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Interactive effects of sex hormones and gender stereotypes on cognitive sex differences—A psychobiosocial approach

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Summary Biological and social factors have been shown to affect cognitive sex differences. For example, several studies have found that sex hormones have activating effects on sex-sensitive tasks. On the other hand, it has been shown that gender stereotypes can influence the cognitive performance of (gender-) stereotyped individuals. However, few studies have investigated the combined effects of both factors. The present study investigated the interaction between sex hormones and gender stereotypes within a psychobiosocial approach. One hundred and fourteen participants (59 women) performed a battery of sex-sensitive cognitive tasks, including mental rotation, verbal fluency, and perceptual speed. Saliva samples were taken immediately after cognitive testing. Levels of testosterone (T) were analysed using chemiluminescence immunoassay (LIA). To activate gender stereotypes, a questionnaire was applied to the experimental group that referred to the cognitive tasks used. The control group received an identical questionnaire but with a gender-neutral content. As expected, significant sex differences favouring males and females appeared for mental rotation and verbal fluency tasks, respectively. The results revealed no sex difference in perceptual speed. The male superiority in the Revised Vandenberg and Kuse Mental Rotations Tests (MRT-3D) was mainly driven by the stereotype-active group. No significant sex difference in MRT-3D appeared in the control group. The MRT-3D was also the task in which a strong gender-stereotype favouring males was present for both males and females. Interestingly, T levels of the stereotype-activated group were 60% higher than that of male controls. The results suggest that sex hormones mediate the effects of gender stereotypes on specific cognitive abilities.

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1. Introduction

Sex differences in specific cognitive abilities are well documented (Maccoby and Jacklin, 1974; Kimura, 1999; Halpern, 2000; Hines, 2004; Hausmann, 2007). Although performances of the sexes overlap to a large degree (McKeever, 1995), women tend to outperform men in specific aspects of verbal ability (McGlone, 1980; Halpern, 2000), whereas men achieve higher scores on some visuospatial tasks (Witkin et al., 1962; McGee, 1979; Hyde, 1981; Voyer et al., 1995; Halpern, 1996).

Several meta-analyses indicate that sex differences in spatial abilities exist and are robust (Tapley and Bryden, 1977; Linn and Petersen, 1985; Voyer et al., 1995; Silverman et al., 1996, see e.g. Halpern, 2000; Hines, 2004; Hausmann, 2007, for a review). Most particularly, the redrawn Vandenberg and Kuse mental rotation test (MRT-3D; Vandenberg and Kuse, 1978; Peters et al., 1995b), which uses 3D cube figures designed by Shepard and Metzler (1971), appears to produce the most reliable sex difference of all spatial paper-pencil tests (Voyer et al., 1995). To perform the MRT-3D, the individual must imagine a cube stimuli revolving in 3D space (Collins and Kimura, 1997). The male advantage in mental rotation decreases with picture plane rotations in 2D space. The meta-analysis of Voyer et al. (1995) showed that, on average, males outperform females in mental rotation by about 0.6 S.D. units but only by 0.2 S.D. units for the spatial visualization category including, for example, the Hidden Figures Test (Ekstrom et al., 1976), in which participants must find a simple figure embedded within a complex pattern (Voyer et al., 1995). Probably, however, 3D processes are not a prerequisite for large gender differences. Collins and Kimura (1997) found a similar male advantage when task difficulty was increased for a 2D mental rotation test.

Sex differences in spatial abilities, and some other cognitive tests, arise at least in part because of the influence of sex hormones. Several studies suggest that gonadal hormones affect spatial abilities during early phases of development (e.g. Williams and Meck, 1991; Christiansen, 1993). For example, it has been shown that participants with congenital adrenal hyperplasia (CAH), a genetic condition that causes an overproduction of adrenal androgens, revealed enhanced performance on some spatial tasks (Perlman, 1973; Resnick et al., 1986; Hampson et al., 1998). However, a well-designed CAH study (Hines et al., 2003) did not find that females with CAH performed better than unaffected females on mental rotation. Mental rotation performance in men with CAH was even impaired. The authors concluded that this outcome is not consistent with the hypothesis that prenatal androgen exposure enhances mental rotation performance.

Other studies suggest activating influences of sex hormones on cognitive abilities which persist throughout the whole lifetime (Gouchie and Kimura, 1991; Van Goozen et al., 1994; Kimura, 1996; Slabbekoorn et al., 1999). Both organizing and activating studies generally show a decrease in spatial abilities with increased estrogen levels, consistent with observed sex differences. Moreover, it has been found that levels of testosterone (T) within the normal adult-male range are accompanied by the male advantage on spatial tasks. However, not all studies found activating effects as a result of hormone administration (Alexander et al., 1998; Liben et al., 2002). For example, Liben et al. (2002) investigated adolescents receiving hormonal treatment for delayed puberty and found that that T and E replacements did not affect spatial performance, although spatial performance showed the typical sex difference. Moreover, inconsistent findings about the relationship between current T levels and performance on spatial tasks for males do exist. Yang et al. (2007) reviewed studies assessing the relationship between mental rotation performance and T in normal men and found evidence for positive (Gordon and Lee, 1986; Silverman et al., 1999; Hooven et al., 2004), negative (Moffat and Hampson, 1996), and no relationship (Gouchie and Kimura, 1991; Kampen and Sherwin, 1996; Alexander et al., 1998; Halari et al., 2005; Falter et al., 2006; Burkitt et al., 2007). Yang et al. (2007) point out that these inconsistencies might partly result from methodological limitations and differences between studies, such as limited accuracy in hormone assays, reliance on free saliva or plasma total T levels, different measures of spatial ability, small sample sizes, presence of female investigators, etc. Similar inconsistencies were also reported for studies including women. Aleman et al. (2004) found that a single administration of T led to an improved performance in the paper-pencil version of the MRT-3D, whereas Burkitt et al. (2007) failed to show any relationship between salivary T levels and MRT-3D performance in women (and men) but reported a positive relationship between T levels and performance on a virtual water maze in women (only).

Other studies investigated the relationship between sex hormones and cognitive abilities in normally cycling women during the menstrual cycle (Gordon et al., 1986; Hampson, 1990a,b; Gordon and Lee, 1993; Epting and Overman, 1998; Hausmann et al., 2000; Mumenthaler et al., 2001; Rosenberg and Park, 2002). However, the relationship between sex hormone levels and cognitive performance in normally cycling women also revealed conflicting results. For example, Hausmann et al. (2000) found cycle-related difference in MRT-3D, with higher scores during the menstrual phase than during the midluteal phase. In this study, MRT-3D performance was positively and negatively related to T and E levels, respectively. This finding has been supported by Maki et al. (2002) who also found higher MRT-3D scores during the menses than midluteal phase, and E levels to be negatively related to MRT-3D performance. Additionally, they found a positive relationship between E levels and verbal fluency (Maki et al., 2002). However, menstrual cycle-related fluctuations in cognitive abilities were not always found (e.g. Gordon and Lee, 1993; Epting and Overman, 1998; Rosenberg and Park, 2002), although typical cognitive sex differences have been confirmed (e.g. Epting and Overman, 1998).

Athough several inconsistencies exist, previous research suggests that levels of sex hormones, and T and E, in particular, are related to cognitive sex differences. Besides biological/hormonal explanations for cognitive sex differences, studies focusing on socio-cultural factors suggest that gender-stereotypes are also strongly related to cognitive sex differences. Of relevance here is research examining stereotype threat (Steele and Aronson, 1995). Stereotype threat can be defined as the fear of conforming to a negative stereotype associated with one's group membership, which paradoxically results in the individual behaving in line with the stereotype. While the original research examined this effect for African Americans and the stereotype of intellectual ability, the effect has been