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Mental rotation does not account for sex differences in left–right confusion

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ABSTRACT

Several studies have demonstrated that women believe they are more prone to left–right confusion (LRC) than men. However, while some studies report that there is also a sex difference in LRC tasks favouring men, others report that men and women perform equally well. Recently, it was suggested that sex differences only emerge in LRC tasks when they involve mental rotation. That is, sex differences that are reported for some LRC tasks are strongly affected by the well-documented male advantage in mental rotation. To test this assumption, 91 participants were investigated on two LRC tasks: The Left–Right Commands Task and the Bergen Left–Right Discrimination Test. Additionally, participants were asked to complete an LRC self-rating questionnaire. To rule out the possibility that sex differences in LRC are confounded by sex differences in mental rotation, male and female participants were matched for mental rotation performance, resulting in a sample of 46 matched participants. These matched participants showed robust sex differences in favour of men in all LRC measurements. This suggests that pronounced sex differences in LRC are a genuine phenomenon that exists independently of sex differences in mental rotation.

1. Introduction

Left–right confusion (LRC) is a common phenomenon experienced by many humans in various situations. Apart from anecdotal evidence, a number of scientific studies reported that healthy adults sometimes experience difficulty when telling left from right (Harris & Gitterman, 1978; McMonnies, 1990; Wolf, 1973). Particularly women believe themselves to be more prone to LRC than men when they are asked to self-assess their ability to make fast and accurate left–right judgements (Hannay, Ciaccia, Kerr, & Barett, 1990; Hirnstein, Ocklenburg, Schneider, & Hausmann, 2009; Jaspers-Feyer & Peters, 2005; Jordan, Wüstenberg, Jaspers-Feyer, Fellbrich, & Peters, 2006). However, whether sex differences in self-ratings have behavioural consequences remains unclear as some studies report lower accuracy (Bakan & Putnam, 1974; Ofte, 2002; Ofte & Hugdahl, 2002b) and slower reaction times in LRC tasks (Snyder, 1991) in women compared with men, while others report no sex differences (Teng & Lee, 1982; Williams, Standen, & Ricciardelli, 1993).

Jordan et al. (2006) suggest that the conflicting results in LRC can be explained by sex differences in specific spatial abilities. For example, in the Bergen Left–Right Discrimination Test (Ofte, 2002; Ofte & Hugdahl, 2002a, 2002b), participants have to mark either the left or right hand of stickman figures that were are drawn either from the front or from the back. Performance in this task may be influenced by the fact that participants have to mentally rotate figures that are shown from the front to make a left–right decision. Mental rotation refers to the ability to mentally rotate two- or three-dimensional objects. Typically, men outperform women in tasks of mental rotation by effect sizes of more than one standard deviation (Linn & Petersen, 1985; Masters & Sanders, 1993; Peters, Lehmann, Takahira, Takeuchi, & Jordan, 2006; Voyer, Voyer, & Bryden, 1995). Jordan et al. (2006) argue that several studies that reported sex differences in LRC (e.g., Bakan & Putnam, 1974; Ofte, 2002; Ofte & Hugdahl, 2002b; Snyder, 1991) are confounded by mental rotation.

In their own study Jordan et al. (2006) tested participants on LRC tasks that did or did not involve mental rotation. In the LCR task that involves mental rotation, participants had to navigate through a three-dimensional virtual maze on the basis of a map they had seen before. Here, a sex difference emerged with men being significantly faster than women. Participants had to mentally rotate their memorized overview image of the maze depending on their position in order to make a correct left–right decision at junctions in the maze. The assumption that the sex difference in this task may be confounded by sex differences in mental rotation is partly supported by a significant positive correlation between the time needed to navigate through the maze and the performance in the Mental Rotation Test (Peters et al., 1995). However, only men, and not women, showed this correlation suggesting that mental rotation may not entirely account for the observed sex dif-

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ference. In the task that did not involve mental rotation, participants had to decide as quickly as possible whether an object (a bunch of pencils) is to the left or right of another object (an iced-tea can) viewed solely from the participants' perspective. No sex differences were observed in this LRC task.

However, there are findings that argue against Jordan et al.'s (2006) notion and suggest that sex differences in LRC exist independently of mental rotation. For example, in the Left–Right Commands Task, Hirnstein et al. (2009) asked their participants to follow verbal commands concerning their own left and right body parts. This task showed a significant sex difference with a large effect size ($d > 0.8$), although no mental rotation was required. Similarly, in the pointing-hands task, in which participants viewed pictures of pointing hands in different orientations and had to indicate either the pointing directions or whether they saw a left or right hand, women committed more LRC than men.

Taken together, it remains still unclear from these studies whether sex differences found for some LRC tasks are a mere artefact of sex differences in mental rotation. To investigate whether sex differences in LRC exist independently of mental rotation, we compared the susceptibility to LRC in men and women that were matched for their mental rotation ability as measured with the Mental Rotation Test (Peters et al., 1995; Vandenberg & Kuse, 1978). Two LRC tasks were used: the Left–Right Commands Task and the Bergen Left–Right Discrimination Test. Both tasks showed robust sex differences previously (Hirnstein et al., 2009; Ofte, 2002; Ofte & Hugdahl, 2002b). If sex differences in LRC are independent of mental rotation, then men and women matched for their mental rotation abilities should still display sex differences in both tasks.

2. Methods

2.1. Participants

Overall, 91 neurologically healthy women ($N = 50$) and men ($N = 41$) participated in the present study. The mean age was 23.5 years ($SD = 3.45$) for women and 25.29 years ($SD = 3.68$) for men. All participants were right-handed, as determined by the Edinburgh Handedness Inventory (EHI; Oldfield, 1971). The laterality quotient (LQ) provided by this test is calculated as $LQ = [(R - L)/(R + L)]/100$, resulting in values between −100 and +100. Positive values indicate right-handedness, while negative values indicate left-handedness. Women had a mean LQ of 91.36 ($SD = 15.12$), while men had a mean LQ of 87.37 ($SD = 17.43$). There was no sex difference in LQ ($t(89) = 1.17$, $p = 0.25$).

2.2. Procedure

Each test session began with two behavioural LRC tasks, the Left–Right Commands Task (Hirnstein et al., 2009) and the Bergen Left–Right Discrimination Test (Ofte, 2002), in counterbalanced order. Subsequently, they completed the EHI, the left–right self-rating questionnaire and the Mental Rotation Test (Peters et al., 1995). Performing the LRC tasks at the beginning of each test session prevented possible stereotype activation effects of the self-rating questionnaire.

2.3. Mental Rotation Test

To select groups of men and women that are matched for mental rotation abilities, all participants performed the Revised Vandenberg and Kuse Mental Rotation Test by Peters et al. (1995). This paper-and-pencil test consists of two subtests with 12 items each. Each item consists of five cube figures, one of them being the target figure. Of the other four figures, two are rotated versions of the target figure whereas the other two cannot be matched with the target figure via rotation. Participants have 3 min to finish each subtest. A score of 'one' per item was given, if both rotated versions of the target had been identified correctly. In all other cases, a score of 'zero' was given, resulting in an overall score between zero and 24 for each participant.

2.4. The Bergen Left–Right Discrimination Test

The original paper–pencil version of the Bergen Left–Right Discrimination Test (Ofte, 2002) was adapted for use on a computer. Stimuli were presented on a standard PC monitor using Presentation® (Neurobehavioral Systems, Inc., Albany, USA). The stimulus set consists of 96 line drawings of a figure with a height of 11 cm. When the head of the figure is highlighted in black, the figure is viewed from the back, so that the left hand of the figure is presented on the left side of the participant. When the head of the figure is highlighted in white, the figure is viewed from the front, so that the left hand of the figure is presented on the right side of the participant. In half of the trials the figure is viewed from the back, in the other half it is viewed from the front. The shoulders are represented by a black triangle. The arms of the figures are located at different positions in relation to the body, with no arm, one arm or both arms crossing the vertical midline of the figure. Circles at the end of the arms represent the hands of the figures. For half of the figures the left hand is coloured red, for the other half the right hand is highlighted in red (see Fig. 1).

Participants had to decide by button press whether the labels 'R' or 'L' below the figure matched the left or right hand highlighted in red. For example, if the right hand was highlighted in red and the label below the figure showed 'R', the trial was correct. Labels were correct in 50% of the trials (matching trials) and incorrect in the other 50% of trials (mismatching trials). The response keys were arranged vertically to prevent possible spatial stimulus-response compatibility effects. Each stimulus was presented until participants pressed one of the two response keys. After a response was made a blank screen was presented for 1000 ms before the next trial began. The original set of 48 stimuli was used twice, once with left and once with right hands highlighted in red. Stimuli were presented in pseudo-randomised order, and LRC rates as well as reaction times for correct left–right decisions were calculated as dependent variables.

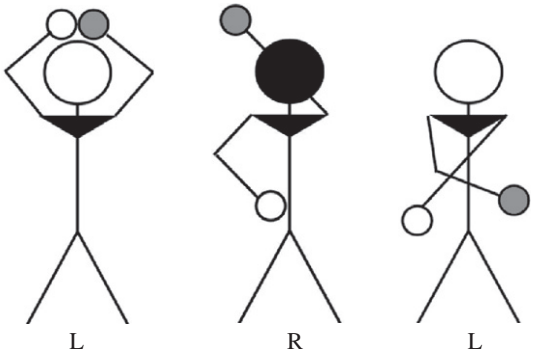

Fig. 1. Stimuli of the Bergen Left–Right Discrimination Test. The stickman figures are viewed from the front (white head) or from the back (black head) and exemplify the three possible arm positions (no arm, one arm or both arms crossing the vertical midline of the stickman figure). Participants have to decide whether the label below the stickman figure corresponds to the hand highlighted in red (here in grey). The first two stickman figures show correct items, whereas the third stickman figure shows an incorrect item.