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Can girls think spatially? Influence of implicit gender stereotype activation and rotational axis on fourth graders' mental-rotation performance

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ABSTRACT

Mental-rotation tasks usually induce large gender differences in favor of males. The influence of task features and stereotype activation on the mental-rotation performance of elementary-school children has rarely been investigated. This study examined the performance of 272 fourth-grade boys and girls in a psychometric mental-rotation task varying implicit gender-stereotype activation (threatening vs. non-threatening task framing) and rotational axis (picture-plane vs. in-depth rotations). Children's gender stereotypes were assessed by a questionnaire. Both genders showed a male stereotype for mental rotation. Implicit gender stereotype activation influenced the gender difference only in picture-plane mental-rotation tasks. Boys outperformed girls in the threatening condition, but not in the non-threatening condition, here. However, in-depth rotation tasks induced a significant male advantage in both the threatening and the non-threatening conditions. Findings suggest that a task framing relating mental rotation to arts induces a stereotype-lift effect and that the rotational axis moderates the effect of implicit gender-stereotype activation.

1. Introduction

Stereotypes are “expectations or beliefs about characteristics associated with different groups” (Swim & Hyers, 2009, p. 411). They influence achievement not only by inducing long-term effects on self-concept and skill development (Appel & Kronberger, 2012; Bussey & Bandura, 1999), but also by interrupting – or, in the case of positive in-group stereotypes, promoting – cognitive, perceptual and motor performance in the test situation (Aronson & McGlone, 2009). The detrimental effect of negative stereotypes is called *Stereotype Threat* (Steele, 1997; Steele & Aronson, 1995), the beneficial effect of positive stereotypes is called *Stereotype Lift* (Walton & Cohen, 2003). The present study examined the situational influence of implicitly activated gender stereotypes on mental-rotation performance, a domain for which large gender differences in favor of male participants are usually found in adults (Lippa, Collaer, & Peters, 2010; Voyer, 2011; Voyer, Voyer, & Bryden, 1995). Furthermore, the influence of rotational axis on boys' and girls' mental-rotation performance was investigated, because previous studies indicate a larger male advantage for in-depth rotations than for picture-plane rotations (Voyer et al., 1995).

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1.1. The gender effect in mental-rotation performance and the influence of rotational axis

Mental-rotation tests, which assess the ability to rotate two- and three-dimensional objects in the mind (Shepard & Metzler, 1971), induce one of the largest cognitive gender differences (Halpern, 2012), which emerge already before adolescence (e.g. Johnson & Meade, 1987; Neuburger, Jansen, Heil, & Quaiser-Pohl, 2011).

In addition to age, task characteristics influence the gender effect in mental rotation, with the “Mental Rotations Test” (MRT, Vandenberg & Kuse, 1978; Peters et al., 1995) inducing the largest male advantage. Objects similar to the cube figures of the MRT, like blocks, dominoes, cube puzzles, and LEGO material, are more frequently part of boys' environments (Kersh, Casey, & Mercer Young, 2008). Because of the gender difference in stimulus familiarity, boys are more likely to process such stimuli holistically (Bethell-Fox & Shepard, 1988), which might in turn support efficient mental rotation. Furthermore, cube figures might activate gender stereotypes of male superiority because they remind of male-stereotyped objects and thus lead to stereotype-threat effects. Results of a recent study with fourth graders suggest that gender-stereotyped stimuli indeed influence the gender difference in children's mental-rotation performance (Neuburger, Heuser, Jansen, & Quaiser-Pohl, 2012a). In addition to stimulus characteristics, dimensionality (picture-plane vs. in-depth rotations) might also contribute to the large male advantage in the MRT (cf. Neuburger et al., 2012a;

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Neuburger et al., 2011; Titze, Jansen, & Heil, 2010a; Voyer et al., 1995). However, there are only a few systematic studies concerning this issue, and therefore, it is not yet clear if the large male advantage in three-dimensional rotation tasks like the MRT is really due to rotational axis or if it simply reflects the higher difficulty (e.g. working memory demands) of such tasks. The present study investigated the effect of the rotational axis on fourth-grade boys' and girls' mental-rotation performance by comparing two mental-rotation tasks which required either picture-plane rotations or in-depth rotations of the Shepard and Metzler (1971) cube figures.

With regard to the underlying causes of the male advantage, there is some evidence for genetic and hormonal influences (e. g. Grimshaw, Sitarenios, & Finegan, 1995; Heil, Kavšek, Rolke, Beste, & Jansen, 2011) but pure biological explanations are not unequivocally supported by the data (Halari et al., 2005; Hines et al., 2003; Rahman, Wilson, & Abrahams, 2004). Moreover, socio-psychological and experiential factors have been demonstrated to influence mental-rotation performance: Task instructions that promote effort attributions or outline the role of stereotypes in explaining the gender difference can enhance mental-rotation performance (Moè, 2012; Moè & Pazzaglia, 2010), and self-confidence has been found to affect mental-rotation performance and to mediate the gender difference (Estes & Felker, 2012). In line with Nash's (1979) gender-role mediation hypothesis, a recent meta-analysis confirmed a positive relationship between masculinity and mental-rotation performance (Reilly & Neumann, 2013). Additionally, various spatial trainings have substantial effects on mental rotation (Uttal et al., 2013), and gender-related differences in spatial experience (e. g. Quaiser-Pohl, Geiser, & Lehmann, 2006; Cherney & London, 2006) are considered as a causal factor contributing to the male advantage. As outlined in current causal models, the multiple factors leading to the male advantage are best conceptualized in a psycho-bio-social framework integrating social, biological, and psychological influences, considering the complex interactions and covariations among the different variables (Halpern et al., 2007; Hausmann, Schoofs, Rosenthal, & Jordan, 2009).

1.2. Stereotype-threat and stereotype-lift effects on mental-rotation performance

Stereotype threat and stereotype lift comprise all of the three causal dimensions, i.e. they include social, biological, and psychological processes: Stereotypes are social phenomena, representing probabilistic beliefs about characteristics of males and females or "paired associations between gender categories and attributes" (Ruble & Martin, 1998, p. 940). Stereotype threat induces a physiological stress response and dysfunctional cognitive and affective processes (Schmader, Johns, & Forbes, 2008), while stereotype lift "may alleviate the self-doubt, anxiety, and fear of rejection that could otherwise hamper performance on important intellectual tests" (Walton & Cohen, 2003, p. 457). The psycho-bio-social nature of the effects of stereotype activation is also supported by the findings of Hausmann et al. (2009), suggesting that sex hormones mediate stereotype threat effects. The activation of stereotypes in a test situation can be implicit, e.g. by priming the stereotyped group identity or by emphasizing the evaluative or diagnostic nature of the test, or explicit, e.g. by indicating a group's inferiority in the test (Nguyen & Ryan, 2008).

Since working memory has been identified as an important mediator and moderator of stereotype threat (Beilock, Rydell, & McConnell, 2007; Schmader et al., 2008) and mental rotation strongly relies on working memory (Kaufman, 2007), it seems plausible to assume that stereotype threat influences girls' and women's mental-rotation performance — given that gender stereotypes in the domain of spatial ability actually exist.

Several studies demonstrate the influence of gender stereotype activation on *adults' and adolescents'* mental-rotation performance (Dunst, Benedek, Bergner, Athenstaedt, & Neubauer, 2013; Hausmann et al., 2009; Heil, Jansen, Quaiser-Pohl, & Neuburger, 2012; Miller, 2012; Moè, 2009; Moè & Pazzaglia, 2006; Sharps, Welton, & Price, 1993). And this effect of stereotypes was found in the results of MRT tests with children, too (cf. Nash, 1979; Neuburger, Ruthsatz, Jansen, Heil, & Quaiser-Pohl, 2013; Rammstedt & Rammsayer, 2001).

Although the male advantage is well documented to emerge before adolescence (e.g. Johnson & Meade, 1987; Titze et al., 2010a; Neuburger et al., 2011), stereotype threat and lift effects on *children*'s mental-rotation performance have rarely been examined, with the few existing studies reporting somewhat heterogeneous results: While Titze, Jansen, and Heil (2010b), who investigated fourth-graders, did not find any effects of gender-stereotype activation on the mental-rotation performance of boys and girls, Neuburger, Jansen, Heil, and Quaiser-Pohl (2012b) found that the gender difference in fourth-graders disappeared when task instruction explicitly outlined either a positive female stereotype or the equal ability of boys and girls. Similarly, in an implicit stereotype-threat paradigm, Huguet and Régner (2007) found that the performance of girls aged 11–13 years in a spatial memory task was impaired when the task was described as "geometry task" in contrast to "memory game"; interestingly, this stereotype-threat effect even occurred despite girls' counter-stereotypic beliefs (Huguet & Régner, 2009). Thus, there is evidence that both explicit and implicit stereotype activation can influence children's spatial performance. The present study aimed at complementing previous research by investigating the effect of implicit stereotype activation on the mental-rotation performance of fourth-graders. Similarly to Huguet and Régner (2007, 2009), gender stereotypes were activated by the task framing, which either outlined that the mental-rotation task measured spatial abilities or that it measured artistic abilities.

1.3. Design and hypotheses

The study examined the effects of implicit stereotype activation and rotational axis on the mental-rotation performance of fourth-grade girls and boys in a 2 (genders: boys vs. girls) × 2 (task framing: threatening vs. non-threatening) × 2 (rotational axis: in-depth vs. picture-plain rotations) between-subjects design. Gender stereotypes were activated by varying the information about the diagnostic purpose of the mental-rotation task (threatening condition: assessing spatial ability, non-threatening condition: assessing artistic ability). Rotational axis was varied by administering either a picture-plane version or an in-depth version of the mental-rotation task. In addition to children's mental-rotation performance, gender stereotypes with regard to mental rotation, spatial imagination, mathematics, and art were examined. On the basis of the results of Neuburger et al. (2013), it was expected that mental rotation would be male-stereotyped only by boys (Hypothesis 1) and that spatial imagery and mathematics would be female-stereotyped by both boys and girls (Hypotheses 2 and 3). With regard to art, no specific hypothesis was formulated because of the lack of previous research regarding children's gender stereotypes about art. Concerning mental-rotation performance, it was expected that both gender-stereotype activation and rotational axis would influence the gender effect: In contrast to the non-threatening task framing, the threatening framing should induce stereotype-threat effects in girls and stereotype-lift effects in boys; therefore, the threatening framing was expected to result in a larger male advantage than the non-threatening framing (Hypothesis 4). Furthermore, in-depth rotations were expected to result in a larger male advantage than picture-plane rotations (Hypothesis 5).

2. Material and methods

2.1. Participants

Participants were recruited from German public schools and randomly assigned to the four experimental conditions by the experimenter. 272