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Women and mental rotation: Incremental theory and spatial strategy use enhance performance

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ABSTRACT

Mental rotation is a spatial skill in which men outperform women. The present research tested a motivational explanation of this gender difference with the hypothesis that positive beliefs will in women favor use of spatial strategies, which in turn will lead to improved MRT performance. Spatial strategy use and two beliefs, namely incremental theory and self-perception of ability in stereotypically masculine (i.e., requiring spatial ability) tasks, were assessed in a sample of 120 women. Two groups of solvers – one spatial, one non-spatial – were selected on the basis of self-rated strategy use. Results demonstrated that use of spatial strategies mediates the effect of incremental theory of masculine tasks on MRT performance, whereas self-perception of ability directly influences MRT performance. Findings are discussed on the basis of a socio-cognitive explanation of gender differences in mental rotation.

The ability to mentally retain an object and rotate it in space is termed mental rotation. This ability is associated with success in topics such as geometry, mathematics, chemistry and physics (Delgrado & Prieto, 2004), and is important for everyday spatial activities such as orientation in unfamiliar places or finding a route on a map (e.g., Linn & Petersen, 1986).

An instrument largely used to assess this ability is the Mental Rotation Test (MRT; Vandenberg & Kuse, 1978), involving comparison of three-dimensional figures (assembled cubes). The test consists of presentation of a 3D target object, followed by four similar objects differing in degree of rotation or as mirror images. Test participants are required to identify the two figures that are identical to the target but rotated in three-dimensional space. Twenty separate target objects are presented, in succession. Typically, in MRT men score up to one standard deviation higher than women (e.g., Voyer, Voyer, & Bryden, 1995). This is one of the robust gender differences observed in spatial tasks, with large effect size for the paper-and-pencil test (Cohen $d = 0.88$) and medium ($d = 0.45$) for the computerized version (Monahan, Harke, & Shelley, 2008). In other spatial abilities, such as navigation, memory, orientation, visualization, perception, there is no gender difference (e.g. spatial visualization, Linn & Petersen, 1985) or women can perform better than men (e.g. object location memory, Postma, Izendoorn, & De Haan, 1998). Generally, men outperform in tasks requiring encoding and/or retrieval of metric properties, geometric information or the use of cardinal direction, while females excel in tasks requiring landmark knowledge or processing (e.g., Iachini, Sergi, Ruggiero, & Gnisci, 2005).

Many suggestions have been put forward to explain gender differences in mental rotation: hormonal, cultural, practice on the task, strategic, motivational. From prenatal life, the fetus is exposed to various kinds of gender-related hormones, which are known to affect brain development and organization (e.g., Burton, Henninger, & Hafetz, 2005). Activational effects due to the level of circulating testosterone (3–10 times higher in men than in women) have also been documented (Yen, Jaffe, & Barbieri, 1999). However, results obtained are mixed and cannot explain the entire variance (e.g., Hooven, Chabris, Ellison, & Kosslyn, 2004): further explanations are needed for the differences observed.

In Western cultures, people consider spatial ability as a predominantly masculine characteristic (Devlin, 2001) and encourage boys more strongly than girls to engage in activities that promote the development of spatial skills (e.g., computer games, math and science courses). In non-Western cultures (e.g., preliterate Indians of the Ecuador) women outperform men in a variety of spatial tests (Pontious, 1991). This suggests that one factor facilitating high mental rotation performance is practice with spatial tasks.

How does greater expertise lead to better results? One relevant aspect is the kind of strategies used. MRT may be performed using either holistic or analytical strategies (Linn & Petersen, 1985). The former involve parallel processes and consist in mentally rotating the whole figure (target) until it matches the answer choices and/or mentally rotating the answer choices until they fit the

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target. Instead, analytical strategies are based mainly on verbal processes, such as counting the cubes, and are less effective and require longer execution times than holistic approaches. On average, women tend to use analytical strategies, while men favor holistic strategies (e.g., Hugdahl, Thomsen, & Ersland, 2006) and these different approaches may partly explain gender differences in both accuracy and speed. In fact, women increase MRT performance if additional time is allowed and if trained with spatial tasks. However, providing additional time does not always reduce the gender gap (e.g., Peters, 2005), while training is more effective for women than men (e.g., Feng, Spence, & Pratt, 2007). This suggests the importance of practice with spatial tasks as a way to improve the strategic approach.

What factors are encouraging women's engagement in masculine and spatial tasks? Here, beliefs may play an important role. Research has highlighted the importance of socio-cultural stereotypes and the way abilities are conceived – that is, as aspects that cannot be modified or else as characteristics that can be improved through effort and learning (Dweck, 1999). A positive stereotype message (Moè & Pazzaglia, 2006; Wraga, Duncan, Jacobs, Helt, & Church, 2006) increases women's performance in spatial tasks, as do instructions consistent with gender-role beliefs (Massa, Mayer, & Bohon, 2005) and use of human figures rather than block stimuli (Alexander & Evardone, 2008). Shaping an incremental theory (Aronson, Fried, & Good, 2002), self-affirming (Martens, Johns, Greenberg, & Schimel, 2006) or priming a positive-performance social identity (McGlone & Aronson, 2006) are ways to maintain self-integrity that helps women perform at the same level as men.

These studies all suggest that women who believe it is possible to improve in masculine tasks, i.e. who have an incremental theory of masculine tasks, should be more motivated to engage in spatial tasks and discover the best strategies for good performance. Self-perception of ability of masculine tasks – i.e., self-evaluation about personal perceived ability to handle a task – can also make a difference. The greater the amount of practice with specific tasks, the higher the self-perception of ability to handle them. Flaberty (2005), after confirming that men prefer practice with masculine activities and women with feminine ones, found a positive correlation between the number of masculine activities performed (e.g., carpentry, making/fixing a radio, building train/car set) and MRT scores, irrespective of gender. Women who have practiced a large number of masculine tasks should have developed a higher self-perception of ability in spatial tasks and consequently perform better in MRT than women who have less practice (e.g., Casey, Nuttall, & Pezaris, 1997).

In the present research, we test the effects of beliefs and use of spatial strategies on MRT performance. First, we predict confirmation that higher spatial strategy use correlates with good MRT performance. Second, we test the effects of beliefs in incremental theory and self-perception of ability of masculine tasks on MRT performance. We expect to find that higher incremental theory and self-perception of ability of masculine tasks corresponds to better MRT performance. Third, more importantly, we test the mediation role of spatial strategy use in MRT performance. We explore whether spatial strategy use mediates the effect of beliefs on MRT performance. Two models are tested with predictor variables incremental theory of masculine tasks (first model) and self-perception of ability of masculine tasks (second model). The mediator (spatial strategy use) and the dependent variable (MRT performance) are the same in both models. Our hypothesis is that incremental theory women would be more likely to use strategic behaviors and therefore reach good performance, and that women who perceive they can tackle masculine tasks would be more likely to adopt the most effective strategies to undertake spatial tasks, and hence increase MRT performance.

1. Method

1.1. Participants

One hundred and twenty female undergraduates were recruited on a voluntary basis during one particular general psychology class, and allowed extra course credit for participation in the research. Mean age was 21.24 years (*SD* = 2.40). Institutional ethics approval was given for the study.

1.2. Materials

1.2.1. Beliefs questionnaire

We devised an instrument listing 15 cognitive tasks selected through previous research (Moè & Pazzaglia, 2006) as stereotypically masculine (solving math problems, engaging in a new sport, finding a route on a map, finding the quickest way to reach a place, building or repairing something), feminine (e.g., learning a foreign language, feeling others' emotions) or neutral (e.g., paying attention during a lecture, being curious to learn new things). Participants were asked to give three ratings for each of the 15 listed tasks: gender stereo-typicality, incremental theory, and self-perception of ability. The questions were (a) 'How much do you think that men differ from women in each of the following tasks?' rating from '-3' = 'women much better' to '+3' = 'men much better'; (b) 'How much can a person improve in each of the following tasks?' rating from '1' = 'not at all' to '7' = 'very much'; (c) 'How good do you think you are in the following tasks?' rating from '1' = 'not at all' to '7' = 'very much'.

1.2.2. Mental rotation test (MRT)

A computerized 10-item modified version of MRT of the original test of Vandenberg and Kuse (1978) was used (Moè & Pazzaglia, 2006). Items were composed of a target and four test stimuli, each 3.5×3.5 cm. The task was to identify the two figures identical to the target but rotated in three-dimensional space. Cronbach alpha was 0.86.

1.2.3. Strategy questionnaire

We devised a questionnaire to assess the strategies employed to solve MRT items, divided into *holistic* strategy – "I rotated the target-stimulus to match the test-stimulus" (item 1), "I rotated the test-stimulus to match the target-stimulus" (item 2), "I globally rotated the stimulus" (item 4) and "I imagined myself rotating around the object" (item 6); or *analytical* – with a typical verbal strategy "I counted the cubes" (item 3) and a sequential strategy "I rotated the stimulus piece by piece" (item 5). Participants were asked to rate how much they used each strategy, on a Likert scale ranging from '1' = 'not at all' to '7' = 'very much'.

1.3. Procedure

Participants were individually tested. They first completed the Beliefs Questionnaire without time limit, and then performed the MRT. Proceeding in this order evokes concern in belief in ability or inability and perhaps performance apprehension and stereotype threat in all participants, thus stressing the motivational aspects in performing a typical masculine task. In contrast, submitting the beliefs questionnaire after performing the MRT should have influenced perceived performance (low or high), as stated in the beliefs questionnaire.

Participants initially read the instructions and had training with three practice items. They were told that the test they were performing was being timed, and should be completed within 4 min. From this they could have inferred the need to work as quickly as