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Sex differences in components of imagined perspective transformation

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ABSTRACT

Little research to date has examined whether sex differences in spatial ability extend to the mental self rotation involved in taking on a third party perspective. This question was addressed in the present study by assessing components of imagined perspective transformations in twenty men and twenty women. Participants made speeded left–right judgements about the hand in which an object was held by front- and back- facing schematic human figures in an "own body transformation task." Response times were longer when the figure did not share the same spatial orientation as the participant, and were substantially longer than those made for a control task requiring left-right judgements about the same stimuli from the participant's own point of view. A sex difference in imagined perspective transformation favouring males was found to be restricted to the speed of imagined self rotation, and was not observed for components indexing readiness to take a third party point of view, nor in left-right confusion. These findings indicate that the range of spatial abilities for which a sex difference has been established should be extended to include imagined perspective transformations. They also suggest that imagined perspective transformations may not draw upon those empathic social-emotional perspective taking processes for which females show an advantage.

1. Introduction

Spatial ability is a domain of cognitive ability in which there are marked differences between the sexes (Hines, 2004). A male advantage in spatial tasks has been confirmed by meta-analysis (e.g., Voyer, Voyer, & Bryden, 1995), and is particularly strong for mental rotation. These differences are likely to have a brain basis: Sexual dimorphisms in parietal lobe structure have been reported that are related to spatial ability as measured by block design (Hanggi et al., 2010) or mental rotation (Koscik, O'Leary, Moser, Andreasen, & Nopoulos, 2009). Tests of mental rotation typically require the imagined rotation of an object presented at one orientation in order to determine whether it is the same as one or more comparison objects presented at another orientation. Irrespective of whether performance is measured via chronometric (e.g., Shepard & Metzler, 1971) or paper and pencil methodology (e.g., Vandenberg & Kuse, 1978), stimuli employed in tests of mental rotation are often two dimensional renderings of volumetric objects such as blocks or other abstract shapes that if physically realised could conceivably be manipulated. The aim of the present study is to investigate whether similar sex differences extend to imagined perspective transformations, as measured by the own body transformation (OBT) task. This task is distinctive in requiring participants to adopt a third party perspective by mentally rotating their own body with respect to both a fixed environmental reference frame and an observed human figure until it aligns with the figure, see Fig. 1.

Evidence that sex differences for object-based mental rotation may not hold for imagined perspective transformations comes from behavioural and neurophysiological evidence that these processes may be dissociable. Ability on tests of object-based mental rotation has been found to be unrelated to ability on perspective taking tasks requiring judgments about objects made from a novel adopted point of view (Kozhevnikov & Hegarty, 2001). Evidence that imagined object rotations and imagined transformation of one's position with respect to an object rely upon dissociable brain systems has been revealed by fMRI (Wraga, Shephard, Church, Inati, & Kosslyn, 2005; see also Creem-Regehr, Neil, & Yeh, 2007). Complementary research has employed the OBT task to assess imagined transformations of whole body perspective by having participants make left or right judgments about a schematic human figure. This has produced evidence that the temporoparietal junction (TPJ) selectively subserves imagined perspective transformations (e.g., Arzy, Mohr, Michel, & Blanke, 2007; Arzy, Thut, Mohr, Michel, & Blanke, 2006; Blanke et al., 2005; Zacks, Rypma, Gabrieli, Tversky, & Glover, 1999), but not mental transformations of objects (Blanke et al., 2005). Furthermore,

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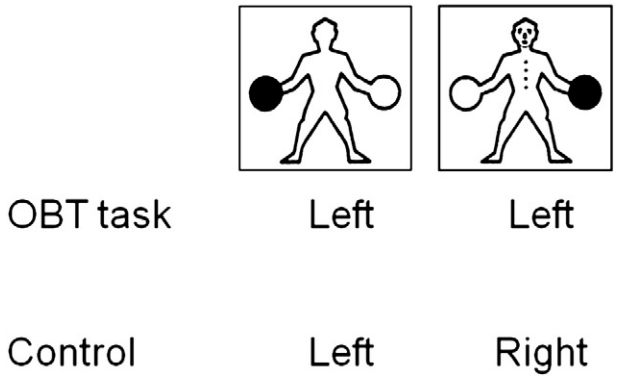

Fig. 1. Illustration of the correct responses for the front- and back-view stimuli presented during the OBT and Control tasks. For the OBT task, participants are instructed to take on the visual spatial perspective of the figure in order to judge which hand the figure was holding the ball. For the Control task, participants perform judgements from their own point of view (which side did the ball appear). Note: Right hand stimuli are not depicted.

ability in an OBT task has been shown to be unrelated to ability for object based mental rotation (Ocklenburg, Hirnstein, Ohmann, & Hausmann, 2011). Therefore sex differences for object-based mental rotation tasks do not necessarily generalise to the OBT task.

The question of whether there are sex differences in perspective transformation has been largely overlooked (Mohr, Rowe, & Blanke, 2010). The majority of studies employing variations on the OBT task either tested only male participants (Arzy et al., 2006, Expt 1, 2007; Zacks et al., 1999), or did not consider sex (Arzy et al., 2006, Expt 2; Bailey, Papadopoulos, Lingford-Hughes, & Nutt, 2007; Blanke et al., 2005; Easton, Blanke, & Mohr, 2009). Of the three studies that have systematically investigated sex differences in the OBT task, no difference was found in two studies (Mohr, Blanke, & Brugger, 2006, in press, Mohr et al., in press), and a male advantage consistent with faster imagined self-rotation was found in the other (Mohr et al., 2010). The latter difference went against the direction hypothesed: Mohr et al. (2010) predicted that women would show an advantage in the OBT task on the basis of earlier reports of a female advantage for social and emotional perspective taking, another sense of "putting oneself in the shoes of others." Thus, with research to date having yielded just one difference that went against hypothesis, there is presently not enough evidence to conclude whether the OBT task yields sex differences, and replication is required.

Two current theories make contrasting predictions about the direction of sex differences in the OBT task. As already mentioned, there are grounds, on the one hand, to hypothesise that females would outperform males on the basis of a female advantage in tests of empathy (Mohr et al., 2010). This hypothesis arises from the view that visuospatial perspective-taking shares common processes with social and emotional perspective-taking. In support of this view, empathy draws upon social-emotional perspective taking and has been associated with a brain network that partially overlaps that for visuospatial perspective taking, including the TPJ (e.g., Apperly, Samson, Chiavarino, & Humphreys, 2004; Blanke et al., 2005; Saxe & Wexler, 2005; Schulte-Ruther, Markowitsch, Shah, Fink, & Piefke, 2008). On the other hand, the male advantage observed by Mohr et al. (2010) is consistent with an alternative view that OBT task performance is mediated by a form of mental rotation that is functionally specific for body-based information (Braithwaite & Dent, 2011). This account would predict that the well established male advantage for mental rotation should extend to imagined perspective transformations, as measured by the OBT task. However, the magnitude of this difference may not necessarily be as great, given evidence that sex differences in object-based mental rotation are less marked for items that depict whole human bodies (Alexander & Evardone, 2008; Rilea, 2008; Roberts & Bell, 2003), or animals (Jansen-Osmann & Heil, 2007), potentially through the engagment of one's own body schema (Amorim, Isableu, & Jarraya, 2006). Therefore, a replication of the male advantage in the OBT task first reported by Mohr et al. (2010) may indicate that men perform imagined self-rotations faster than women, lending support to Braithwaite and Dent's (2011) account.

A methodological issue exists with how the rate of imagined self-rotations should be measured within the OBT task. Mohr et al. (2010), in common with Thakkar et al. (2009), computed for all participants a composite measure ("RT index" = (front − back) / (front + back) * 100) to capture the rotational cost in time to make a left/right hand judgement for trials in which the figure did not share the participant's perspective. They found that composite scores were higher for female participants, which seems to imply that women tend to take longer to perform perspective transformations. However these results are open to interpretation because the composite measure employed would be elevated by facilitated performance for back-view figures as well as poorer performance for front-view figures. Women might have been expected to show facilitated performance for back-view figures if women identify more readily than men with figures that share the same orientation as themselves. Evidence to support this contention comes from the finding that motor identification with an imagined back-view figure is related to empathy in women (cf. Marzoli, Mitaritonna, Moretto, Carluccio, & Tommasi, 2011), in line with Mohr et al.'s hypothesis. Therefore, it is possible that the sex difference in the RT index reflects females showing, relative to males, more efficient imagined transformation of one's position to that of another when perspectives coincide, less efficient transformation when perspectives differ, or some combination of these two processes. Given this interpretative issue, our analysis of sex differences in the speed of perspective transformations focuses on untransformed RTs to rule out the possibility that any sex difference in performance relates only to the back-view stimuli.

The current study was therefore designed to re-examine evidence for sex differences in imagined perspective transformations, as measured by the OBT task. A control task was also introduced to assess whether any differences were selective to the perspective transformation component of this task. This control task required participants to make left–right judgements about the same stimuli as the OBT task, but from their own spatial perspective (Gardner & Potts, 2010; Zacks et al., 1999; see Fig. 1). By asking participants to make judgements about which side the ball appeared, this task was designed to control for the processes involved in making left-right judgements about schematic figures, in view of evidence for a sex difference in left-right discrimination ability (e.g., Ocklenburg et al., 2011; Ofte & Hugdahl, 2002). It also enabled us to isolate two components of imagined perspective transformations either of which may potentially show sex differences. The comparison between OBT and control performance, which we refer to as the "point of view" effect, provides an index of the costs to response time of imagining oneself taking the point of view of a third party. The comparison between front- and back-facing stimuli in the OBT task, in keeping with Mohr et al.'s RT index, provided a measure of the perspective transformation component – indexing, specifically, the speed of an imagined self-rotation of 180 degrees. These putative components of OBT task performance correspond to those currently a focus of investigations into sex differences in mental rotation (Jansen-Osmann & Heil, 2007). We predict that if there is a male advantage for specifically the perspective transformation component of OBT task performance, sex should selectively moderate the size of the orientation effect, with females producing elevated RTs relative to males particularly for the front-view stimuli within the OBT task.

2. Method

2.1. Participants

Forty students (20 male, 20 female) from the University of Westminster volunteered to take part in this study. The ages for the