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Differences in salivary testosterone, digit ratio and empathy between intellectually gifted and control boys

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ABSTRACT

Testosterone was shown to organize brain structure and modulate cognitive functions. Higher prenatal testosterone exposure has been proposed to increase systemizing and to decrease empathizing. Whether intellectually gifted (IQ > 130) individuals differ in these aspects is largely unexplored. The aim of this paper is to compare the prenatal testosterone exposure (reflected by 2D:4D), the actual testosterone levels, and the ability of empathizing and systemizing in gifted boys (N = 66) and control boys of same age (N = 80). The comparison revealed significantly lower salivary testosterone levels ($d = -3.35$, $t = 2.46$, $p = 0.02$) in gifted group compared to controls. Although the effect size was quite robust, this result did not remain significant after the correcting for multiple testing (new p value calculated after Bonferroni correction was 0.006). Lower left 2D:4D (standing for higher prenatal testosterone level; $d = -1.33$, $t = 4.96$, $p < 0.0001$) was observed in intellectually gifted boys compared to control boys surviving the correction for multiple testing. No significant difference between groups was found in the number of CAG repeats in gene encoding the androgen receptor ($d = -0.06$, $t = 0.38$, $p =$ ns). Intellectually gifted boys achieved significantly lower score in reading mind in the eye test ($d = -0.75$, $t = 3.38$, $p = 0.003$) that remained significant after correcting for multiple comparisons. It can be speculated that higher prenatal testosterone reflected by lower 2D:4D organizes the brain of gifted boys in a different way in comparison with controls. Consequences include differences in cognitive functions such as lower ability to mentalize—to understand the mental state of others. The physiological mechanisms of testosterone in intellectually gifted boys, especially at the molecular level remain to be elucidated.

1. Introduction

Recent neurophysiological research showed several unique neurobiological features in gifted individuals suggesting a specific pattern of brain development (Winner, 2000). Cerebral lateralization theory claims that specific brain development in precocious individuals can be explained by fetal testosterone organizational effect. Higher than normal concentrations of testosterone *in utero* may interfere brain development, typically inhibiting the areas for left hemisphere functioning while enhancing the development of other areas typically in the right one (Geschwind & Galaburda, 1985). This developmental organization leads into atypical laterality, hemisphere

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cooperation and dominance in right hemisphere activities (Geschwind & Galaburda, 1985; Mrazik & Dombrowski, 2010).

It has been proposed that the ratio of the second to fourth digits (2D:4D) may be a proxy of prenatal androgen exposure, such that low 2D:4D ratio is associated with high prenatal androgen exposure (Beaton, Rudling, Kissling, Taurines, & Thome, 2011; Manning & Fink, 2008; Manning & Robinson, 2003; Manning, Scutt, Wilson, & Lewis-Jones, 1998; Manning et al., 2000; Zheng & Cohn, 2011). Recently, an accumulating research has shown 2D:4D to be related to a multitude of sex-dependent, hormonally influenced biosocial traits. In males a high (female-typical) 2D:4D ratio predicts an enhanced tendency to empathize and a reduced tendency to systemize. In women, by contrast, the 2D:4D ratio was unrelated to these traits (Von Horn, Backman, Davidsson, & Hansen, 2010). Another study found 2D:4D to be unrelated to systemizing and empathizing in normal adults (Honekopp, 2012). Regardless of mixed results in previous studies, digit ratio is still the best available retrospective marker of average differences in prenatal androgen stimulation.

Previous research pointed out differences between gifted boys and control group. Significantly lower number of CAG repeats in the androgen receptor (AR) gene in gifted indicates stronger androgen signaling in this group (Celec et al., 2013). It was suggested it might compensate lower salivary testosterone levels detected in gifted (Ostatnikova et al., 2007). Increasing number of CAG repeats linked with less sensitive AR was shown to improve mental rotation score in gifted boys (Durdiakova et al., 2013). Contrastingly, Lee with colleagues found no association between CAG repeat length and fluid intelligence in older men (Lee et al., 2010). To our best knowledge there is still a lack of information about how the number of CAG in AR affects social intelligence, empathy or systemizing.

Testosterone may not only regulate cognitive functions organizationally, by affecting fetal brain development, but also activationally, by its current effects on the brain (van Honk et al., 2011). It was shown that administration of testosterone in young women led to a significant impairment in their cognitive empathy, and that this effect is powerfully predicted by a proxy of fetal testosterone (reflected by digit-to-fourth digit ratio) (van Honk et al., 2011). Testosterone is able to modulate the processing of facial expressions. Basal testosterone levels generally decrease aversion to threatening stimuli, and/or may specifically facilitate approach towards signals of dominance challenge (Wirth & Schultheiss, 2007). Exogenous administration of testosterone reduces the detection of the facial signal of anger and fear and predisposes individuals to antisocial behavior. It seems to have no effect in perception of joy faces (van Honk & Schutter, 2007).

Empathy and systemizing are human characteristics that can be influenced by experience and socialization but testosterone exposure is also shown to play its role. Empathizing is the ability to identify with other people's thoughts and feelings and to be able to respond to these mental states with appropriate emotions (Baron-Cohen & Wheelwright, 2004). This is an aspect of social interaction where there is usually a strong advantage for females. Systemizing has been defined as the drive to analyze, explore, and construct a system (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003). A growing body of evidence suggests that, on average, males spontaneously systemize to a greater degree than females. Boys, on average, engage in more mechanical and constructional play than girls. The ability to read the mind from the eyes (mentalizing, reading the mind) is also sexually dimorphic, with females on average typically outperforming males (Sapienza, Zingales, & Maestripieri, 2009). Testosterone is thought to be involved, as it represents the biggest hormonal difference between the sexes and affects sociality (Baron-Cohen, Knickmeyer, & Belmonte, 2005). Difficulties with empathizing may be fundamental in autism. Baron-Cohen suggested that autism is a manifestation of an "extreme male brain." The male brain tends toward systemizing and mechanistic thinking and presents the lack of empathy. This phenomenon can be explained by prenatal exposure to higher testosterone levels *in utero* bringing the evidence that testosterone can be considered very important etiologic factor in brain development and modulation of certain cognitive domains (Baron-Cohen, 2002). Fetal testosterone levels are positively correlated with scores on the systemizing quotient (SQ) and are negatively correlated with scores on the empathy quotient (EQ) (Chapman et al., 2006).

The aim of this paper is to compare gifted and control boys. Prenatal testosterone exposure (expressed as 2D:4D) was compared in gifted and standard boys. We speculate that higher prenatal testosterone exposure causes atypical cerebral laterality in gifted individuals that should be evident in lower 2D:4D. Prenatal testosterone effects have been proposed to increase systemizing (the drive to understand lawful input–output relationships), to decrease empathizing (the drive to understand others). We conducted the comparison of the empathy, systemizing and mind reading in gifted and control boys. We also analyzed the differences in salivary testosterone levels and genetic variability in AR in order to partly reveal the effect of testosterone exposure on empathy and systemizing in humans.

2. Methods

2.1. Participants

Sixty-six intellectually gifted boys between 10 and 14 years of age were enrolled in our study. Boys were attending the special school for intellectually gifted learners founded in Bratislava, Slovakia in 1998. Admission criterion for being accepted to this kind of special school was general intelligence score of IQ 130 and more. Control group consists of 80 boys with an average intelligence level. Control boys were randomly chosen from regular public grammar schools in Bratislava and its surroundings. Probands and their parents were instructed, informed about the concept of the study and signed the inform consent. All procedures were approved by Ethical Committee of Faculty of Medicine. Probands were requested to collect the whole saliva samples into sterile tube (Sarstedt, Nümbrecht, Germany) between 8:00 to 10:00 am in respect to the circadian rhythm of testosterone. All volunteers were requested not to eat, drink or wash teeth 30 min before collection procedure. The conventional wisdom about sex differences in IQ is that males and females have the same average IQ. However, there is sample research showing a smaller general lead for males, mostly from age 15 years on (Flores-Mendoza et al., 2013; Lynn & Tse-Chan, 2003). It is stipulated that males are more