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# Seeing It Their Way: Evidence for Rapid and Involuntary Computation of What Other People See

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In a series of three visual perspective-taking experiments, we asked adult participants to judge their own or someone else's visual perspective in situations where both perspectives were either the same or different. We found that participants could not easily ignore what someone else saw when making self-perspective judgments. This was observed even when participants were only required to take their own perspective within the same block of trials (Experiment 2) or even within the entire experiment (Experiment 3), i.e. under conditions which gave participants a clear opportunity to adopt a strategy of ignoring the other person's irrelevant perspective. Under some circumstances, participants were also more efficient at judging the other person's perspective than at judging their own perspective. Collectively, these results suggest that adults make use of rapid and efficient processes to compute what other people can see.

*Keywords:* visual perspective taking, theory of mind, social cognition, self

When inferring what someone else is seeing, feeling, wanting, or thinking, we often hold a different point of view ourselves. Being able to put our own perspective aside is thus a fundamental facet of our ability to read other people's minds. Previous research shows that it is not easy to resist interference from one's own perspective. For example, when asked to infer someone else's desire or belief, children before the age of 4 years usually respond according to their own, more salient, mental state (e.g., Moore et al., 1995). Even older children and adults still show strong biases towards their own perspective, especially when reasoning about what someone else knows or thinks (Apperly, Samson, & Humphreys, 2009; Bernstein, Atance, Loftus, & Meltzoff, 2004; Keysar, Lin, & Barr, 2003; Royzman, Cassidy, & Baron, 2003). It has been suggested that such biases reflect, in children and adults, an automatic or default activation of self-perspective that needs to be corrected or inhibited (e.g., Birch & Bloom, 2004; Epley, Keysar, Van Boven, & Gilovich, 2004).

The processes by which we inhibit the self perspective have been shown to be distinguishable at the functional and neural level from other perspective taking processes. For example, Samson and colleagues described the case of a patient who was specifically unable to take someone else's perspective when he himself held a strong view (Samson, Apperly, Kathirgamanathan, & Humphreys, 2005). However, in situations where his perspective was less salient, the patient was able to infer someone else's mental state, indicating that his deficit was in inhibiting his own perspective rather than taking someone else perspective per se (see also, Samson, Apperly, & Humphreys, 2007).

There is also evidence that self-perspective inhibition relies on effortful processes. For example, the ability of children to resist interference from their own perspective on false belief tasks strongly correlates with their general executive function abilities (e.g., Carlson & Moses, 2001), and it has been shown that adults make more egocentric errors under cognitive load (e.g., Epley et al., 2004). Being able to override one's own perspective thus seems a necessary and demanding process when taking someone else's perspective.

In sharp contrast to the previous statement, a few studies have now shown that infants and nonhuman animals like chimpanzees do not necessarily succumb to egocentric biases on all perspective-taking tasks. For example, it has been shown that children as young as 14 months old (Sodian, Thoermer, & Metz, 2007), as well as chimpanzees (Hare, Call, Agnetta, & Tomasello, 2000), do take into account that an object visible to them is not necessarily visible to others (if it is occluded by an obstacle within the other individual's line of sight, for example), thus appearing to overcome any interference from their own visual experience. Furthermore, recent findings suggest that children well before the age of 3 are actually able to infer quite complex mental states, such as someone else's false belief (or, more conservatively, someone else's outdated knowledge access), based on what the person has or has not seen in the recent past, even if the other person's outdated visual experience differs from the infants' own visual

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experience (Onishi & Bailargeon, 2005; Southgate, Senju, & Csibra, 2007; Surian, Caldi, & Sperber, 2007).

Why would inhibiting one's own perspective be so demanding in some circumstances (so that even adults show an egocentric bias) and so easy in other circumstances (so that infants and nonhuman animals who are known to have limited cognitive resources apparently easily override the bias)? One possibility is that the specific conditions in which infants and animals were tested allowed them to use some basic computation to process the other person's perspective without the need to engage in effortful and explicit perspective-taking processes. Through this basic computation, the other person's perspective may become so salient that there is less competition from any alternative perspective that infants or animals may have. It is then possible that if placed in similar conditions, even adults could rely on these basic computations, and would thus find it easier to take the other person's perspective. To investigate this issue, we focused on visual perspective taking since most of the recent controversial findings relating to infants' or animals' surprising perspective-taking abilities are based on the observation that they can easily take into account someone else's discrepant present visual experience (Sodian et al., 2007) or outdated visual experience (Onishi & Bailargeon, 2005; Southgate et al., 2007; Surian et al., 2007).

The visual perspective-taking task we chose is similar to the type of tasks that infants and chimpanzees can perform successfully (Hare et al., 2000; Sodian et al., 2007). The visual perspective-taking ability that we are tapping into here is sometimes referred to in the literature as Level 1 perspective taking, requiring simply to judge whether or not someone can see a stimulus, as opposed to the more complex Level 2 perspective-taking ability that requires one to judge "how" rather than "whether" someone sees a particular stimulus (Flavell, Everett, Croft, & Flavell, 1981; Michelon & Zacks, 2006). Participants saw a picture of a room with a human avatar facing one of the walls, and with red discs displayed on the walls. In the consistent perspective condition, both the participant and the avatar could see the same amount of discs. In the inconsistent perspective condition, the participant and the avatar each saw a different amount of discs (some of the discs were not visible to the avatar). Participants were then asked to explicitly judge how many discs could be seen, either from their own perspective or from the avatar's perspective, while ignoring the irrelevant perspective. In order to assess the more "implicit" processing of perspectives (i.e., the processing of what someone else sees or what oneself sees without the need to make an explicit perspective judgment about it), we measured the extent to which the irrelevant perspective interfered with participants' explicit judgments about the relevant perspective. Slower response times and more errors in the inconsistent compared to the consistent condition when participants judge the avatar's perspective would indicate that what participants themselves saw interfered with their judgments of the avatar's perspective (egocentric intrusions). Conversely, slower response times and more errors in the inconsistent compared to the consistent condition when participants judged their own perspective would indicate that computation of what the avatar saw interfered with participants' judgment of their own perspective (altercentric intrusions). We were particularly interested in the latter interference effect as it would suggest that even though the avatar's perspective was irrelevant, participants could not prevent themselves from computing what the avatar saw. It would further suggest that the computation of what the avatar saw was very rapid, i.e. rapid enough to interfere with explicit self-perspective judgments. Furthermore, to examine the extent to which any implicit computation of what the avatar saw facilitated explicit judgments about the avatar's perspective, we compared the ease with which participants made explicit judgments about the avatar's perspective, compared to explicit judgments about their own perspective.

The same paradigm was used in three different experiments. In the first experiment, trials in which participants had to judge their own perspective and trials in which participants had to judge the avatar's perspective were mixed within the same blocks. In Experiment 2, we tested the amount of strategic control that participants had over their perspective taking. Trials in which participants had to judge their own perspective and trials in which participants had to judge the avatar's perspective were separated into distinct blocks of trials to give the participants a greater chance to avoid taking the avatar's perspective when it was unnecessary to do so. In Experiment 3, we tested even more stringently the extent to which participants could ignore the avatar's perspective by having them exclusively judge their own perspective throughout the task.

## Experiment 1

### Participants

Sixteen undergraduate students or postgraduate students participated in the experiment in return for course credit or a small honorarium (13 women, mean age: 20.6 years, age range: 19–25).

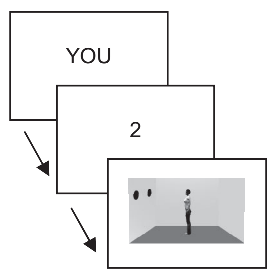
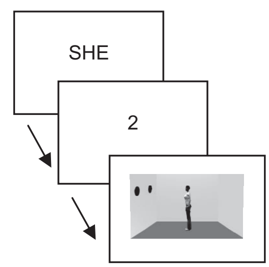
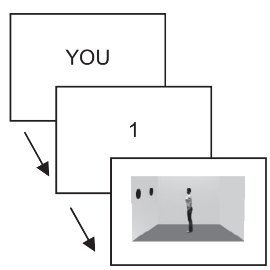
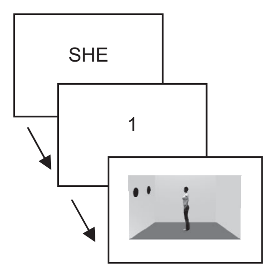
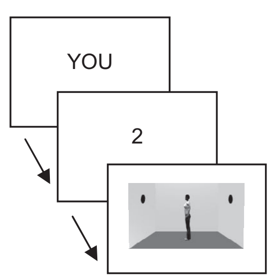
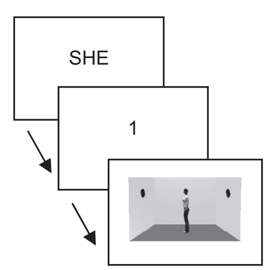
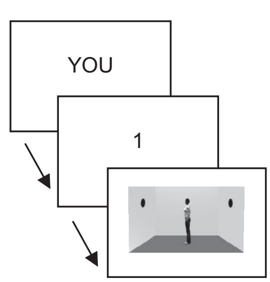
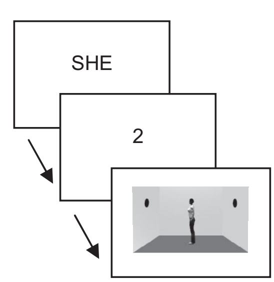
### Stimuli and Procedure

The stimuli consisted of a picture showing a lateral view into a room with the left, back, and right walls visible, and with red discs displayed on one or two walls. A human avatar was created with the three-dimensional animation software Poser 6 (e frontier, Scotts Valley, California) and was positioned in the centre of the room. The avatar was always 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 50% of trials, the avatar's position meant that s/he saw the same discs as the participants (Consistent perspective condition). On 50% of trials, the avatar's position meant that s/he could not see some of the discs that were visible to the participants (Inconsistent perspective condition). The position of the avatar was kept constant across consistent and inconsistent trials, but the position of the discs changed (see Appendix).

DMDX software was used to control the stimulus presentation and data collection (Forster & Forster, 2003). Each trial began with a fixation cross presented for 750 ms. Five hundred ms later, the word "YOU" or "HE"/"SHE" was presented for 750 ms, telling participants whether to take their own perspective (Self condition) or that of the avatar (Other condition). Five hundred ms later, a digit (0-3) appeared for 750 ms, which specified the perspective content for the participant to verify. Finally, the picture of the room appeared until participants pressed one of two mouse buttons to judge whether the picture matched ("yes" response) or mismatched ("no" response) the given content from the given perspective. If no response was given within 2,000 ms, the next trial was presented. On matching ("yes" response) consistent and inconsistent trials, the digit specifying the perspective content always corresponded to the number of discs seen from the relevant perspective (either self or other, see Table 1). On mismatching ("no" response) inconsistent trials, the digit specified the number of discs seen from the irrelevant perspective (i.e., the number of discs seen by the avatar when participants were asked to judge their own perspective or the number of discs seen by the participants themselves when they were asked to judge the avatar's perspective, see Table 1). On mismatching ("no" response) consistent trials, the digit specified a number of discs that did not correspond to anyone's perspective, and thus this made them particularly easy to process (this being the only way to create mismatching consistent trials, see Table 1). Because of the unbalanced way in which mismatching trials had to be constructed, we considered mismatching ("no" response) trials as fillers and only analyzed the data of the matching ("yes" response) trials.

There were 96 matching ("yes" response) trials: 48 trials where participants were asked to verify their own perspective (with 24 consistent perspective trials and 24 inconsistent perspective trials) and 48 trials where participants were asked to verify the avatar's perspective (with 24 consistent perspective trials and 24 inconsistent perspective trials). There was an equal number of mismatching ("no" response) trials. We also added 16 filler trials where no discs were displayed on the wall so that "0" would also sometimes be the correct

Table 1
*Example of Trials Used in Experiment 1 in the Different Experimental Conditions*

| Variable | Self | Other |
|---|---|---|
| Consistent | | |
| Matching ("Yes" response) |  |  |
| Mismatching ("No" response) |  |  |
| Inconsistent | | |
| Matching ("Yes" response) |  |  |
| Mismatching ("No" response) |  |  |

response for self-perspective trials. These filler trials included an equal number of self and other trials, consistent and inconsistent trials and, matching and mismatching trials. The trials were divided in 4 blocks of 52 test trials (48 test trials and 4 filler trials) and were preceded by a block of 26 practice trials. The order of the trials within a block was pseudo-randomized and then fixed across participants so that there were no more than three consecutive trials of the same type and so that self and other trials were equally often preceded by the same perspective (no shift of perspective) and by a different perspective (shift of perspective). The order of presentation of the blocks was counterbalanced across participants.

## Results

We performed a 2 × 2 repeated measure analysis of variance (ANOVA) with the type of Perspective taken (Self vs. Other) and the Consistency of the two perspectives (Consistent vs. Inconsistent) as within subject variables. Response time (RT) and number of errors were used as dependent variables in two separate analyses. Figure 1 displays the mean RT and percentage of errors in each experimental condition.

**Reaction time analysis.** Response omissions due to the time-out procedure (0.1% of the data) and erroneous responses (4.2% of the data) were eliminated from the data set.

The ANOVA revealed a significant main effect of Consistency, $F(1, 15) = 45.51$, Mean Standard Error ($MSE$) = 2,127.31, $p < .001$, $\eta_p^2 = .752$, with RTs being overall slower when both perspectives were inconsistent ($M$ = 702 ms) than when both perspectives were consistent ($M$ = 624 ms). The main effect of Perspective was not significant, $F(1, 15) < 1$, $MSE = 2{,}385.19$, $p = .51$, $\eta_p^2 = .03$ but there was a significant Consistency × Perspective interaction effect, $F(1, 15) = 18.30$, $MSE = 764.49$, $p < .01$, $\eta_p^2 = .550$. Paired t-tests showed a significant Consistency effect when participants judged the avatar's perspective, $t(15) = 8.39$, $p < .001$, with a 107-ms advantage in the consistent condition, and a significant but numerically smaller Consistency effect when participants judged their own perspective, $t(15) = 3.43$, $p < .01$, with a 48 ms advantage in the consistent condition. Furthermore, there

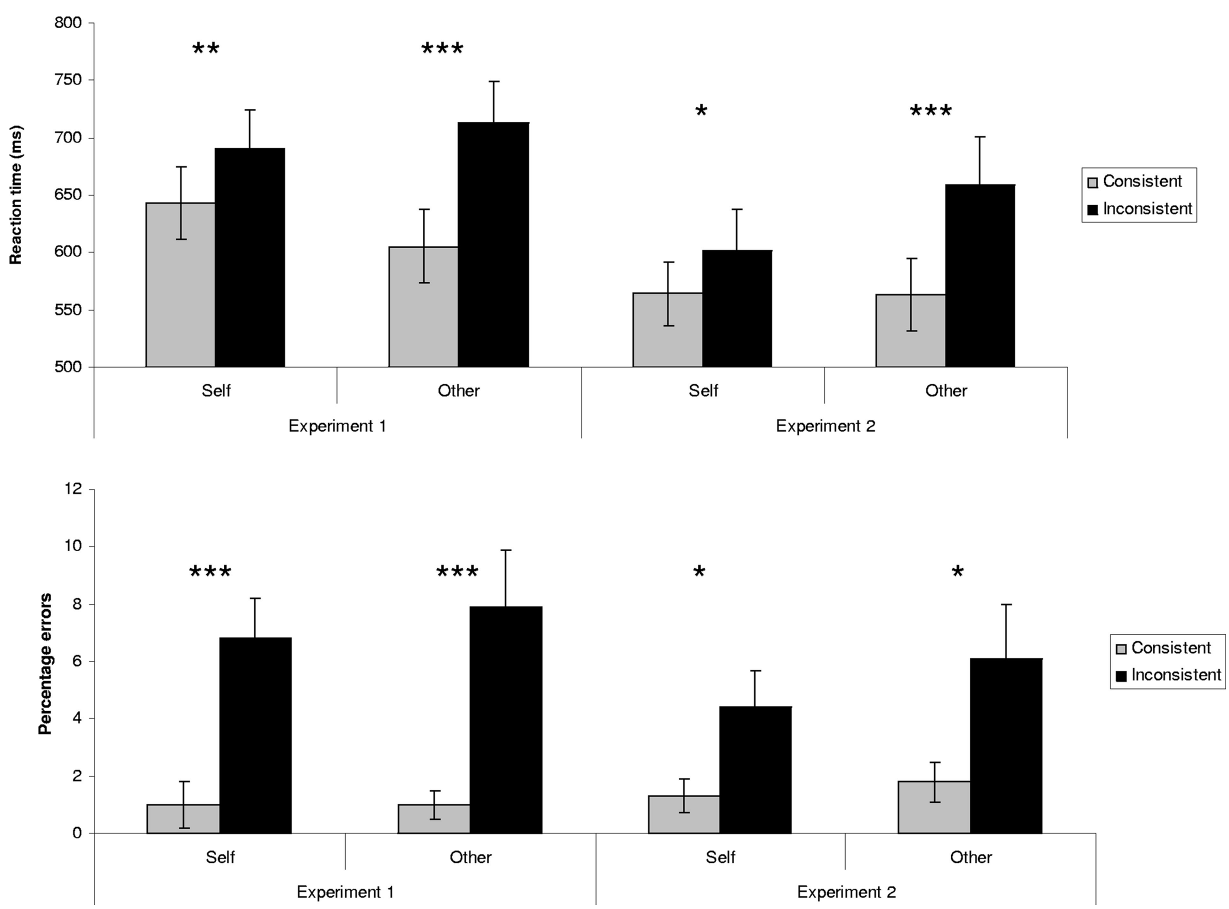



*Figure 1.* Mean (and *SE*) RT (upper panel) and percentage errors (lower panel) in Experiment 1 (self and other trials are mixed within blocks) and Experiment 2 (self and other trials are presented in separate blocks). The difference between inconsistent and consistent trials when judging the other perspective reflects egocentric intrusions whereas the difference between inconsistent and consistent trials when judging the self perspective reflects altercentric intrusions. Symbols indicate significance level (* $p < .05$. ** $p < .01$. *** $p < .001$. ns = nonsignificant).

was a significant Perspective effect on consistent trials, $t(15) = 4.37$, $p < .01$, with participants being, in fact, quicker at judging the avatar's perspective ($M = 605$ ms) than their own perspective ($M = 643$ ms). The effect of Perspective was not significant on inconsistent trials, $t(15) = 1.19$, $p = .25$; participants were equally slow when judging the avatar's and their own perspective ($M = 713$ ms and 691 ms respectively).[1]

**Error analysis.** The ANOVA showed a significant main effect of Consistency, $F(1, 15) = 21.96$, $MSE = .003$, $p < .001$, $\eta_p^2 = .594$, with participants making more errors when both perspectives were inconsistent ($M = 7.3\%$ errors) than when both perspectives were consistent ($M = 1\%$ errors). The main effect of Perspective and the Consistency × Perspective interaction effect were not significant (all $F$s $< 1$, $p > .58$, $\eta_p^2 <$ or $= .02$). There were thus no speed-accuracy trade-offs.

## Discussion

Both the analysis of the RTs and the analysis of the error rate revealed the existence of egocentric as well as altercentric intrusions. Participants were influenced by their own visual experience when judging what the avatar saw (egocentric intrusions) and, more interestingly, they were influenced by what the avatar saw when judging their own visual experience (altercentric intrusions). Egocentric intrusions caused larger interference than the altercentric intrusions in terms of reaction times, but both effects were significant, and moreover, both types of intrusions interfered equally when taking into account the participant's accuracy. These results suggest that participants could not easily ignore the irrelevant perspective (i.e., either what they saw or what the avatar saw) and that both perspectives were processed spontaneously at an implicit level at the very least.

The implicit computation of what the avatar saw seem to have provided useful information to explicitly judge the avatar's perspective. Participants were as quick and as accurate to make explicit judgments about the other person's visual experience compared to their own visual experience. In fact, the analysis of the RTs showed that participants were even significantly quicker at judging the avatar's perspective than their own perspective in some circumstances, i.e. when both perspectives were consistent.

Although in Experiment 1, participants were cued to take self or other perspectives before being presented with the picture stimulus, it is possible that the spontaneous computation of the irrelevant perspective occurred simply because self-perspective and other-perspective trials were mixed within the same block of trials, making both perspectives relevant to the task. We thus slightly modified the paradigm to present the self- and other-perspective judgments in clearly separated blocks as this would give the participants a clearer opportunity to strategically ignore the irrelevant perspective.

# Experiment 2

## Participants

Sixteen undergraduate students or postgraduate students participated in this experiment in return of course credit or a small honorarium (11 women, mean age: 26.1 years, age range: 20–33).

## Stimuli and Procedure

We used the exact same stimuli and procedure as in Experiment 1 except that self- and other-perspective trials were presented in separate blocks and participants were told before each block which perspective they had to judge (and hence which perspective they could ignore). The two self-perspective and the two other-perspective blocks were presented in an alternated fashion with half of the participants starting by judging their own perspective and the other half of the participants starting by judging the avatar's perspective.

## Results

Similarly to Experiment 1, we performed a 2 × 2 repeated measure ANOVA (with Consistency and Perspective as the independent variables and RT and number of errors as dependent variables). Figure 1 displays the mean RT and percentage of errors in each experimental condition. We also performed additional analyses on the RT and number of errors with Experiment 1 vs. 2 as an additional between subject variable, in order to directly test the impact of within-block perspective shifting.

**Reaction time analysis.** Data of Experiment 2 were preprocessed in the same way as for Experiment 1: 0.2% of the RT data were eliminated because of the timeout procedure and 3.4% of the data were eliminated because of erroneous response.

The analysis of the data of Experiment 2 showed a significant main effect of Consistency, $F(1, 15) = 25.50$, $MSE = 2{,}804.02$, $p < .001$, $\eta_p^2 = .63$, with participants responding slower in the inconsistent ($M = 630$ ms) than the consistent ($M = 563$ ms) condition. The effect of Perspective just failed to reach significance, $F(1, 15) = 3.94$, $MSE = 3{,}369.50$, $p = .07$, $\eta_p^2 = .208$, with a slight advantage for self-perspective judgments ($M = 582$ ms) over other-perspective judgments ($M = 611$ ms). Finally, there was a significant Consistency × Perspective interaction effect, $F(1, 15) = 9.08$, $MSE = 1{,}553.90$, $p < .01$, $\eta_p^2 = .377$. Paired $t$-tests revealed a significant Consistency effect when participants judged the avatar's perspective, $t(15) = 5.99$, $p < .001$, with a 97 ms advantage in the consistent condition, and a significant but again numerically smaller Consistency effect when participants judged their own perspective, $t(15) = 2.20$, $p < .05$, with a 37 ms advantage in the consistent condition. The effect of Perspective was not significant on consistent trials ($t < 1$, $p = .95$): participants were as quick at judging the avatar's perspective ($M = 563$ ms) as at judging their own perspective ($M = 564$ ms). But there was a significant Perspective effect on inconsistent trials, $t(15) = 2.74$, $p < .05$, with participants being slower at judging the avatar's perspective ($M = 659$ ms) than their own perspective ($M = 601$ ms).[2]

The analysis of the combined data from Experiment 1 and 2 showed no main effect of Experiment, i.e., no main effect of shifting of perspectives; $F(1, 30) = 2.09$, $MSE = 67{,}640.10$, $p =$

[1] These effects were not due to outliers as we obtained the same results by removing (per subject and per condition) RTs that were 2 $SD$ away from the mean.

[2] Removing outliers that were 2 $SD$ away from the mean did not change the results except that the main effect of Perspective just passed the significance level, $F(1, 15) = 5.50$, $MSE = 3{,}072.52$, $p < .05$, $\eta_p^2 = .268$.

.16, $\eta_p^2 = .065$. The effect of Experiment did not interact with Consistency and did not modulate the Consistency × Perspective interaction (for both $F < 1$, $p > .53$, $\eta_p^2 < .02$) but it did marginally modulate the Perspective effect, $F(1, 30) = 3.83$, $MSE = 2{,}877.35$, $p = .06$, $\eta_p^2 = .113$. The previously reported analyses performed separately with the data of Experiments 1 and 2 had shown that there was no main effect of Perspective in Experiment 1, but that there was a marginal effect of Perspective, at the advantage of self-perspective judgments, in Experiment 2. Independent t-tests further showed that RTs for other-perspective judgments were not significantly different across both experiments, $t(30) < 1$, $p = .34$, but RTs for self perspective judgments were marginally faster in Experiment 2 (blocked condition) than Experiment 1, shifting condition; $t(30) = 1.91$, $p = .07$.[3]

**Error analysis.** Numerically, the overall error rate was lower in Experiment 2 than in Experiment 1 (4.2% and 3.4%, for Experiments 1 and 2, respectively). The ANOVA analysis performed first on the data of Experiment 2 showed a significant main effect of Consistency, $F(1, 15) = 6.70$, $MSE = .003$, $p < .05$, $\eta_p^2 = .309$, with participants making more errors in the inconsistent ($M = 5.2\%$ errors) than the consistent condition ($M = 1.6\%$ errors). The main effect of Perspective, $F(1, 15) = 1.22$, $MSE = .002$, $p = .29$, $\eta_p^2 = .075$, and the Consistency × Perspective interaction effect, $F < 1$, $MSE = .001$, $p = .52$, $\eta_p^2 = .029$, were not significant. Thus, the pattern of errors suggested no speed-accuracy trade-offs.

Combining the data from Experiment 1 and 2, the analysis showed that overall there was no significant difference in accuracy across Experiments 1 and 2, $F < 1$, $MSE = .004$, $p = .51$, $\eta_p^2 = .015$, and the Experiment type did not modulate any of the other variables, all $F$s $< 1.76$, $p > .19$, $\eta_p^2 < .06$.

## Discussion

We found again clear evidence for altercentric intrusions both in the RT and error analyses. Similarly to Experiment 1, egocentric intrusions produced larger interference than the altercentric intrusions, but only as far as the reaction times were concerned. The two intrusion effects produced similar error rates. Thus, although participants explicitly knew the relevant perspective in advance and the relevant perspective was now constant throughout a block of trials, participants still could not completely ignore the irrelevant perspective, as we again found evidence for a bidirectional interference effect both in the RT and error analyses.

The direct comparison of Experiments 1 and 2 showed that whether participants had to shift between perspectives within a block of trials or not, the size of the altercentric intrusion effect was not significantly affected and nor was the ease with which participants explicitly judged the avatar's perspective. However, repeatedly judging their own perspective within a block speeded up explicit self-perspective judgments on both consistent and inconsistent trials. It is possible that in the latter case, participants may have construed the task slightly differently and started to compute how many discs there were in the room without any perspective attribution, i.e., without processing this explicitly as part of their "own perspective." We will discuss this further in the General Discussion.

Because participants took both perspectives in the practice trials and then alternated between perspectives in the experimental blocks, it could be argued that the interference effects only occurred because the irrelevant perspective on a given trial was nevertheless relevant at some point in the overall task. The fact that both perspectives were employed in separate blocks may not have rendered the irrelevant perspective fully irrelevant. A yet clearer demonstration that both visual experiences were computed spontaneously would come from an experiment where the intrusions are observed even when participants have never to switch perspective (i.e. when the irrelevant perspective remains irrelevant throughout the task).

There are some other points to consider. It could be argued that the consistency effect we observed resulted from the specific spatial layout of the discs on the wall and has nothing to do with perspective taking per se. For example, on inconsistent trials, the discs were often (but not always) spread across two walls, whereas in the consistent condition, the discs were always confined to one wall. So the consistency effect may have resulted, not from the irrelevant perspective interference per se, but from slower processing of the content of the room when the discs were spread across two walls, irrespective of which perspective the participants had to judge.

To address these issues, we conducted an additional experiment that specifically addressed the robustness and validity of the altercentric intrusion effect. In Experiment 3, participants were only asked to judge their own perspective (no shift of perspective was involved at all). On half of the trials, the avatar was presented in the middle of the room and in the other half of the trials a rectangle of similar size to the avatar was presented in the middle of the room. It was important that the exact same layouts of discs were presented when the avatar was in the middle of the room than when the rectangle was in the middle of the room. We predicted that if the consistency effect on self-perspective judgment is really due to intrusion of the avatar's perspective, we should observe a consistency effect only when the avatar is in the middle of the room, since the rectangle has no perspective. In contrast, if the consistency effect observed on self-perspective judgments is solely due to the spatial layout of the discs on the walls, we should observe a consistency effect both when the avatar is in the middle of the room and when the rectangle is in the middle of the room as the effect would be independent of perspective taking.

# Experiment 3

## Participants

Sixteen undergraduate students or postgraduate students participated in this experiment in return of a small honorarium (8 women, mean age: 23.75 years, age range: 19–39). One participant was eliminated because he made on average more than 30% errors and was then replaced by another additional participant to keep the number of participants at 16.

[3] Removing outliers that were 2 *SD* away from the mean made the marginal effects pass the significance level, Experiment × Perspective interaction: $F(1, 30) = 6.29$, $MSE = 3{,}046.17$, $p < .05$, $\eta_p^2 = .173$; effect of Experiment on Self-perspective judgments: $t(30) = 2.19$, $p < .05$.

### Stimuli and Procedure

We used the same consistent and inconsistent perspective stimuli as in Experiment 1 to create the "avatar distractor" condition (24 consistent matching, 24 consistent mismatching, 24 inconsistent matching, and 24 inconsistent matching). The "rectangle distractor" condition was created by duplicating the avatar trials but replacing the avatar by a rectangle which had one green line on one side and a purple line on the other side to create the equivalent of a front and back (each colored line appeared equally often on the right as the left side of the rectangle, see Figure 2).

The procedure was equivalent to Experiment 1, except that participants were told in advance that they only had to judge their own perspective and should ignore the stimuli in the middle of the room. The event sequence within a trial was the same as in Experiment 1 except that participants were always presented with the perspective cue "YOU." Trials with the avatar distractor and trials with the rectangle distractor were randomly intermixed within 4 blocks of trials (48 test trials + 4 filler trials per block), preceded by a block of 26 practice trials.

### Results

We first performed a 2 × 2 repeated measure ANOVA with Consistency (consistent vs. inconsistent) and Distractor type (avatar vs. rectangle) as the independent variables and, RT or number of errors as the dependent variable. Figure 3 displays the mean RT and percentage of errors in each experimental condition. Secondly, to investigate any change of pattern over time, we performed an additional analysis by adding Time (first half of trials vs. second half of trials) as an independent variable.

**Reaction time analysis.** Data were preprocessed in the same way as for Experiment 1: no RT data had to be eliminated because of the timeout procedure and 2.5% of the data were eliminated because of erroneous responses.

The Consistency × Distractor analysis revealed no significant main effect of Consistency, $F(1, 15) = 1.12$, $MSE = 898.41$, $p = .31$, $\eta_p^2 = .070$, and a main effect of Distractor that failed to reach significance, $F(1, 15) = 3.42$, $MSE = 784.937$, $p = .09$, $\eta_p^2 = .186$, with an overall trend for responses to be slower when the distractor was the avatar (583 ms) than when it was the rectangle (570 ms). There was a significant Consistency × Distractor interaction effect, $F(1, 15) = 5.99$, $MSE = 475.95$, $p < .05$, $\eta_p^2 = .285$. Paired t-tests indicated that there was a significant Consistency effect when the avatar was in the middle of the room, $t(15) = 2.44$, $p < .05$, with a 21-ms advantage in the consistent condition, but no significant Consistency effect when the rectangle was in the middle of the room ($t < 1$, $p = .59$). Furthermore, on consistent trials, there was no Distractor effect ($t < 1$, $p = .97$): participants judged their own perspective as quickly when the avatar was in the middle of the room ($M = 572$ ms) as when the rectangle was in the middle of the room ($M = 573$ ms). In contrast, on inconsistent trials, the Distractor effect was significant, $t(15) = 3.43$, $p < .01$: participants were slower to respond when the avatar was in the middle of the room ($M = 594$ ms) compared to when the rectangle was in the middle of the room ($M = 567$ ms).[4]

The Consistency × Distractor × Time analysis showed as the only additional effect, an effect of Time that failed to reach significance, $F(1, 15) = 3.38$, $MSE = 2{,}481.39$, $p = .09$, $\eta_p^2 = .184$, with participants responding slightly faster in the first half of the experiment ($M = 577$ ms), as compared with the second half ($M = 593$ ms). Time did not significantly interact with any variables, all $F$s $< 3.07$, $p > .10$, $\eta_p^2 < .170$. Most notably, the Consistency × Distractor × Time interaction effect was not significant, $F(1, 15) = 2.02$, $MSE = 875.48$, $p = .18$, $\eta_p^2 = .119$.[5]

**Error analysis.** Overall the number of errors was very small (2.5 %) and neither the main effects or the interaction effect were significant in the Consistency × Distractor analysis, all $F$s $< 1.2$, $p > .29$, $\eta_p^2 = .07$. There were thus no speed-accuracy trade-offs. In the Consistency × Distractor × Time analysis, the only significant effect was a main effect of Time, $F(1, 15) = 5.45$, $MSE = .001$, $p < .05$, $\eta_p^2 = .266$, with participants making fewer errors in the second half of the experiment ($M = 2\%$) compared to the first half ($M = 3\%$; all interactions with Time: $F$s $< 2.88$, $p > .11$, $\eta_p^2 < .170$. The Consistency × Distractor × Time interaction effect did not even approach significance, $F < 1$, $p = .65$, $\eta_p^2 = .014$.

### Discussion

Experiment 3 replicated the consistency effect on self-perspective judgments, but only when the avatar was presented in the room. In other words, what we coined as altercentric intrusion only occurred when the avatar was present in the room. These findings speak against two alternative explanations of the interference effects we observed in Experiments 1 and 2. Firstly, the altercentric intrusion effect is not merely the result of a specific spatial layout of the discs: without the presence of the avatar the same layout of discs did not produce any difference in performance between trials where the discs were all displayed on the same wall (consistent stimuli) and trials where the discs were

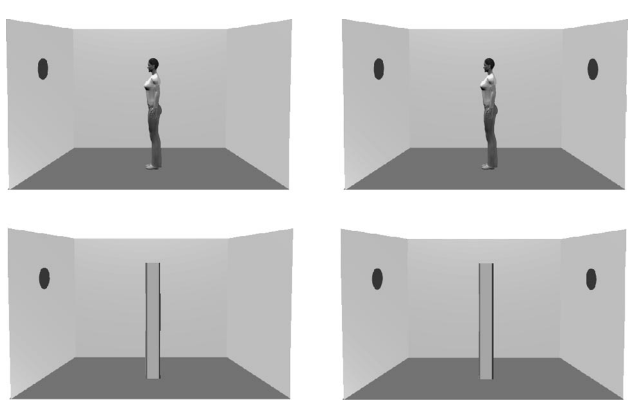


*Figure 2.* Examples of stimuli used in Experiment 3 in the avatar-distractor condition (upper line) and rectangle-distractor condition (lower line) and for consistent trials (left column) and inconsistent trials (right column).

[4] The same results were obtained when outliers that were 2 *SD* away from the mean were removed.

[5] When performing the same analysis but removing outliers that were 2 *SD* above or below the mean, the main effect of Time reached the significance level, $F(1, 15) = 8.78$, $MSE = 2{,}764.92$, $p < .05$, $\eta_p^2 = .369$, but this time showed that participants responded faster in the second half of the experiment. All interactions including the time factor remained nonsignificant, all $F$s $< 1$, $p > .37$, $\eta_p^2 < .06$.

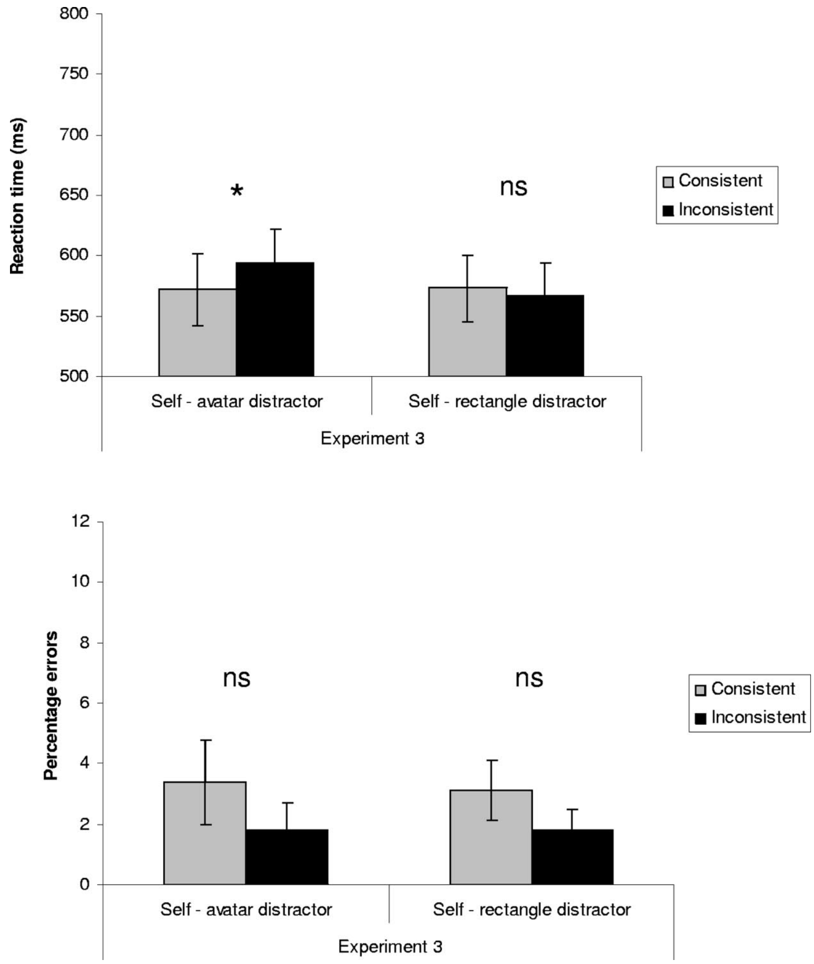



*Figure 3.* Mean (and SE) RT (upper panel) and percentage errors (lower panel) in Experiment 3 (self trials only). The difference between inconsistent and consistent trials reflects the interference from the distracting object (either the avatar or the rectangle). Symbols indicate significance level ($^{*}$ $p < .05$. $^{**}$ $p < .01$. $^{***}$ $p < .001$. ns = not significant).

(often) displayed on separate walls (inconsistent stimuli). Secondly, the avatar's intrusion in participants' self-perspective judgment did not occur only as a result of a switching cost when participants have to switch between perspectives or because participants computed both perspectives because they know that both are relevant for the task. Indeed, in Experiment 3, we found the altercentric intrusion even though participants only judged their own perspective throughout the task. However, the size of the intrusion was reduced. This suggests that the intrusions do occur when the other perspective is irrelevant but occur even more when the other perspective is relevant. It is interesting to note that, although participants performed better over time (responding more accurately in the second half of the experiment), the altercentric intrusions remained throughout the task as evidenced by the absence of a Consistency × Distractor × Time interaction effect in both the RT and error analysis. This shows that throughout the task, participants were unable to completely ignore what the avatar could see.

Of course, this does not show that the avatar's perspective would always be processed in any conceivable context, or that the effects observed will be totally immune from top-down control. Although participants were never required to take the avatar's perspective in Experiment 3, it is possible that instruction to focus on self-perspective (via the repeated presentation of the cue word "YOU" at the onset of each trial) served to draw participants' attention to the avatar, leading them to process the avatar's perspective when they would not otherwise have done so (such an effect might be analogous to the "ironic errors" in movement control whereby participants make precisely the errors that they intended to avoid; see Wegner, Ansfield, & Pilloff, 1998). Testing the conditions that trigger participants to process someone else's perspective, even when they do not need to, is clearly an important avenue for future research. Likewise, it would be interesting to know whether *any* form of top-down control could enable participants to arrest their processing of the avatar's perspective. One recent study indicates that processing of gaze direction—which resists top-down control in many circumstances—may be modulated by participant's beliefs about whether the gaze stimulus can actually see anything (Teufel et al., 2009). It seems reasonable to speculate that similar effects might be observed in the current paradigm, where participants might not experience interference from the presence of the avatar if they thought that the avatar could not see.

## General Discussion

Being able to take someone else's perspective and resisting the interference from our own point of view has often been seen in the literature as requiring cognitively effortful processes which take time to develop in children (e.g., Birch & Bloom, 2004). Recent findings in infants and nonhuman animals have, however, challenged this view by showing that despite their limited cognitive resources, infants and chimpanzees find it quite easy to take into account someone else's discrepant perspective under certain circumstances (e.g., Hare et al., 2000; Onishi & Bailargeon, 2005; Sodian et al., 2007; Southgate et al., 2007; Surian et al., 2007). These contradictory findings led us to hypothesize that, in addition to the more sophisticated perspective-taking processes that are traditionally studied in older children and adults, there may also be some basic and effortless computation available to adults to process someone else's perspective. We thus designed a new visual perspective-taking paradigm that could potentially highlight the existence of such computations. The paradigm investigated the ability to process what someone else can or cannot see, i.e. the minimum type of processing required in many of the tasks that infants and chimpanzees successfully pass (e.g., Hare et al., 2000; Sodian et al., 2007). The paradigm allowed us to measure the implicit processing of someone else's perspective (i.e. the processing of what the other person sees when no explicit judgment is required about the other person's perspective) and the explicit processing of someone else's perspective (i.e. the explicit judgment of what the other person sees).

In Experiments 1 and 2, participants were asked to judge either their own visual experience or someone else's visual experience under conditions where the other person could either see the same objects (consistent condition) or a smaller number of objects (inconsistent condition) than the participants themselves. We were particularly interested in any interference from what the other person could see on self-perspective judgments (i.e. slower and less accurate self-perspective judgments in the inconsistent than the consistent condition), as this would signal that even when the other person's perspective was irrelevant to the task, participants could not prevent themselves from computing what the other person saw. We found such interference effects in Experiment 1 when participants switched between self and other perspective judgments, and we found the same interference effect in Experiment 2 when participants where repeatedly asked to judge their own perspective across the same block of trials. Experiment 3 offered even stronger evidence that participants could not prevent themselves from processing what the other person saw, as we found the interference effect even though participants had only to make self-perspective judgments across the entire duration of the experiment (i.e. under conditions where the other person's perspective was never relevant to the task).

Experiment 3 showed that the interference effects were not an artifact of a specific stimulus configuration. It was the case in our paradigm that when both perspectives were in conflict, the discs presented in the stimuli were most often (though not always) displayed on two separate walls of the room whereas when there was no conflict between perspectives, the discs were always displayed on a single wall. It might have been that the slower responses and greater errors that we found when participants had to judge the number of discs they can see from their perspective had nothing to do with interference from the other person's perspective, but rather reflected a decreased efficiency in processing the number of discs when these were displayed on two walls. This alternative explanation can be ruled out with the findings of Experiment 3, where we used exactly the same disc configurations, once with the avatar in the middle of the room and once with an inanimate object in the middle of the room. We only found the equivalent to the altercentric intrusion effect on participants' self-perspective judgments when the avatar was in the middle of the room and not when the inanimate object was placed in the middle of the room.

Experiment 1 and 2 also allowed us to directly compare the ease with which participants explicitly judged someone else's visual experience relative to their own visual experience. In Experiment 1, if any significant difference between self- and other-perspective judgments was observed, it showed an advantage for judgments about the avatar's perspective whereas in Experiment 2, if any significant difference between self- and other-perspective judgments was observed, it showed an advantage for self-perspective judgments. The results of the analyses directly comparing Experiments 1 and 2 showed that the efficiency of the computation of the avatar's perspective did not change significantly across both experiments but it was the self-perspective judgments that were overall speeded up in Experiment 2 (blocked condition) compared to Experiment 1. There could be two interpretations for this. On the one hand, it is possible that in the blocked conditions of Experiment 2 participants still computed what the avatar's could see, but they could more easily ignore this information, thereby speeding their self-perspective judgments. However, if this were the case, we would have expected that any speeding of responses would have benefited judgments on inconsistent trials in particular, but this does not seem to have been the case. Rather the results show more rapid responses for both consistent and inconsistent trials, with the absolute size of the interference effect being quite similar across both experiments.

The alternative interpretation is that participants construed the task slightly differently in Experiment 2. We suggest that the demands in shifting perspectives from one trial to the next in Experiment 1 forced participants to construe their explicit judgments as truly perspective judgments both when judging what the avatar could see and when judging what they themselves could see. Under those circumstances, explicit judgments about the avatar's perspective were as quick if not quicker than explicit judgments of the participants' own perspective. In contrast, in Experiment 2, where participants were repeatedly asked to judge a specific perspective, it is possible that participants started to construe the task differently when judging their own perspective. Instead of making any explicit "perspective" attribution to themselves, participants may have merely processed the number of discs visible in the room. In comparison with this, more simple, judgment, judgments about the avatar's perspective were rather similar in speed, or even slower. However, even if this interpretation is correct, it is equally important to note that the altercentric effect was still observed in Experiment 2, suggesting that participants' judgments remained vulnerable to interference from what the avatar could see.

Across Experiment 1 and 2, the relative ease with which participants explicitly judged the avatar's perspective compared to their own perspective was most striking on consistent perspective trials. On inconsistent trials, the advantage tipped towards self-perspective judgments. This pattern of results can be explained by making four basic assumptions. Firstly, what participants saw from the scene was not construed as their "own perspective" from the onset. It is plausible to think that the explicit attribution of a self-perspective to our visual experiences requires an additional process to the processing of the scene itself. Participants were thus able to compute the number of discs present in the scene in a perspective neutral fashion, a process that would be easily achieved by subitizing given that the total number of discs never exceeded 3 (Trick & Pylyshyn, 1994). Secondly, in our particular task, participants were able to explicitly attribute a perspective to the avatar very quickly and even before they made the explicit attribution of their own perspective. This would have happened because the avatar was highly visible and processed as part of the scene at the onset. Thirdly, yes/no judgments were delayed when a conflict was detected between the total number of discs that participants could see and the number of discs that they processed as seen by the avatar (i.e. on inconsistent trials). It is indeed not unusual to find increased reaction times when a conflict is detected while processing information (for examples see, Kornblum, Hasbroucq, & Osman, 1990). Fourthly, once information has been explicitly construed as self-related, this information becomes more salient. This has been documented in the context of a variety of other tasks (see the "self-reference effect", e.g., Cunningham, Turk, Macdonald, & Macrae, 2008; Symons, & Johnson, 1997) and is in line with the usual egocentric biases reported in the literature (e.g., Birch & Bloom, 2004).

It would thus follow that it is only when participants delayed their judgments on inconsistent trials, which allowed for the extra time needed to compute a self-perspective and which made the self-perspective more salient than the avatar's perspective, that explicit judgments about the avatar's perspective were cognitively more costly than judgments about the self-perspective. This might offer an explanation for why infants and chimpanzees do not necessarily suffer from egocentric biases when computing what someone else sees as they may not have computed a competing, explicit "self-perspective."

Thus, taken all together, our results show that in our simple visual perspective-taking task, what the other person could see was computed spontaneously even when it was not relevant to the task. Furthermore, this information helped participants make explicit judgments about the other person's perspective as easily as and sometimes even more easily than explicit judgments about their own perspective.

How was the other person's perspective computed? It is well documented in the literature that an adult's attention is spontaneously drawn to where someone else is looking (for a review see Frischen, Bayliss, & Tipper, 2007). This is typically observed in a spatial cuing paradigm where participants are asked to respond to a target that follows a valid or invalid directional cue. When the cues are someone else's gaze direction, it is usually observed that participants respond faster to targets that appear in the location gazed at than to targets that appear in other locations, even if the gaze cue is not predictive of the target location (Driver et al., 1999). It is likely that similar attentional cueing effects produced by the avatar's gaze, head, and/or body orientation contributed to the ease with which the avatar's visual experience was computed. However, our results show that it is not only the object seen by the other person that is easily available to participants to process (as demonstrated previously in the spatial cueing paradigms), but also the fact that this object *is seen by the other person.* This is shown most clearly by the relative ease with which participants made explicit judgments of the avatar's perspective, which in some circumstances were made even more easily than self-perspective judgments. This would not be expected if the avatar's gaze merely made objects seen by the avatar more salient from the participant's own point of view. Thus, instead of having their attention simply drawn to the object seen, it seems that participants were able to quickly compute the avatar's line of sight (see Michelon & Zachs, 2006). What was computed may not necessarily have been construed as the avatar's "perspective" (although it could have been), but it was easily incorporated into explicit judgments about what the avatar could see.

The fast and efficient calculation of what the other person sees is likely to come at the cost of flexibility (see e.g., Apperly & Butterfill, 2009, for a general discussion of this issue). If correct, this would contrast sharply with many "theory of mind" abilities. In everyday folk psychological reasoning, adults can ascribe a very wide variety of beliefs, desires, and intentions, and this ability does not depend upon the immediate availability of cues about what a target sees, hears etc. These folk psychological abilities are highly flexible, but do not appear to be automatic (Apperly, Riggs, Simpson, Chiavarino, & Samson, 2006) and are relatively inefficient and demanding of cognitive control processes (e.g., Keysar et al., 2003). In contrast, we speculate that the processes that drive the altercentric interference effect and that facilitate explicit perspective judgments in our perspective-taking paradigm may be cognitively efficient, but dependent upon direct cues (such as where the avatar is looking) and are able to represent only a limited quantity or kind of content for what the avatar sees (e.g., possibly small numbers only; possibly only "what" someone can see but not "how" something is seen). We have avoided referring to these simple perspective-taking processes as "automatic" because automaticity is difficult to establish without a more exhaustive investigation of the range of circumstances in which such phenomena are observed. However, we note that the current data suggest that these processes are relatively resistant to strategic control, with participants computing the avatar's perspective even when they do not need to. We predict that further research may show that these processes make few demands on general cognitive resources for memory and executive control. On this view, simple perspective taking might not be disrupted by concurrent performance of a task that taxes executive functions, in marked contrast to more complex "theory of mind" tasks (e.g., Bull, Phillips, & Conway, 2008; McKinnon & Moscovitch, 2007).

Finally, it is important to highlight that the mechanisms by which what the other person sees is computed may be specific to the social domain, but need not be in order to provide useful information in social situations. For simple perspective-taking problems, the content of someone else's perspective does not require the complex representational apparatus often discussed in the literature on theory of mind (e.g., Leslie, 1987; Leslie & Thaiss, 1992; Perner, 1991). In an ecologically useful range of circumstances, adults may be influenced by much more low-level computation when solving perspective-taking tasks.

## Conclusion

To summarize, we report evidence that, in simple visual perspective-taking tasks, one's own and someone else's visual experience influence each other. Egocentric intrusions are consistent with many other reports of egocentric biases in children and adults when they take someone else's perspective. But, for the first time, we report here evidence for the reverse "altercentric" intrusions in visual perspective taking. We found that these intrusions arose even when participants were given a clear opportunity to ignore the other person, suggesting that the computation of what someone else sees was done very rapidly and effortlessly. This finding may help explain recent reports of success in very young children and nonhuman animals on tasks requiring taking into account someone else's current or past visual experience.

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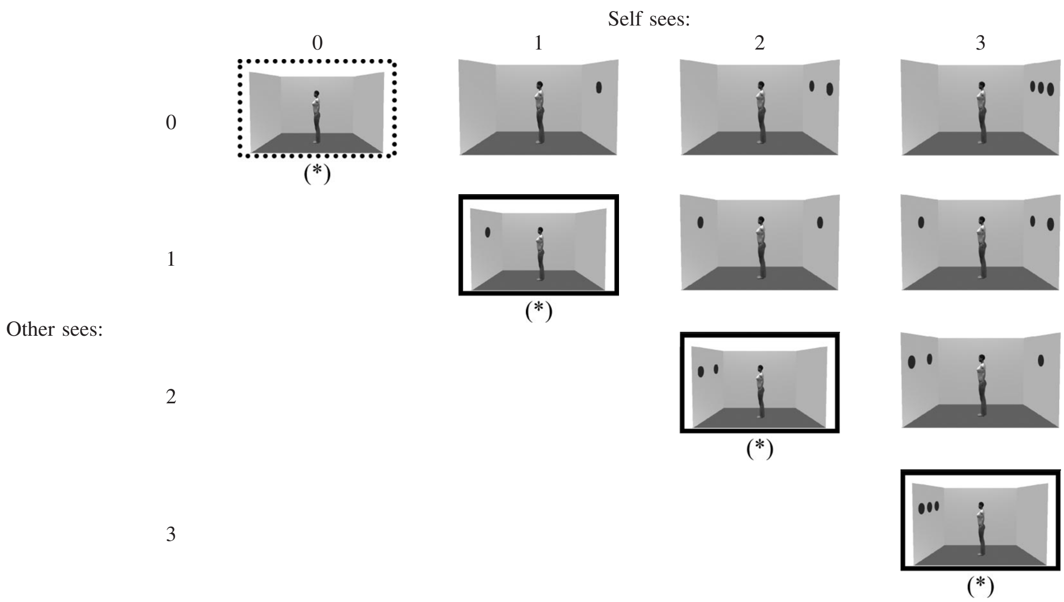
(*Appendix follows*)

## Appendix

### Stimuli Used in Experiment 1

Pictures bordered with a full line show the consistent stimuli; the picture bordered with a dashed line shows the consistent stimulus presented as filler trials, and the non-bordered pictures show the inconsistent stimuli. The mirror image of each of these stimuli was also presented in the experiment.




* These stimuli were repeated twice as often as the other stimuli in order to balance the overall number of consistent and inconsistent trials.

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