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Spatial abilities following prenatal androgen abnormality: targeting and mental rotations performance in individuals with congenital adrenal hyperplasia

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Abstract

In most mammals, behaviors that show sex differences are influenced by androgen during early life. In the current study, the hypothesis that androgen influences the development of human spatial abilities was investigated. Participants included 40 females and 29 males with congenital adrenal hyperplasia (CAH), a genetic disorder that causes overproduction of adrenal androgens beginning prenatally, and 29 unaffected female and 30 unaffected male relatives of individuals with CAH. Participants ranged in age from 12–45 years. Measures of spatial abilities included two mental rotations tasks and two targeting tasks, all of which showed large sex differences favoring males in the unaffected relative controls. Females with CAH (exposed to higher than normal levels of androgen prenatally) performed better than unaffected females on the targeting tasks, and resembled unaffected males and males with CAH in this respect. However, females with CAH did not perform better than unaffected females on the measures of mental rotations abilities. Males with CAH showed unaltered performance on the targeting tasks, and impaired performance on the mental rotations tasks. Results are discussed in terms of differences in experiential and hormonal contributions to different spatial abilities, as well as in terms of possible differences in critical periods for hormonal influences on targeting versus mental rotations abilities. Specifically, we speculate that, although androgen may influ-

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ence targeting abilities prenatally, if hormones influence the development of mental rotations ability, they do so at some other time, perhaps during the first six months of postnatal life.

Keywords: Spatial abilities; Androgen; Sex differences; Targeting; Mental rotations; CAH; Critical periods; Development; Behavior; Gender

Although males and females do not differ in general intelligence, there are sex differences in specific aspects of cognitive performance, including some spatial and mathematical abilities at which males excel on average, and verbal fluency at which females excel on average (Collaer and Hines, 1995; Halpern, 2000). The largest differences are those in certain spatial abilities, particularly mental rotations ability (the ability to rotate figures rapidly and accurately in the mind) and targeting performance (the ability to aim projectiles accurately at a specified point in space).

The magnitude of sex differences in human behavior can be described using standard deviation ("*d*") units. Group differences in behavior, including sex differences, are considered large if d is 0.8 or greater, moderate if *d* is about 0.5 and small if *d* is 0.2 or less (Cohen, 1988). Meta-analytic studies suggest that the sex difference in three-dimensional mental rotations performance is large ($d = 0.9$), whereas that for two dimensional performance is small to moderate ($d = 0.3$–0.5) (Linn and Petersen, 1985; Voyer et al., 1995). The sex difference in targeting appears to be larger than that on either type of mental rotations task ($d = 1.3$–1.9) (Jardine and Martin, 1983; Watson and Kimura, 1991). Sex differences in other aspects of spatial abilities, such as spatial perception (the ability to position stimuli (e.g., lines) accurately, despite distracting information (e.g., a tilted frame)) and spatial visualization (the ability to use analytic strategies to manipulate spatial information) are smaller (d = 0.38–0.56 for spatial perception and $d = 0.16$, for spatial visualization) (Linn and Petersen, 1985; Voyer et al., 1995), as are sex differences in mathematical reasoning ($d = 0.32$) (Hyde et al., 1990) and verbal fluency (the ability to produce words with certain characteristics rapidly) ($d = 0.33$–0.53) (Kolb and Whishaw, 1985; Hyde and Linn, 1988; Spreen and Strauss, 1991).

It has been suggested that sex differences in spatial abilities may relate in part to the early hormone environment, particularly to levels of androgens prenatally (Hines, 1990; Kimura, 1992, 1999), but see also Hines (2002) for a revised perspective based on more recent findings. The original suggestion linking hormones to spatial abilities derives from evidence that the early hormone environment has dramatic influences on the development of behaviors that show sex differences in other mammals. For instance, female rats and rhesus macaques exposed prenatally or neonatally to higher than normal levels of androgens show more male-typical play behavior as juveniles and more male-typical sexual behavior as adults (Goy and McEwen, 1980; Meaney and Stewart, 1981). Spatial abilities have not been studied as extensively as play behavior and sexual behavior. However, male rats perform better than female rats on some spatial tasks, and females exposed to elevated levels of androgen or its metabolites during early development show enhanced performance on these tasks,