Published in final edited form as:
Psychol Sci. 2010 August ; 21(8): 1069–1071. doi:10.1177/0956797610376075.

Having a Male Co-Twin Masculinizes Mental Rotation Performance in Females

Eero Vuoksimaa[1], **Jaakko Kaprio**[1,2,3], **William S. Kremen**[4,5], **Laura Hokkanen**[6], **Richard J. Viken**[7], **Annamari Tuulio-Henriksson**[2,6], and **Richard J. Rose**[1,7]

[1]Department of Public Health, University of Helsinki [2]Department of Mental Health and Substance Abuse Services, National Institute for Health and Welfare, Helsinki, Finland [3]Institute for Molecular Medicine, University of Helsinki [4]Department of Psychiatry, University of California, San Diego [5]VA San Diego Healthcare System, San Diego, California [6]Department of Psychology, University of Helsinki [7]Department of Psychological and Brain Sciences, Indiana University, Bloomington

Probably the most robust cognitive sex difference is that, on average, males outperform females in tests of mental rotation ability (Voyer, Voyer, & Bryden, 1995). This sex difference is evident across many different cultures (Silverman, Choi, & Peters, 2007), and it appears early in infancy, at 3 to 5 months of age (Moore & Johnson, 2008; Quinn & Liben, 2008).

Studies have suggested that elevated levels of fluctuating testosterone are associated with better spatial abilities among females, whereas in males, lower fluctuating testosterone levels relate to better spatial abilities (Gouchie & Kimura, 1991; Moffat & Hampson, 1996). In persons with congenital adrenal hyperplasia, which usually affects the production of sex steroids, the organizational effects of elevated prenatal testosterone may account for improved spatial test performance in females and impaired spatial test performance in males (Puts, McDaniel, Jordan, & Breedlove, 2008). Moreover, a positive relationship between mental rotation test (MRT) performance and prenatal testosterone has been reported in healthy girls (Grimshaw, Sitarenios, & Finegan, 1995).

Animal studies have shown that female fetuses located adjacent to male fetuses in the uterus can be masculinized through prenatal exposure to testosterone (Ryan & Vandenbergh, 2002). In humans, prenatal masculinization can be studied by comparing female twins from opposite-sex twin pairs with female twins from same-sex pairs. Sisters of twin brothers have been reported to be masculinized in physiological traits, including maternal fitness (Lummaa, Pettay, & Russell, 2007) and second-to-fourth-finger ratio (van Anders, Vernon,

Corresponding Author: Eero Vuoksimaa, Department of Public Health, P.O. Box 41 (Mannerheimintie 172), 00014 University of Helsinki, Helsinki, Finland. eero.vuoksimaa@helsinki.fi.

Declaration of Conflicting Interests
The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

& Wilbur, 2006), but other studies have not demonstrated the same results (Medland, Loehlin, & Martin, 2008; Medland, Loehlin, Willemsen, et al., 2008). One commonly cited study concerns mental rotation ability in female twins from opposite- and same-sex pairs (Cole-Harding, Morstad, & Wilson, 1988); however, this study was published only as a meeting abstract.

In the study reported here, we assessed masculinization effects on MRT performance among female twins with male co-twins by comparing their performance with that of female twins with female co-twins. We also investigated whether or not there are differences in MRT performance between males with female co-twins and males with male co-twins.

Method

We studied MRT performance in 804 twins (mean age = 22.39 years, *SD* = 0.62) from the population-based FinnTwin12 study (Kaprio, Pulkkinen, & Rose, 2002). There were 351 females from same-sex pairs, 223 males from same-sex pairs, 120 females from opposite-sex pairs, and 110 males from opposite-sex pairs. Subjects gave written informed consent for their participation. The study protocol was approved by the Ethical Committee of Helsinki and Uusimaa Hospital District and by the institutional review board of Indiana University, Bloomington.

We used a redrawn version of the Vandenberg and Kuse MRT with a 3-min time limit for each of the two parts (Peters et al., 1995); both parts consisted of 12 trials. On each trial, the task was to mark the two figures (out of four) that matched the target figure by mentally rotating the figures through the vertical axis. Subjects received 1 point for each trial on which they marked both correct alternatives. The possible total score ranged from 0 to 24.

Results

The mean scores (with 95% confidence intervals, or CIs, in parentheses) for different twin groups were as follows (see Fig. 1): $M = 9.01$ (95% CI = 8.50, 9.53; $N = 351$) for female twins from same-sex pairs; $M = 10.26$ (95% CI = 9.53, 10.99; $N = 120$) for female twins from opposite-sex pairs; $M = 12.87$ (95% CI = 12.17, 13.56; $N = 223$) for male twins from same-sex pairs; and $M = 13.74$ (95% CI = 12.76, 14.71; $N = 110$) for male twins from opposite-sex pairs. The group of female twins from same-sex pairs included females from monozygotic pairs ($M = 9.02$, 95% CI = 8.33, 9.72) and same-sex dizygotic pairs ($M = 9.00$, 95% CI = 8.22, 9.78); there was no significant difference ($p = .96$) in the means of these two groups of females with same-sex co-twins. The group of male twins from same-sex pairs included males from monozygotic pairs ($M = 12.29$, 95% CI = 11.25, 13.33) and same-sex dizygotic pairs ($M = 13.43$, 95% CI = 12.50, 14.35); there was no significant difference ($p = .11$) in the means of these two groups of males with same-sex co-twins.

Male twins from same-sex pairs performed significantly better than female twins from same-sex pairs, $F(1, 309) = 75.66$, $p < .0001$, $d = 0.87$. Among females, twins from opposite-sex pairs performed significantly better than twins from same-sex pairs, $F(1, 302) = 7.45$, $p < .01$, $d = 0.30$, whereas among males, the better performance of twins from opposite-sex pairs was not statistically significant, $F(1, 236) = 2.03$, $p = .16$, $d = 0.18$. The better performance of females with a twin brother relative to females with a twin sister was similar when we excluded monozygotic female twins from the comparison, $F(1, 197) = 5.34$, $p = .022$, $d = 0.30$. Within opposite-sex pairs, males performed significantly better than females, $F(1, 135) = 46.10$, $p < .0001$, $d = 0.74$.

In a regression analysis, the superior MRT performance of female twins from opposite-sex pairs compared with female twins from same-sex pairs remained statistically significant, $b = 1.31$, $p = .006$, after controlling for age, birth weight, gestational age, mother's age at the twins' birth, and computer-game experience. Greater gestational age was associated with better MRT performance in females, $b = 0.19$, $p = .044$.

Discussion

In a sample of individual twins, we replicated the sex difference in MRT performance previously observed in singletons (Silverman et al., 2007). We also found that females with male co-twins outperformed females with female co-twins.

Our results are consistent with the prenatal masculinization hypothesis, according to which masculinization occurs in females with male co-twins as a result of intrauterine exposure to testosterone. Our finding does not necessarily contradict earlier negative findings of prenatal masculinization in other traits, because timing of sex-related differentiation is trait-specific: For example, spatial ability probably differentiates after second-to-fourth-finger ratio, and these two traits show no association with one another in females (Puts et al., 2008).

The alternative socialization explanation for our result is that females with twin brothers are exposed to different sex-typed activities than are females with twin sisters and are thus masculinized in their mental rotation ability. For example, a previous study showed that short-term training in action video games reduced the gender difference in MRT performance (Feng, Spence, & Pratt, 2007). However, computer-game playing, a possible indicator of practice effects, had a trivial association to MRT performance in our study, and this suggests that our results are not explained fully by the possible tendency of sisters of twin brothers to engage in more male-typical activity than other females do.

The effect of having a male co-twin on females' MRT performance remained even when we controlled for pregnancy-related variables and compared only dizygotic twins. This supports the inference that our results were not caused by differences related to monozygotic and dizygotic twinning. Interestingly, gestational age was associated with MRT performance only in females. Because this measure relates to prenatal development, this result may suggest that prenatal events affect mental rotation ability differently in females and males.

Finally, our results may reflect both prenatal hormonal and postnatal environmental factors, and these factors may be inextricably linked: Prenatal exposure to testosterone may subtly masculinize females, with the result that these girls may gravitate toward male-typical activities that enhance mental rotation ability.

Acknowledgments

We thank the participating twins, the testers, and Michael Peters for providing the redrawn version of the mental rotation test we used in our study.

Funding

This research was supported by the National Institute of Alcohol Abuse and Alcoholism (Grants AA-12502, AA-00145, and AA-09203 to R.J.R.), the Academy of Finland (Grants 100499, 205585, and 118555 to J.K.; Grant 131332 to A.T.-H.), and the Academy of Finland Centre of Excellence in Complex Disease Genetics. E.V. was supported by the Finnish Cultural Foundation (Helvi and Arvo Lehtovaara Fund) and the Helsinki University Jubilee Fund.

References

Cole-Harding S, Morstad AL, Wilson JR. Spatial ability in members of opposite-sex twin pairs. Behavior Genetics Abstracts. 1988; 18:710.

Feng J, Spence I, Pratt J. Playing an action video game reduces gender differences in spatial cognition. Psychological Science. 2007; 18:850–855. [PubMed: 17894600]

Gouchie C, Kimura D. The relationship between testosterone levels and cognitive ability patterns. Psychoneuroendocrinology. 1991; 16:323–334. [PubMed: 1745699]

Grimshaw GM, Sitarenios G, Finegan JA. Mental rotation at 7 years: Relations with prenatal testosterone levels and spatial play experiences. Brain and Cognition. 1995; 29:85–100. [PubMed: 8845125]

Kaprio J, Pulkkinen L, Rose RJ. Genetic and environmental factors in health-related behaviors: Studies on Finnish twins and twin families. Twin Research. 2002; 5:366–371. [PubMed: 12537860]

Lummaa V, Pettay JE, Russell AF. Male twins reduce fitness of female co-twins in humans. Proceedings of the National Academy of Sciences, USA. 2007; 104:10915–10920.

Medland SE, Loehlin JC, Martin NG. No effects of prenatal hormone transfer on digit ratio in a large sample of same- and opposite-sex dizygotic twins. Personality and Individual Differences. 2008; 44:1225–1234.

Medland SE, Loehlin JC, Willemsen G, Hatemi PK, Keller MC, Boomsma DI, et al. Males do not reduce the fitness of their female co-twins in contemporary samples. Twin Research and Human Genetics. 2008; 11:481–487. [PubMed: 18828730]

Moffat SD, Hampson E. A curvilinear relationship between testosterone and spatial cognition in humans: Possible influence of hand preference. Psychoneuroendocrinology. 1996; 21:323–337. [PubMed: 8817730]

Moore DS, Johnson SP. Mental rotation in human infants: A sex difference. Psychological Science. 2008; 19:1063–1066. [PubMed: 19076473]

Peters M, Laeng B, Latham K, Jackson M, Zaiyouna R, Richardson C. A redrawn Vandenberg and Kuse mental rotations test: Different versions and factors that affect performance. Brain and Cognition. 1995; 28:39–58. [PubMed: 7546667]

Puts DA, McDaniel MA, Jordan CL, Breedlove SM. Spatial ability and prenatal androgens: Meta-analyses of congenital adrenal hyperplasia and digit ratio (2D:4D) studies. Archives of Sexual Behavior. 2008; 37:100–111. [PubMed: 18074217]

Quinn PC, Liben LS. A sex difference in mental rotation in young infants. Psychological Science. 2008; 19:1067–1070. [PubMed: 19076474]

Ryan BC, Vandenbergh JG. Intrauterine position effects. Neuroscience and Biobehavioral Reviews. 2002; 26:665–678. [PubMed: 12479841]

Silverman I, Choi J, Peters M. The hunter-gatherer theory of sex differences in spatial abilities: Data from 40 countries. Archives of Sexual Behavior. 2007; 36:261–268. [PubMed: 17351740]

van Anders SM, Vernon PA, Wilbur CJ. Finger-length ratios show evidence of prenatal hormone-transfer between opposite-sex twins. Hormones and Behavior. 2006; 49:315–319. [PubMed: 16143332]

Voyer D, Voyer S, Bryden MP. Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. Psychological Bulletin. 1995; 117:250–270. [PubMed: 7724690]

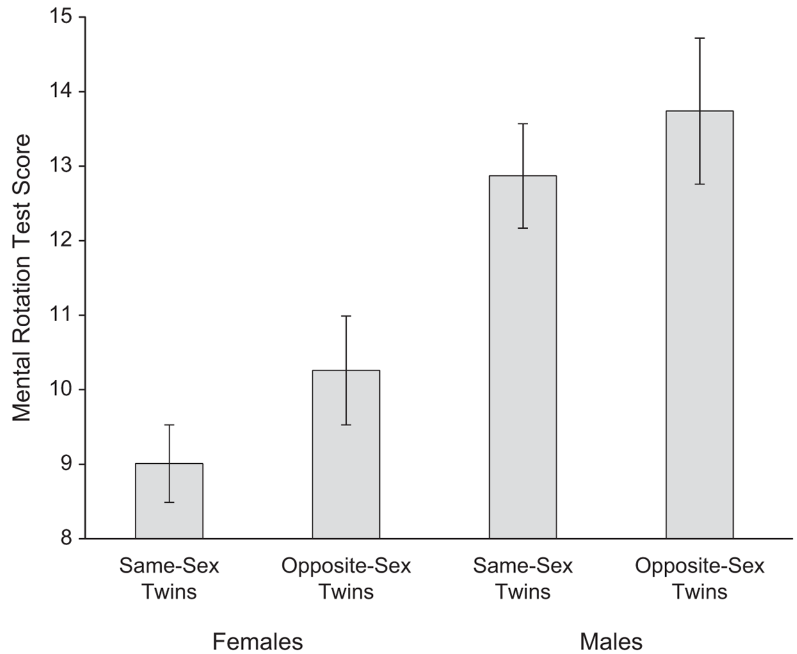

Fig. 1.
Mean mental rotation test scores (with 95% confidence intervals) for females and males from same-sex and opposite-sex twin pairs.