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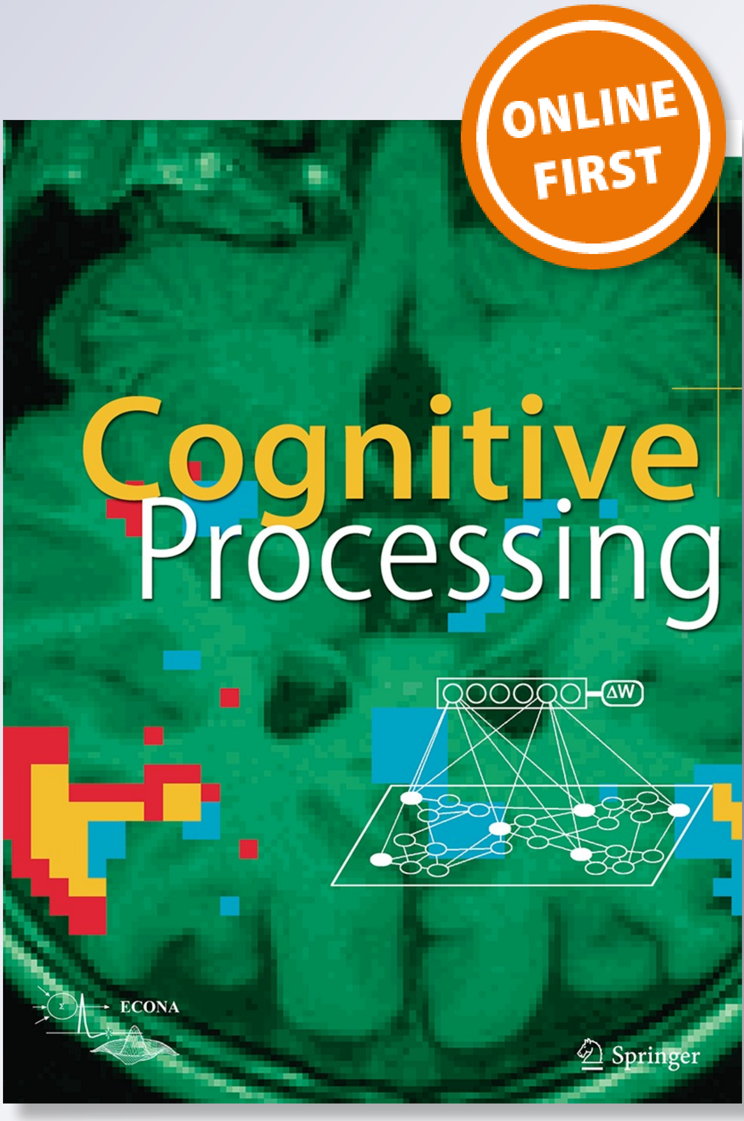

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SHORT REPORT

What's so difficult with adopting imagined perspectives?

Marios N. Avraamides[1] · Adamantini Hatzipanayioti[1] · Alexia Galati[1]

Abstract Research on spatial cognition suggests that transformation processes and/or spatial conflicts may influence performance on mental perspective-taking tasks. However, conflicting findings have complicated our understanding about the processes involved in perspective-taking, particularly those giving rise to angular disparity effects, whereby performance worsens as the imagined perspective adopted deviates from one's actual perspective. Based on data from experiments involving mental perspective-taking in immediate and remote spatial layouts, we propose here a novel account for the difficulty with perspective-taking. According to this account, the main difficulty lies in maintaining an imagined perspective in working memory, especially in the presence of salient sensorimotor information.

Keywords Perspective-taking · Spatial viewpoints · Sensorimotor interference

What's so difficult with adopting imagined perspectives?

In our daily life, we frequently find ourselves in situations in which we have to mentally adopt a spatial perspective other than the one we physically occupy, whether to process information that is perceptually available (e.g., as when inspecting a map and imagining ourselves at a particular orientation in a depicted intersection) or is stored in our memory (e.g., as when imagining ourselves at a distal location in our town in order to provide route directions). Research on spatial cognition has documented that, in many cases, such mental perspective-taking gets slower and more prone to error as the imagined perspective adopted deviates from our actual perspective—what has been termed as an *angular disparity effect*. In the present paper, we examine when and why this is the case. We briefly review two accounts supported by the extant literature, and based on data from our own research, we propose a novel hypothesis for the difficulties associated with perspective-taking.

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The mental transformation hypothesis

Studies on perceptual perspective-taking present participants with stimuli, such as human figures, at various orientations and ask them to make laterality judgments (e.g., indicate whether the left vs. the right arm of the figure is outstretched and whether an external object is placed on the left or the right of the figure). Typical results show strong correlations between response latency and the angular deviation of the stimulus from the upright orientation. Also, response latencies for back-facing figures (i.e., that have the same facing orientation as the participant) are generally shorter than for front-facing figures (e.g., Zacks et al. 1999), further suggesting that most participants solve the task by mentally transforming their own perspective to the orientation of the figure before responding. These findings therefore support the proposal that the difficulty of perspective-taking emerges from the mental transformation process entailed by the task (but see May and Wendt 2013).

If the mental transformation process is indeed responsible for the angular disparity effect observed in perspective-taking, then providing information in advance about the to-

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be-adopted perspective should eliminate, or at least reduce, the effect. A study by Sohn and Carlson (2003) examined this hypothesis. In this study, participants viewed on each trial a display with a top-down drawing of a table and five names randomly arranged around it at pre-defined positions. Participants were instructed to adopt the perspective of a specified reference person and indicate from that perspective the position of a target person, using the verbal labels "near-left," "near-right," "far-left" and "far-right." On some trials, information about the perspective to be adopted appeared before information about the target (advance-viewpoint condition), whereas on others, this information appeared following information about the target (advance-target condition) (Exp. 1). SOAs were also manipulated (0, 200, 400, 600, 800 ms), under the rationale that, when viewpoint information was available in advance, longer SOAs would provide participants with sufficient time to process and adopt the imagined perspective in anticipation of the target. Compared to the advance-target condition, in the advance-viewpoint condition, participants were faster to respond and, importantly, the angular disparity effect was reduced—although not completely eliminated—with increasing SOAs. This finding suggests that mental transformation processes can only partly account for the difficulty in perspective-taking: On the one hand, advance information about the to-be-adopted perspective presumably permits people to transform their perspective, such that they make a judgment from that perspective more quickly later on; on the other hand, such advance information does not entirely eliminate the cost of making judgments from increasingly offset perspectives. Indeed, in a follow-up experiment (Exp. 2), Sohn and Carlson (2003) provided evidence that spatial conflicts during the response stage may also play a role. In this experiment, participants responded with keys on the keyboard arbitrarily associated with target positions. Results showed that, although participants were again faster to respond in the advance-viewpoint condition compared to the advance-target condition, angular disparity effects in the advance-viewpoint condition were completely eliminated. Taken together, the findings from the two experiments suggest that, at least with perceptual tasks, both mental transformation processes and spatial conflicts at the response level contribute to the difficulties associated with mental perspective-taking.

The sensorimotor interference hypothesis

The role of spatial conflicts in perspective-taking was first discussed by May in the context of his sensorimotor interference hypothesis (May 1996; also May 2004). May (2004) proposed two types of spatial conflicts. First, object direction disparity (ODD) refers to spatial conflicts that occur during *response computation* and are caused by the discrepant location of the target as specified relative to the observer's actual and imaginal standpoints. May argued that sensorimotor codes specifying actual locations are automatically activated and interfere with the computation of the location from imagined perspectives. In the case of perspectives that entail imagined rotation but not translation, ODD is equal to the angular difference between the actual and imagined perspectives. Second, head direction disparity (HDD) refers to the difference between the actual and the imagined heading of the observer at *response execution*. HDD reflects the need to transform the computed response vector to egocentric coordinates before executing body-based responses such as pointing.

May (2004) provided evidence for the sensorimotor interference hypothesis with a study examining participants' memory about locations within their immediate surroundings. In one experiment, participants stood in the center of a layout and memorized the locations of objects placed around them. Then, while blindfolded, participants pointed toward object's locations from imagined perspectives, with information about the to-be-imagined perspective being provided in advance of target information (SOAs: 1, 3, and 5 s). May (2004) hypothesized that if the difficulties with perspective-taking occur at the early stage of the imagination process as the mental transformation hypothesis implies, then latency should decrease with increasing SOAs and angular disparity effects should be eliminated or reduced. In fact, when the imagined perspective was misaligned with the participant's actual perspective, pointing errors and response latencies increased monotonically with angular disparity and, although overall response latencies decreased with increasing SOAs, there was no interaction between SOA and angular disparity. That is, even though the mental transformation hypothesis can account for the poorer overall performance with increasing angular disparity, which is consistent with the mental transformation hypothesis, it cannot account for the finding that advance-viewpoint information did not reduce angular disparity effects. Instead, angular disparity effects obtained here can be altogether attributed to the presence of spatial conflicts between sensorimotor and imagined perspectives during response computation and execution, emerging from having to locate objects in the immediate environment but from imagined perspectives.

Maintaining imagined perspectives

If spatial conflicts are responsible for the angular disparity effects in May's (2004) study, then why were the overall response latencies still reduced with increasing SOAs? One possibility is that large SOAs allowed participants to process the advance information and reduce cognitive load for the subsequent processing of the target, even if they could not adopt the perspective in advance. This cannot be ruled out without a corresponding advance-target condition, which the experiment lacked. However, another explanation is that participants did adopt the imagined perspectives in the long SOAs trials but failed to maintain them until the target became available; nevertheless, this could allow them to re-adopt the perspective faster when the target appeared.

Our proposal here is that in testing situations such as those of May (2004), spatial conflicts in the form of ODD influence response computation by interfering with the cognitive processes required to maintain an imagined perspective in working memory. Maintaining an imagined perspective even for a short time is crucial for computing a non-egocentric response vector. In our view, angular disparity effects reflect the increasing difficulty of the mental transformation with larger rotations, but critically the output of that transformation process may not be maintained active in working memory when spatial conflicts exist. Such conflicts are expected to be stronger and harder to suppress, even with large SOAs, in situations where the observer is embedded in the memorized layout and thus maintains self-to-object relations in a transient spatial representation (Avraamides and Kelly 2008).

Compatible with this conjecture are the findings of a study we recently conducted in our laboratory (Avraamides et al. 2013). Motivated by previous evidence that sensorimotor influences are diminished when reasoning about remote environments (e.g., Kelly et al. 2007; Avraamides and Kelly 2010), we set out to compare the influence of advance-viewpoint information on the angular disparity effects when reasoning about remote versus immediate environments. The experiments involved studying a layout of six objects placed at different positions around the participants in a square virtual environment, presented through a virtual reality head-mounted display. Following encoding, participants' memory was tested though a series of trials that involved pointing to objects from imagined perspectives. The order in which viewpoint and target information was presented varied as in Sohn and Carlson (2003), although in our study, participants carried out the task in a self-paced manner (i.e., they pressed a key on the joystick to request the next piece of information). In one experiment (Exp. 2), participants completed testing in the same environment used for learning, after all objects were removed. In another experiment (Exp. 3), they were immersed in a different virtual environment for testing. Results revealed that when testing took place in a different environment, advance-perspective information eliminated angular disparity effects for perspectives at canonical directions of the egocentric reference frame of participants (i.e., objects on the participant's left, right, and back) and reduced them for objects in the diagonal directions (e.g., front right). In contrast, although overall response latency was shorter with advance-perspective information compared to advance-target, angular disparity effects persisted, without any reduction, when participants were tested in the learning environment.

Our interpretation of these findings is that in remote testing, where sensorimotor information about the actual physical orientation is reduced, participants are better able to maintain an imagined perspective in anticipation of the target, leading to the elimination of angular disparity effects at least for perspectives at canonical directions. The residual disparity effect for the diagonal directions could reflect either an HDD cost (i.e., transforming a response vector to egocentric coordinates might have been more difficult from non-canonical perspectives) or some remaining difficulty in maintaining the non-canonical perspectives for a prolonged period of time. Altogether, the shorter latency for the advance-perspective condition coupled with the persisting angular disparity effect when participants were tested in same environment, suggests that participants' main difficulty likely was to maintain the imagined perspective without having perceptual support regarding the objects' locations.

The perceptual task of Sohn and Carlson (2003) involves an intermediate situation between the two testing conditions of our own study, as participants were disembedded from the layout but had visual access to it as external observers. Not being immersed in the layout could have allowed participants to adopt the imagined perspective and maintain it in working memory even when it preceded the target. Moreover, the perceptual availability of the layout throughout the trial could have made easier the maintenance of the perspective in working memory, causing the reduction in disparity effects in the advance-viewpoint condition (Exp. 1), and their complete elimination in the corresponding condition with a non-spatial response (Exp. 2). The persisting angular disparity effect in Exp. 1 could reflect the difficulty in mapping verbal spatial labels to space from imagined perspectives (see Avraamides and Sofroniou 2006).

In Avraamides et al. (2013), we described another experiment (Exp. 1) that resembled that of Sohn and Carlson (2003), albeit with a memory task, three-dimensional stimuli, and pointing responses. Participants viewed the virtual environment on a desktop computer and used the mouse to turn around to observe the objects during study. Testing was also carried out on desktop computer in a different laboratory. Results from this experiment indicated that advance-viewpoint information led to a reduction in angular disparity effects, but only for canonical perspectives; no benefits were observed for diagonal perspectives other than an overall reduction in response latency compared to an advance-target and a simultaneous presentation condition. This finding suggests that in the absence of perceptual support, maintaining an imagined perspective in working memory is difficult, especially for perspectives that are misaligned with the egocentric reference frame. However, the use of a body-based pointing response in this experiment (vs. verbal labels) allows the possibility that the reduction in the angular disparity effect in canonical orientations stemmed from the easier transformation of the computed response vector to body coordinates. Further research is needed to distinguish these explanations.

Conclusion

We propose here that the main difficulty people face with mental perspective-taking in remembered environments relates to maintaining the perspective in working memory. Adopting a perspective mentally requires time, which is reflected in angular disparity effects. Providing advance information about a perspective allows the observer, under certain situations, to adopt and maintain the perspective in anticipation of further information. However, maintaining an imagined perspective is difficult when spatial conflicts arise from strong sensorimotor cues, as when reasoning about one's immediate surroundings. Although our proposal is compatible with findings from previous studies, it still needs to be evaluated by systematic research. Understanding the difficulties associated with reasoning from perspectives other than our own and developing methods to counteract those difficulties is essential nowadays when an increasing number of modern technologies involve such reasoning (e.g., tele-operating drones and robots).

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