Abstract.

A growing body of work suggests that in some circumstances humans may be capable of ascribing mental states to others in a way that is fast, cognitively efficient, and implicit (implicit mentalising hypothesis). However, the interpretation of this work has recently been challenged by suggesting that the observed effects may reflect 'sub-mentalising' effects of attention and memory, with no ascription of mental states (sub-mentalising hypothesis). The present study employed a strong test between these hypotheses by examining whether apparently automatic processing of another's visual perspective (Samson, Apperly, Braithwaite, Andrews & Bodley Scott, 2010) is influenced by experience-dependent beliefs about whether that person can see (e.g., Heyes 2014). Altercentric interference was observed when participants judged their own perspective on stimuli involving an avatar wearing goggles that participants believed to be transparent, but not when they believed the goggles to be opaque. These results are consistent with participants ascribing mental states to the avatar, and not with the sub-mentalising hypothesis that altercentric interference arises merely because avatars cue shifts in spatial attention.

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Introduction

What do you think I think you think? *Explicit* judgements about others' mental states develop late in children and remain cognitively demanding for adults, requiring effortful deployment of executive resources (e.g., Apperly, 2010; German & Hehman, 2006; Perner & Lang, 1999; Samson, Apperly, Kathirgamanathan & Humphreys, 2005; Wellman, Cross & Watson, 2001). At least some aspects of mentalising, however, may be achieved in a way that is much more cognitively efficient. In accord with this notion, recent studies have shown that the visual point of view of others (Samson et al., 2010), their actions (Sebanz, Knoblich & Prinz, 2003), and even their beliefs (Kòvacs, Teglas, & Endress, 2010; Schneider, Lam, Bayliss & Dux, 2012) may be processed *implicitly* in a relatively automatic, fast, and efficient manner.

For example, adults may spontaneously process what another person can see (Level-1 visual perspective taking), even when the processing of other person's perspective is irrelevant to task and results in interference with explicit judgements of one's own perspective (Samson et al., 2010). This altercentric intrusion effect has been reported in both adults and children, suggesting that it may reflect the operation of a cognitively efficient process present since infantcy (Surtees & Apperly, 2012). This and other lines of evidence (Clements & Perner, 1994; Sebanz et al., 2003; Southgate, Senju & Csibra, 2007; Surian, Caldi & Sperber, 2007; Zwickel, 2009; Baillargeon, Scott & He, 2010; Kovacs et al., 2010; Schneider et al., 2012; Schneider, Nott & Dux, 2014) support the view that humans have two distinct systems for mentalising (Apperly & Butterfill, 2009): one early developing, automatic, fast and efficient, implicit system, and a later developing, controlled, slow, and flexible explicit system. Level-1 visual perspective taking requires only limited cognitive control and may be part of this low-level and implicit system for mind reading.

However, recent theoretical and empirical work has questioned the existence of implicit mentalising in adults and infants, and suggested that results reported to date could be due to

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'sub-mentalising', whereby domain general cognitive processes for memory and attention simulate the effects of mentalising in social contexts (Heyes, 2014; Santiesteban, Catmur, Hopkins, Bird & Heyes, 2014). It therefore remains unclear whether the altercentric intrusion effect provides evidence of implicit mentalising.

The current study

Our experiment used a novel adaptation of Samson et al.'s (2010) avatar paradigm to test the alternative predictions arising from the *sub-mentalising hypothesis* (Heyes, 2014) and the *implicit mentalising hypothesis* for Level 1 visual perspective taking. In the original version of the paradigm, participants judged the number of discs that they could see on the walls of a cartoon room (self-perspective) or the number of discs that could be seen by an avatar standing in the room (other-perspective). On consistent perspective trials, both the participant and the avatar could see the same number of discs. On inconsistent perspective trials, the avatar saw fewer discs than the participant did (some of the discs were not visible to the avatar). When participants made explicit judgements about the avatar's perspective (other-perspective judgements), they were slower and more error prone when the avatar's perspective differed from their own (egocentric intrusion effect). This is consistent with reports of egocentric bias in adults (e.g., Royzman, Cassidy & Baron, 2003). Critically, however, participants were also slower and more error prone to make explicit judgements of their own perspective (i.e., how many discs *they* saw) when the avatar happened to see a different number. This is clearly compatible with implicit mentalising, because it suggests that, even when the avatar's perspective was irrelevant to the task, participants could not prevent themselves from computing what they saw (altercentric intrusion effect).

In the avatar paradigm, however, the avatar is not only an agent with a distinct perspective on the scene; s/he is also a directional cue, oriented towards one side of the scene or the other. It has been known for some time that such directional cues can lead to automatic reorientation of a viewer's attention from the centrally presented stimulus to the side to which

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the cue is oriented, and that similar effects (albeit with some distinctive characteristics) may be obtained from social stimuli such as faces and non-social spatial cues such as arrows (e.g., Tipples, 2002). It is of course highly likely that such spatial cueing is an important component of the processes leading to the altercentric effects observed by Samson et al. (2010). However, the sub-mentalising hypothesis holds that spatial cueing might be wholly sufficient to account for the altercentric effects. Consistent with this view, Santiesteban et al. (2014) recently reported altercentric interference for arrow stimuli. Participants were slower to verify the number of discs that they could see, when this number was inconsistent (rather than consistent) with the number to which an arrow was pointing. Because arrows have directional, but not agentive features, this has been interpreted as evidence for sub-mentalising (in this case, a generic attentional process), rather than implicit mentalising.

One problem with the Santiesteban et al.'s manipulation, however, is that it does not successfully control for attribution of mental states. Previous studies have shown that simple geometric shapes can activate theory of mind processes (Klein, Zwickel, Prinz & Frith, 2009; Castelli, Happé, Frith & Frith, 2000). Arrows, in particular, are used to indicate direction and there is evidence that even young children attach not only attentional, but also intentional meanings to arrow cues. For example, Pellicano and Rhodes (2003) pitted arrow and gaze cues against one another in a task where 3- to 4-year-olds were asked to judge which of a set of chocolates was desired and would be acted upon by a cartoon character. Children were more likely to rely on the arrow cue than the gaze cue, suggesting that the intentional aspect of overlearned symbols such as arrow cues may not only guide mental state ascriptions but may be selected in preference to gaze cues in some circumstances. As Santiesteban et al. acknowledge, it is thus possible that "generalizing from the avatar to the arrow stimulus, participants represented the number of dots in front of the arrow as the number of dots that the arrow could 'see', engaging in implicit mentalising in both the avatar and the arrow condition" (Santiesteban et al., 2014).

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To examine the implicit mentalising hypothesis against sub-mentalising hypothesis in the absence of such confounds, here we adopted an approach in which mental state attribution was manipulated directly while holding the stimuli constant. Following Teufel, Alexis, Todd, Lawrance-Owen, Klayton, & Davis (2009), the avatar wore one of two pairs of coloured goggles, both with highly mirrored lenses such that it was impossible to see the eyes of the wearer. Using a belief induction procedure, participants were led to believe that, from the perspective of the avatar, one pair was transparent and the other pair was completely opaque. While watching the stimuli, they therefore believed that, when wearing one pair of googles, the avatar could see the discs on the wall (*seeing* condition), whereas when wearing the other pair, the avatar could not see the discs of the wall (*non-seeing* condition).

The sub-mentalising hypothesis predicts that the spatial information from the avatar's body orientation is a sufficient condition for observation of the altercentric effect. If this is correct, then we would expect the altercentric intrusion in both the seeing condition and the non-seeing condition, i.e., irrespective of the participant's attribution of a 'seeing' mental state to the avatar. Alternatively, if the altercentric intrusion effect depends on calculation of what the avatar can see (consistent with the implicit mentalising hypothesis), then the effect should only occur when participants believe that the avatar can see. We would thus predict that the effect would occur in the *seeing* condition, but not in the *non-seeing* condition.

Method

Participants

Eighteen undergraduates postgraduate students from the University of Birmingham took part in this experiment (11 females; mean age: 23.80 ± 3.54, range 20-38 years) for credits or for a small honorarium (£4). All had normal or corrected-to-normal vision, and were naïve to the purpose of the study. The study was performed in accordance with the ethical standards laid down in the revised Helsinki Declaration (World Medical Association General Assembly, 2008).

Stimuli and procedures

The stimuli and procedures were similar to those of Samson et al. (2010). Participants were presented with a picture showing a lateral view of a room with the left, back, and right walls visible, and with discs displayed on one or two walls (the left and the right ones). A human avatar was positioned in the centre of the room, facing either the left or the right wall. Female participants were presented with a female avatar and male participants were presented with a male avatar.

On half of the trials, both participants and the avatar could see the same amount of dots (consistent perspective trials), whereas on the other half of trials, the avatar could see fewer dots than the participant (inconsistent perspective trials; see Supplemental Material)

On the 33% of trials, the avatar did not wear goggles (*eyes* condition, neutral stimuli). On the remaining 66% of trials, the avatar wore a coloured pair of goggles (red or orange), both with highly mirrored lenses such that it was impossible to see the eyes of the avatar (Figure 1). Prior to the experiment (see the belief induction procedure described below), participants were informed that the orange (or red) pair of goggles was transparent, while the red (or orange) pair of goggles was opaque. While watching the stimuli, they therefore believed that avatar could see through the orange pair of goggles (*seeing* condition, 33% of trials), but not through the red pair (*non-seeing* condition, 33% of trials), or vice versa. In order to avoid confusion about the goggles colour associated with the *seeing* and the *non-seeing* conditions, transparent goggles trials and opaque goggles trials were not mixed together in the same block: participants completed three blocks where the *seeing* and *eyes* trials were mixed together and three blocks where the *non-seeing* and *eyes* trials were mixed together. To have the same total number of trials for each condition, each block included 66% of goggles stimuli and 33% of neutral stimuli. Block order and goggles colour (red_seeing and orange_non-seeing; orange_seeing and red_non-seeing) were counterbalanced between participants.

E-prime software was used to control the stimulus presentation and data collection. Each trial began with a fixation cross presented for 750 ms. 500 ms later, the word "YOU" or "HE"/"SHE" appeared for 750 ms, telling participants whether they had to judge the scene using their own perspective (self perspective) or that of the avatar (other perspective). 500 ms later, a digit (0-3) appeared for 750 ms and specified the perspective content for the participant to verify. Finally, the picture of the room (640 x 480 pixel) appeared in the centre of the screen for a maximum of 2000 ms or until participants completed the trial by pressing one of two keys to indicate whether or not the digit correctly specified the number of discs seen from the relevant perspective. Participants were instructed to respond as quickly and accurately as possible when the picture of the room appeared.

Three hundred trials were divided in 6 blocks of 50 test trials (48 test trials and 2 filler trials) and were preceded by a block of 26 practice trials. For each condition, there were 24 consistent trials and 24 inconsistent trials. The number of YES and NO responses trials was the same for each condition (24 YES responses and 24 NO responses). The order of blocks was counterbalanced between subjects and the order of trials within a block was randomized. Filler trials (no dots present in the image of the room) allowed the cued number "0" to also match self-perspective judgments.

Belief induction

Before the first block associated with the seeing or the non-seeing condition started, participants tried on a red and an orange pair of goggles in order to gain first person experience of the visual properties of the goggles and the visual experience of the avatar. They were asked to watch in the direction of the monitor for one minute. Two pairs of googles were used. Depending on the condition, the insides of the lenses of the orange and the red pair of goggles were made completely opaque using a black cardboard. The other pair was untreated and thus transparent to the wearer. Half of the participants, chosen at random, wore red goggles that were transparent from their perspective and an orange pair that was opaque; this pattern was reversed for the

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remaining half of the participants. Hence, to all participants, one pair of goggles (associated with the *seeing* condition) signalled that the avatar could see, and the other pair (associated with the *non-seeing* condition) signalled that the avatar could not see. The lenses of all goggles had identical external appearances.

Manipulation check

In order to assess the efficacy of the deception procedure, after the experiment, participants were asked to perform a visual search task wearing one pair of goggles at their own choice. All participants chose the pair of goggles associated with the *seeing* condition.

Results

Trials in which participants made an error were discarded from the RT analysis (4.54%). In addition, individual trials were removed if responses were made in excess of 2.5 standard deviations of the participant's mean reaction time (1.63%). One participant had to be excluded from the analysis due to excessively slow response times (2.5 SD over the overall conditional means in 8 out of 12 experimental conditions). As for Samson et al. (2010), because of the unbalanced way in which mismatching trials had to be constructed, we considered the mismatching ("no" response) trials as fillers (as they would artificially inflate the consistency effect) and only analysed the data of the matching ("yes" response) trials. RTs and errors were submitted to a 3 x 2 x 2 repeated measures ANOVA with Condition (eyes, seeing, and non-seeing), Perspective (self, other) and Consistency (consistent, inconsistent) as within-subject factors. Sphericity of the data was verified prior to performing statistical analyses (Mauchly's test, $p>0.05$). For significant two-way interactions, t-tests were performed between the appropriate levels of the factors involved, using a Bonferroni correction (α level < 0.05) for multiple tests.

RT analysis. The ANOVA showed a significant main effect of Perspective ($F(1,16)=5.85$, $p=0.027$, $p\eta^2=0.269$), and a significant main effect of Consistency ($F(1,16)=49.90$, $p<0.001$,

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pη^2=0.757). The main effect of Condition did not approach significance (F(1,16)=0.576, p=0.568, pη^2=0.035). There was also a significant Condition x Consistency interaction (F(1,16)=11.87, p<0.001, pη^2=0.426), a significant Perspective x Consistency interaction (F(1,16)=8.44, p=0.010, pη^2=0.345), and a significant Perspective x Condition (F(1,16)=5.01, p=0.013, pη^2=0.239) interaction. These two-way interactions were qualified by a significant three-way Condition x Perspective x Consistency interaction (F(1,16)=3.71, p=0.035, pη^2=0.188).

The three-way interaction was tested by running separate ANOVAs in each condition (see Figure 2). For the *eyes* condition, there was a reliable effect of Perspective (F(1,16)=50.89, p<0.001, pη^2=0.761) and a reliable effect of Consistency (F(1,16)=36.87, p<0.001, pη^2=0.697), which were further qualified by a significant interaction between Perspective and Consistency (F(1,16)=21.73, p<0.001, pη^2=0.576). Paired-sample t-tests confirmed a significant egocentric intrusion effect when participants judged the avatar's perspective, with RTs being faster for consistent (614 ms) than for inconsistent trials (748 ms) (t(16)=7.88, p<0.001). Further, there was a significant altercentric intrusion effect when participants judged their own perspective, with faster RTs for consistent (579 ms) than for inconsistent trials (621 ms) (t(16)=2.32, p=0.034).

For the *seeing* condition, there was no main effect of Perspective (F(1,16)=0.678, p=0.422, pη^2=0.041), but a significant main effect of Consistency (F(1,16)=27.45, p<0.001, pη^2=0.632), further qualified by a significant Perspective x Consistency interaction (F(1,16)=9.81, p=0.006, pη^2=0.380). Paired-sample t-tests revealed a significant egocentric intrusion effect when participants judged the avatar's perspective, with quicker responses for consistent (610 ms) than for inconsistent trials (719 ms) (t(16)=5.16, p<0.001). There was also evidence for a significant altercentric intrusion effect, with faster RTs for consistent (625 ms) than for inconsistent trials (671 ms) when participants judged their own perspective (t(16)=3.28, p=0.005).

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For the *non-seeing* condition, no effect approached significance (Perspective: $F(1,16)=0.761$, $p=0.396$, $p\eta^2=0.045$; Consistency: $F(1,16)=0.738$, $p=0.403$, $p\eta^2=0.044$; Perspective x Consistency: $F(1,16)=0.065$, $p=0.801$, $p\eta^2=0.004$).

Accuracy analysis. The 3 x 2 x 2 ANOVA revealed a significant main effect of Consistency ($F(1,16)=9.18$, $p=0.008$, $p\eta^2=0.365$) and a significant main effect of Perspective ($F(1,16)=5.06$, $p=0.039$, $p\eta^2=0.240$). The effect of Condition was non-significant ($F(1,16)=1.82$, $p=0.178$, $p\eta^2=0.102$). These effects were qualified by a significant Condition x Consistency interaction ($F(1,16)=3.59$, $p=0.039$, $p\eta^2=0.183$), whereby participants were more accurate in consistent than in inconsistent trials for the *eyes* ($p=0.014$; 99.26% vs 93.87% of accuracy) and the *seeing* conditions ($p=0.015$; 97.79% vs 90.68%), with no difference between consistent and inconsistent trials for the non-seeing condition ($p=0.743$; 95.83% vs 95.34%; see Figure 3). No other interaction was found to be significant.

Discussion

Previous studies sought to manipulate mental state attribution by manipulating the stimulus properties (Samson et al., 2010; Santiesteban et al., 2014). For example, Santiesteban and colleagues (2014) replaced the avatar with an arrow to manipulate the attribution of a 'seeing' mental state. A problem with this strategy is that the complex dependencies between the stimulus properties and mental state attribution make it impossible to determine which of these two factors is responsible for differential findings.

The belief induction procedure provides a valuable strategy to overcome this limitation, ensuring full control over stimulus properties (see also Teufel, Fletcher, & Davis 2010; Heyes, 2014). In the present study, we adopted this strategy to directly test the implicit mentalising hypothesis against the sub-mentalising hypothesis. Participants were asked to judge either their own visual perspective or the perspective of a human avatar wearing red or orange googles, which participants believed to be either transparent or opaque. When participants believed that

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the avatar was wearing transparent goggles and could therefore see the discs on the wall, they were slower to judge their own perspective on inconsistent trials compared to inconsistent trials (altercentric intrusion effect). However, when they believed that that the goggles were opaque and the avatar could not see, there was no altercentric intrusion effect. The sub-mentalising hypothesis that altercentric interference is the sole consequence of the directional features of the stimuli has no resources to explain our observation of an altercentric intrusion effect in the seeing condition, but not in the non-seeing condition, because the directional features of the stimuli were identical in the two cases (Heyes, 2014). The only difference between these conditions was participants' belief about whether or not the avatar was able to see the discs on the wall.

Importantly, however, we find common ground with the sub-mentalising account insofar as it seems entirely plausible that shifts in attention due to exogenous spatial cues may be necessary for observing altercentric interference, even though the mere presence of such cues is not sufficient. This is important because it helps expose theoretically distinct interpretations of implicit mentalising. One interpretation is that implicit mentalising arises through a cognitive mechanism that is entirely distinct from other cognitive processes. On this account, shifts in attention due to exogenous spatial cues are not part of the information processing pathway that leads to altercentric interference. An alternative interpretation is that implicit mentalising is closely integrated with attentional processes, and that cue-driven shifts in attention are integral to the fast and efficient calculation of what the avatar sees. This interpretation derives support from studies showing that the automatic tendency to shift one's attentions towards locations looked at by others is top-down influenced by mental state attribution (Teufel, Alexis, Clayton, & Davis, 2010; see also Teufel et al., 2009). When observers believed that the other person could see, the tendency to follow another's gaze was automatic (in the sense that it could not be entirely suppressed). However, when they believed that the other person could not see, gaze following could be overridden voluntarily. These findings suggest an interactive relationship between the

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mechanisms supporting basic sensory processing of social information and mentalising processes (Teufel et al., 2009).

These interpretations of implicit mentalising clearly differ in their processing architectures and would give rise to distinct experimental predictions. What they have in common is that altercentric interference arises from ascription to the avatar of a mental state of 'seeing' that differs from what participants see themselves. That is to say, altercentric interference results from mentalising, not sub-mentalising.

In the non-seeing condition, we found no effect of Consistency on other-perspective trials, suggesting participants were not influenced by their own visual perspective when judging the avatar's perspective. This lack of egocentric intrusion may appear surprising given the robustness and generality of egocentric biases (e.g., Royzman et al., 2003). However, we believe that the most likely explanation for this effect is a theoretically uninteresting consequence of our design, which necessarily led to the avatar in the non-seeing condition having an entirely predictable perspective of "zero" on every trial. Since participants believed that the avatar could not see, other-perspective judgements could be made on the basis of this stored knowledge without ad hoc computation of *how many discs could be seen*, either from the avatar's perspective or from their own perspective. As a result, their response did not suffer from egocentric biases.

Conclusions and future directions

Results reported to date on implicit mentalising have been criticized on the ground that they could be due to sub-mentalising, i.e., to domain-general cognitive processes sensitive to low-level stimulus features. A strategy to disentangle these two levels of explanation involves using 'self-informed' belief induction variables – variables that people know to be indicative of what an agent can or cannot see and, therefore, does or does not believe, only through extrapolation from their own experience (Heyes, 2014). This strategy has been pursued in research involving chimpanzees (e.g., Penn & Povinelli, 2007), human adults (e.g., Langton,

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2009; Teufel et al., 2009) and infants (e.g., Senju, Southgate, Snape, Leonard, & Csibra, 2011). Here, we combined the logic of self-informed belief induction with the avatar task to test for the implicit attribution of seeing to the avatar. We found that altercentric intrusions depended on the attribution of a seeing mental state to the avatar. Indeed, an altercentric interference effect was only observed when participants believed that the avatar could see the discs on the opposing wall. These findings speak against a reductive sub-mentalising account and suggest that the altercentric intrusion effect is instead due to the implicit mentalising of another person's visual perspective.

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Figure captions

Figure 1. Examples of stimuli used for the goggles conditions. A) Avatar wearing orange goggles (consistent condition). B) Avatar wearing orange goggles (inconsistent condition). C) Avatar wearing red goggles (consistent condition). D) Avatar wearing red goggles (inconsistent condition).

Figure 2. Graphical representation of the three way interaction *Condition* (eyes, seeing, and non-seeing) by *Perspective* (self vs. other) by *Consistency* (consistent vs. inconsistent) on RTs. Bars represent standard errors of the means. Asterisks indicate significance for the main contrasts of interest.

Figure 3. Graphical representation of the interaction *Condition* (eyes, seeing, and non-seeing) by *Consistency* (consistent vs. inconsistent) on accuracy. Participants were more accurate in consistent than in inconsistent trials for the *eyes* and the *seeing* conditions. Bars represent standard errors of the means.