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Cars or dolls? Influence of the stereotyped nature of the items on children's mental-rotation performance

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ABSTRACT

This study inquired the influence of stimulus features on children's mental-rotation performance with novel gender-stereotyped test versions (M-MRT and F-MRT) administered to 290 elementary-school children (147 second graders and 143 fourth graders; age: M = 8.87, SD = 1.09). No significant gender difference and no significant interaction of gender and stimulus type could be demonstrated. Multiple regression revealed that mental-rotation performance was predicted by perceptual speed and stimulus type (female or male stereotyped) but not by the perceived stereotyped nature or the perceived familiarity of the stimuli. As expected the objects used in the M-MRT were more familiar to boys than to girls, while the objects used in the F-MRT were more familiar to girls than to boys. Furthermore, the cube figures (based on Shepard & Metzler, 1971) were perceived as more male stereotyped. Overall, findings suggest that stimulus attributes influence mental-rotation performance. Results can be discussed with regard to the influence of the stimulus characteristics of Shepard and Metzler's cube figures on the large gender differences in tests in which these figures are used.

1. Introduction

Mental rotation is defined as the fast and accurate rotation of two- or three-dimensional objects in mind (Linn & Petersen, 1985) and it is the component of spatial abilities for which the most pervasive gender differences are found (Voyer, Voyer, & Bryden, 1995). With regard to age groups older than ten years, male subjects consistently outscore female subjects (e.g. Linn & Petersen, 1985; Neuburger, Jansen, Heil, & Quaiser-Pohl, 2011). However, the question at what age gender differences in mental rotation emerge is still controversially discussed. Furthermore, results seem to depend on the test used as the measuring instrument (Voyer et al., 1995). Mixed results have a lot to commend that next to biological agents, socio-cultural factors play an important role in spatial ability development.

1.1. Influence of psychobiosocial factors

Studies with infants and neuropsychological research indicate that specific genes (Bock & Kolakowski, 1973; Pezaris & Casey, 1991; Quinn & Liben, 2013) and gender hormone levels (Alexander & Son, 2007; Hausmann, Slabbekorn, Van Goosen, Cohen-Kettenis, & Güntürkün, 2000; Hausmann, Schoofs, Rosenthal, & Jordan, 2009) contribute to gender differences favoring males. At the same time, the malleability of spatial abilities is well demonstrated (Uttal et al., 2012), and the influence of experiential variables, e.g. spatial activities and the parental use of spatial language, on mental-rotation performance has been proofed in plenty surveys in adults (Nazareth, Herrera, & Pruden, 2013; Baenninger & Newcombe, 1989) and in children (Quaiser-Pohl, Geiser, & Lehmann, 2005; Casasola, 2008). Furthermore, patrilineal versus matrilineal society structures (Hoffman, Gneezy, & List, 2011), socio-economic status (Levine, Vasilyeva, Lourenco, Newcombe, & Huttenlocher, 2005), gender-role socialization (Neuburger, Ruthsatz, Jansen, Heil, & Quaiser-Pohl, 2013; Reilly & Neumann, 2013; Saucier, McCreary, & Saxberg, 2002), and socio-cognitive factors, e.g. stereotypes (Moé, 2009) and participants' confidence (Estes & Felker, 2012; Cooke-Simpson & Voyer, 2007), have been found to affect gender differences in mental-rotation performance. Especially the fear of confirming an existing negative stereotype can have detrimental effects on mental-rotation performance (e.g. Moé & Pazzaglia, 2006). It has impressively been demonstrated that instructions, e.g. stressing causal attributions to effort or ability, can influence males' and females' accomplishment (Moé & Pazzaglia, 2010) and might induce stereotype threat or lift effects in adolescents. Moé (2012) showed that externalizing factors for gender differences, e.g. by explicitly stressing that common hold gender stereotypes are the source of female underachievement, can lead to an improvement of womens' performances. But already from the very beginning of the occurrence of gender differences, stereotype threat effects have been demonstrated: With fourth graders, an instruction that explicitly reduces stereotypes by outlining the equal skills of boys and girls has been found to completely eliminate gender differences

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in spatial performance (Neuburger, Jansen, Heil, & Quaiser-Pohl, 2012). For the same age group, the male advantage could be reduced by describing a mental-rotation task as diagnostic for artistic instead of mathematic abilities (Neuburger, Ruthsatz, Jansen, & Quaiser-Pohl, 2013). Interestingly, even without explicitly or implicitly activating gender stereotypes, a spatial activity itself can lead to feelings of nervousness and worsen achievement: Ramirez, Gunderson, Levine, and Beilock (2012) found spatial anxiety to be aligned with lower accuracy levels in mental-rotation performance among seven-year-old girls with high working memory. Since working memory plays an important role in stereotype threat processes (Schmader, Johns, & Forbes, 2008), this result shows that spatial tests in general are in danger of inducing stereotype threat effects, impairing females' working memory capacity. In this context, motivational and attentional processes play an important role. Already young children tend to show a higher attention to gender-congruent information and consequently more interest in own-gender activities (Martin & Ruble, 2004). Hence, independent from possibly underlying stereotype threat or lift effects, childrens' gender identity can lead to an increased motivation to do well in tasks which are perceived to be relevant to their own sex. Moreover, as larger gender differences in mental rotation are found when the test is given under strict time limits (Voyer, 2011), confidence and time limitation are also discussed as factors increasing the gender effect (Voyer, 2011; Goldstein, Haldane, & Mitchell, 1990).

1.2. Influence of task features

In a meta-analysis of 286 effect sizes of studies with various age groups the “Mental Rotation Test” (MRT) was found to induce the largest gender effect in mental-rotation ability with an effect size of $d = 0.67$ (Voyer et al., 1995). The original MRT consists of 24 items showing one target and four comparisons (two rotated versions of the target and two distractors). The stimuli are rotated cube figures invented by Shepard and Metzler (1971), and the distractors are either mirrored versions of the target or strucurally different cube figures. Some of the items contain comparisons in which parts of the figures are fully or partially occluded as a result of the rotation in three-dimensional space. The two rotated versions of the target have to be crossed out to solve the item. Participants are given six minutes (with a short break after three minutes) to solve as many items as possible. Specific features of the MRT might account for the robust and large gender differences on the MRT. One aspect are the occluded items mentioned above, because men were found to outscore women more on those items than on non-occluded items (Voyer & Hou, 2006; Bors & Vigneau, 2011). A second aspect concerns the items in which the distractors are mirrored versions of the target, since a higher male advantage has been demonstrated for such items (Bors & Vigneau, 2011). The present study took a closer look at the stereotypicality of the stimuli as characteristic of the MRT.

1.2.1. Influence of gender-related stimulus attributes

Previous studies compared performance in mental-rotation tasks with cube figures versus human figures and found the magnitude of gender differences to be significantly shortened in the human-figure condition (Doyle & Voyer, 2013; Alexander & Evardone, 2008). Even more interesting was the closer examination of the human-figure effects: in Alexander and Evardone's (2008) analyses, women achieved better scores for both male and female figure items, but men's perfomance did not differ from the cube-figure condition when stimuli were female figures. Doyle and Voyer (2013) couldn't confirm these findings. In their study, performance declined among both men and women when mentally rotating human figures compared to cube figures. However, this discrepance might be due to differences in the stimulus material and the fact that the gender of Doyle and Voyer's (2013) human figures didn't become that apparent. Nonetheless, these findings suggest that stimulus attributes, e.g. complexity, meaning and familiarity, influence mental-rotation performance and thus might contribute to the large gender effect in the MRT. The cube figures of the MRT are quite similar to LEGO® bricks, dominos or other objects used in building and construction toys, which are more frequently part of boys' realm of experience (Kersh, Casey, & Mercer Young, 2008), stereotyped to be preferred more by boys than by girls (Neuburger, Ruthsatz, Jansen, Heil, et al., 2013), and in which (e.g. ability to play with LEGO®) boys are stereotyped to achieve better results by male and female german fourth graders (Ruthsatz, Neuburger, Jansen, & Quaiser-Pohl, 2014). In line with Alexander and Evardone's (2008) assumption that gender differences in the degree to which stimuli are self-referent might impact differences in performance, the stereotyped nature of Shepard and Metzler`s cube figures possibly leads to an improvement of boys because they resemble stereotypically male objects. Since Bethell-Fox and Shepard (1988) demonstrated that more familiar stimuli are more likely to be holistically processed, the result that females more often use analytic strategies in the MRT (Geiser, Lehmann, Corth, & Eid, 2008; Janssen & Geiser, 2010) might be a consequence of gender differences in stimulus familiarity. However, Bethell-Fox and Shepard's results should be considered carefully, as Smith and Dror (2001, p. 739) already raised concerns that “Bethell-Fox and Shepard achieved familiarity through exposure to the stimuli in the context of the rotation task. Familiarity with the rotation task itself, therefore, could be different from familiarity with the stimuli per se.” Furthermore, cube figures might invoke gender stereotypes of male advantage because they remind of male-stereotyped objects and thus lead to stereotype threat effects in girls and stereotype lift effects in boys as described above. Consequently, Neuburger, Heuser, Jansen, and Quaiser-Pohl (2012) examined the effects of gender-stereotyped stimulus material on children's mental-rotation performance, but the direction of the interaction between gender and stimulus material did not confirm the expected effects of stimulus stereotypicality. Unexpectedly, girls slightly outperformed boys in the “male”-stimuli condition. However, the study is limited by some constraints. Results might be due to the higher visual complexity of the male stimuli compaired to the female stimuli and further uncontrolled confounding variables, e.g. representativity of the sample (all subjects were students from a natural-scientific secondary school) and the within-subject design (possible sequence effects).

1.3. Aims and hypotheses

The current study aimed at elaborating the findings of the pilot study of Neuburger, Heuser, et al. (2012). By selecting only the reliable items and by adapting them regarding complexity and familiarity, the limitations of the pilot study were considered. Therefore, two novel rotation tasks were developed by revising the test items of the pilot study: the *Male-Mental-Rotation-Test* (M-MRT) and the *Female-Mental-Rotation-Test* (F-MRT). The majority of the original items was modeled on a selection of stimuli from the standardized set of pictures from Snodgrass and Vanderwart (1980). Stimuli that were not familiar to boys or girls in the expected way as well as not reliable test items were replaced by new items. Additionally, the complexity of the male and female stereotyped stimuli was adapted. This revision was firstly based on several interviews with children, in which they were asked to assess the levels of difficulty and the degree of familiarity. Secondly, it was based on the assessment of the authors and the graphic designer, and thirdly on the reliability analyses of the results of pre-tests with fourth graders. None of the original items stayed unchanged, while they all were at least modified in their levels of complexity or familiarity (see Fig. 1 for instance).

The two test versions were created to systematically investigate the influence of gender-stereotypical stimuli and rotational axis on the gender difference in mental-rotation performance. Since mental rotation ability develops in elementary-school age and a male superiority in psychometric mental-rotation tasks is consistently found from this age onwards, second and fourth graders were chosen as sample. A time limit was set from three minutes to five minutes to achieve a better