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Blocks and bodies: Sex differences in a novel version of the Mental Rotations Test

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Abstract

A novel version of the Mental Rotations Test (MRT) that alternated the standard block figures with three-dimensional human figures was administered to 99 men and 129 women. Women and men differed predictably in their retrospective reports of childhood play and digit ratios, a putative measure of prenatal androgen action. Compared to the block figure items, human figure items on the modified MRT were associated with an improvement in performance in both sexes. However, consistent with the study hypothesis, the enhancing effect of the human figure condition on performance as measured by conventional scores was smaller in men compared to women and not at all evident in men when performance was measured by ratio scores. A closer inspection of the human figures effects on test scores showed performance in women improved for both male and female figure items. In contrast, relative to scores on block figure items, performance in men improved when stimuli were male figures but did not improve when stimuli were female figures. These results add to the evidence that the magnitude of sex differences in scores on the MRT may vary according to the test content and item properties. The findings suggest that online measures of cognitive processing in response to different classes of test stimuli (e.g., animate vs. inanimate objects, self-relevant vs. neutral stimuli) may prove useful in research aimed at understanding the hormonal and social factors contributing to the sex difference in performance on the MRT.

Keywords: Sex differences; Mental rotation; Human figures; Digit ratios

Introduction

Converging evidence from research on human and nonhuman animal species suggests that behaviors showing large sex differences are sensitive to hormonal influences (Alexander and Peterson, 2001; Cohen-Bendahan et al., 2005; Collaer and Hines, 1995). Therefore, research on human sex differences and their association to hormonal factors has often included the Mental Rotations Test (MRT) (Vandenberg and Kuse, 1978), a task that shows a robust male advantage in test scores (Voyer et al., 1995). The MRT measures how well individuals match objects that differ in their spatial orientation and, like all matching tasks, this multi-step cognitive process includes perceptual and decision making components (Parsons, 2003). Additionally, findings that reaction times and error rates increase with increasing angular differences between objects have indicated that comparisons are made after mentally rotating internal representations of objects to the same orientations (Shepard and Metzler, 1971). Results from research measuring brain activation (Hugdahl et al., 2006; Jordan et al., 2002) and patterns of visual attention (Alexander and Son, 2007) during task performance have suggested that this process differs between men and women, such that men may generally manipulate holistic representations (i.e., a mental image of the object is constructed and then rotated), whereas women may generally manipulate component part representations (i.e., they may focus on comparing object parts). Holistic representations correspond to a single unit that can be manipulated in the mind. However, piecemeal representations are perceived relations among multiple units or parts that must be preserved during spatial transformations. Therefore, compared to holistic representations, piecemeal representations are more difficult to sustain as angular differences between objects increase (for a discussion, see Amorim et al., 2006), consistent with the higher MRT error rates in women compared to men.

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Interestingly, the type of stimuli that must be represented mentally in these tasks appears to influence the variable magnitude of sex differences observed across measures (Voyer et al., 1995). For example, the MRT that uses three-dimensional block figures shows a large sex difference (Voyer et al., 1995), as does a similar test using two-dimensional abstract shapes (Collins and Kimura, 1997). In contrast, other tests such as those depicting two-dimensional panda bears (Grimshaw et al., 1995) or two-dimensional facial profiles (Merriman et al., 1985) do not. Tasks using abstract shapes or figures as test stimuli may yield large sex differences because, compared to meaningful stimuli, constructing and maintaining mental representations of abstract shapes are a more difficult task. It may also be significant in understanding the large sex differences in error rates on the MRT that experience or familiarity with stimuli increases the likelihood that holistic representations of such stimuli are constructed (Bethell-Fox and Shepard, 1988). As male-typical play includes stronger preferences for blocks and construction toys (Alexander and Hines, 1994), we hypothesized that the MRT may afford an advantage to men because male-typical play provides greater familiarity or comfort with figures constructed by cubes or blocks and so promotes the use of holistic strategies that facilitate task performance.

This proposed relationship between play experiences and scores on the MRT differs from the suggestion that the boys' higher level of experience with object manipulation, movement and construction (Sherman, 1967; Tracy, 1987) supports sex-linked cognitive strategies or brain processes that explain the persistent male advantage in spatial ability (Linn and Petersen, 1974; Maccoby and Jacklin, 1974; Voyer et al., 1995). The general understanding of that association between play and spatial ability is that the high spatial content of male-typical play facilitates the development of the general ability to perform spatial transformations (Voyer et al., 2000). However, both male-typical play and female-typical play include spatial manipulation of objects and the relevant spatial content of female-typical play styles (e.g., dressing dolls) is supported by findings that damage to brain parietal areas results in dressing difficulties as a function of deficits in mental rotation ability (Fitzgerald et al., 2002; Yamazaki et al., 2001). Thus, we reasoned that male-typical play may enhance the mental rotation of replicas of inanimate objects such as vehicles and blocks, whereas female-typical toy play, such as dressing dolls, may enhance the mental rotation of animate forms or body parts.

The goal of the present investigation was to examine sex differences in scores on a novel test of mental rotation ability using three-dimensional human figures. Importantly, recent researchers (Amorim et al., 2006) have established that matching three-dimensional human figures with different spatial configurations involves mental rotation, as indicated by an increase in reaction times and error rates with angular disparity between the human figures. As well-established body schemas in adults serve as a strong reference that promotes holistic mental rotation strategies (Amorim et al., 2006), we expected that scores in both sexes may be higher in the test of mental rotation ability using human figures relative to the test using block figures. However, in view of the evidence that males appear more likely than women to employ a holistic strategy in the typical MRT using block figures (Alexander and Son, 2007; Hugdahl et al., 2006), we hypothesized that the effect of human figures on scores would be larger in women compared to men.

Methods

Participants

Ninety-nine men (mean age = 19.67 years, SD = 1.87) and 129 women (mean age = 19.69 years, SD = 1.42) between 18 and 25 years of age were recruited from Introductory Psychology courses at Texas A&M University. Participants were tested during the months of October and November in eight separate group sessions of up to 30 people. All women and men provided informed consent and received partial credit towards a course requirement.

Measures

Subject characteristics

The Extended Range Vocabulary Test (Ekstrom et al., 1976) was included as a control measure of general cognitive ability that does not show a sex difference. The measure loads strongly on factors identified as indicating crystallized intelligence (e.g., Rossman and Horn, 1972), has good reliability (0.76 = 0.89) (Ekstrom et al., 1976), and is used widely in research on sex differences in cognitive abilities to support the specificity of any sex differences in task performance (e.g., Alexander et al., 1998; Chipman and Hampson, 2006; Choi et al., 2006; Miles et al., 2006).

The ratio of the lengths of the second and fourth digits of the right hand (2D:4D) and the Pre-School Activities Inventory (PSAI; Golombok and Rust, 1993) were included as measures of characteristics that typically differ between the sexes to support the representational nature of the sample. The 2D:4D ratio is a sexually dimorphic trait that some evidence suggests is a direct correlate of prenatal sex steroid levels (Lutchmaya et al., 2004; Manning et al., 1998), such that smaller ratios are correlated with higher androgen levels. However, a recent proposal is that digit ratios may be better described as a measure of perinatal androgen action (McIntyre, 2006), consistent with findings that smaller digit ratios are associated with androgen receptor alleles showing fewer terminal domain CAG repeats, a marker of greater androgen sensitivity (Manning et al., 2003). In this research, the 2D:4D ratio was calculated by obtaining a digital photo scan of the participant's right hand. Color images of hands were later used to measure the distance in millimeters from the basal crease to the tip of the second and fourth fingers with digital vernier calipers. Two independent judges coded finger lengths for each hand copy. Consistent with the findings of previous research using this method of assessment (Alexander, 2006; McIntyre, 2006), measurements averaged across the two judges showed excellent inter-rater reliability (rs > .95).

The PSAI is a 24-item questionnaire measuring sex-linked childhood play preferences, including toys, activities, and characteristics. The PSAI shows that moderate test–retest reliability (r = .62 = r = .66) and PSAI scores in children correlate moderately with teacher ratings of behavior (boys = r = .37, girls = r = .48) (Golombok and Rust, 1993). When used with adults (Alexander, 2006; Hines et al., 2004), the sex difference in recalled childhood preferences is very large (d = 2.65–3.25).

Dancing aggies: a modified Mental Rotations Test

The redrawn Vandenberg and Kuse (1978) Mental Rotations Test (MRT-1; Peters et al., 1995) consists of 24 items depicting a target and four alternatives (two correct and two distracters). The modified task consisted of 12 original test items alternating with 12 test items depicting human figures, such that items 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, and 23 were the modified human figure items and items 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, and 24 corresponded to the original task items of the same number. The 12 human figure items, constructed using Autodesk Maya 6.5 software, depicted three-dimensional men (items 1, 5, 9, 13, 17, and 21) and women (items 3, 7, 11, 15, 19, and 23) dressed in identical T-shirts and pants. Items from the original task were used as templates for the spatial orientation of the figure in three-dimensional space and for the serial positioning of correct items and distracters. Like the MRT block figure items, human figure items included occlusions of some features (see Fig. 1), a test item characteristic