

Lack of Correlation between Fetal Testosterone Levels and Incidence of Autism in Engineering

Abstract

Researchers have studied connections between fetal testosterone, autism, and qualities useful to engineers, such as a systemizing personality and spatial skills. However, few have analyzed the suggestion of Simon Baron-Cohen, a researcher at the University of Cambridge, that fetal testosterone may be a link between autism and engineering-related fields. An examination of recent studies reveals data that is inconsistent with this hypothesis. Though there is a positive correlation between fetal testosterone levels and severity of autistic symptoms, there is a curvilinear relationship between fetal testosterone levels and spatial ability, such that men with low fetal testosterone levels perform highest. In addition, there is no correlation between the scores of Baron-Cohen's Autism Quotient (AQ) and Systemizing Quotient (SQ), further contradicting his hypotheses. These inconsistencies weaken the argument that fetal testosterone links autism and engineering abilities. However, Baron-Cohen has intriguing ideas concerning autism and its causes, so perhaps researchers can improve his methodology to help to understanding this unfortunate disorder.

Introduction

Autism is one of a number of related disorders known as Autism Spectrum Disorders (ASDs). As the name suggests, these disorders lie on a spectrum and vary by severity. [1] ASDs are developmental disorders that make basic social interactions challenging for affected individuals and their families. Autism itself is characterized by delays and impairments in communication skills and social interactions, restricted interests, rigid routines, and repetitive

behaviors, all of which appear in an autistic individual by the age of three. Despite their social disabilities, however, autistic individuals seem to have an interest in mechanisms and systems.

[2] Other ASDs have similar symptoms. For example, individuals with Asperger syndrome (AS), which appears to be a mild form of autism, have stilted language use but no delayed communication skills and normal to above average IQ. [3]

One researcher studying autism, Simon Baron-Cohen proposed that autism is an extreme manifestation of the male brain. [4] His extreme male brain (EMB) theory is an extension of his empathizing-systemizing model. [5] He defines systemizing as the drive to analyze, construct, and predict systems such as machines, and defines empathizing personalities as the drive to analyze and predict people's behavior and respond accordingly. [5, 6] On average, men have systemizing personalities, while women have empathizing personalities. [5] Over the past few years, Baron-Cohen has suggested that autistic people are strong systemizers and weak empathizers. [5, 7]

Further studies led Baron-Cohen to believe that there is a link between maleness, autism, and abilities common to engineers. He observed that the male-to-female ratio for autism is 4:1 and that of AS is 9:1. [3] Similarly, males outnumber females in fields in which systemizing and spatial skills are useful, such as mathematics, physics, and engineering. [3] Furthermore, students within the aforementioned fields have more family members with an ASD, and more relatives of autistic individuals are or were in an occupation related to engineering. [2] These observations led Baron-Cohen to suggest that there is a connection between maleness and autism, and also a link between engineering-related skills and autism. [3]

One possible link between autism and certain skills common to engineers is fetal testosterone. As a developmental disorder, autism could develop *in utero*, when genetic or

environmental factors may cause abnormalities in the brain, so fetal levels, rather than adult levels, of testosterone may cause autism. [2] In animal studies, sexual differentiation occurs when there is the greatest difference in the amount of testosterone that male and female fetuses experience, which in the case of humans, occurs between twelve to eighteen weeks of gestation. [4] Thus, though brain development continues neonatally, the EMB theory and systemizing-empathizing model suggests that fetal testosterone is more likely a link between autism and engineering-related skills than neonatal testosterone levels. [4] A male fetus is more likely to experience abnormally high fetal testosterone levels than a female fetus, possibly explaining the male-to-female ratio seen in the ASDs. [3]

Furthering the studies of Baron-Cohen and others may lead to a better understanding of autism. By knowing how to interact with autistic individuals, educators can develop better ways to help affected people cope with their difficulties and pursue activities that once intimidated them. Understanding autism can lead to helping affected individuals in various aspects of their life, and enhance their day-to-day lives regardless of the difficulties they may have with social interactions.

Though Baron-Cohen and his lab have conducted a variety of studies to support their hypotheses, few researchers have supported or refuted his ideas. Therefore, my research will focus on prenatal testosterone levels as a link between autism and engineering-related abilities.

Overview of 2D:4D

Scientists wishing to determine the environment an individual experienced prior to birth by study anatomical features defined by prenatal conditions. One such feature is the 2D:4D ratio – the ratio between the lengths of the second digit (index finger) and the fourth digit (ring finger), possibly determined within the first three months of conception. [8] During development,

estrogen seems to promote second digit development, while testosterone promotes fourth digit development, such that, on average, males have smaller 2D:4D than females. [9]

Current Research

Fetal Testosterone and Autism

Comparing autistic and unaffected individuals reveals that the latter group's digit ratios vary by sex, while autistic individuals do not show this sexual dimorphism. [3] Autistic children have a lower 2D:4D ratio than do unaffected children and children with AS, and there seems to be a negative correlation between severity of autism and 2D:4D ratio. [3, 8] Relatives (mothers, fathers, and siblings) of autistic individuals have lower than average 2D:4D ratios, which suggests that autism has genetic causes. [3] That study also found that both parents of autistic children had lower than average 2D:4D. [3] This finding supports Baron-Cohen's hypotheses in that families with higher fetal testosterone levels also have more occurrences of autism.

Other studies indicate that higher levels of fetal testosterone contribute to autistic-like symptoms. A study of four-year-old children found a negative correlation between fetal testosterone concentration and quality of social relationships, as well as a positive correlation between fetal testosterone concentration and restricted interests. [4] A study involving students at the University of York indicated that males got higher scores than females on the Autism Quotient (AQ), a test developed by Baron-Cohen to indicate presence of autistic characteristics. [7] Another study found that women with autistic symptoms had a higher rate of testosterone-related disorders, such as dysmenorrhea and polycystic ovarian syndrome. [10] Each of the aforementioned studies provides support for Baron-Cohen's hypothesis that there is a positive correlation between fetal testosterone levels and autism.

However, in one of the largest studies involving 2D:4D ratio analysis, researchers could not find a correlation between 2D:4D and AQ score. [11] Males and females received scores on the AQ comparable to those in other studies, but there was no indication that there was a relationship between 2D:4D and AQ score. Since the AQ is a self-report test, it is possible that the test itself is faulty. Individuals may lie, interpret questions differently, or have false perceptions about themselves. The fact that males continued to score higher than females on the AQ suggests that there is a sex-related component contributing to autism. There seems to be enough evidence suggesting that there is a correlation between fetal testosterone and autism, so the fault may lie in using a self-report test.

Fetal Testosterone and Engineering-Related Qualities

Engineers and individuals in related fields, such as physics, tend to have systemizing personalities and benefit from having improved spatial ability. In a large study involving first and second year students attending Ghent University in Belgium, the students who received the highest scores on the Systemizing Quotient (SQ), a test Baron-Cohen developed to quantify individual preferences towards systemizing, belonged to disciplines in science, particularly engineering and physics. [6] Another study involving university students showed that those in the sciences performed better than those in the humanities on spatial tasks. [7] In addition, numerous studies have shown a male advantage in spatial skills performance, particularly with tasks involving mental rotation and targeting, suggesting a correlation with androgen levels. [12] To determine the effects of prenatal testosterone on systemizing and spatial skills, various groups have studied students and faculty members at several universities, prepubescent children, individuals with congenital adrenal hyperplasia, digit ratio, and sexual orientation.

In a study of faculty members at the University of Bath in the United Kingdom, researchers correlated 2D:4D ratio to field of interest. [9] For faculty members within the fields involving the most systemizing, including chemical engineering, mathematics, and physics, the average digit ratio was above 0.995 – closer to the female average. On the other hand, faculty members in fields involving less systemizing, including psychology, had an average digit ratio below 0.98, which is the average for males in that region. Most of the faculty members were men, particularly in the heavily systemizing fields, where 81% were men. As predicted by Baron-Cohen, there were more men in fields involving more systemizing, but contrary to his predictions, the men with the digit ratios closer to those exhibited by women dominated the engineering-related fields.

Various studies have compared SQ scores to sex-related attributes. A study of four-year-old children revealed a positive correlation between fetal testosterone concentration measured from amniotic fluid and the SQ adapted for children. [5] Among twenty students at the University of York, males got higher SQ scores than did females. [7] When researchers in Austria compared 2D:4D ratio to SQ score, however, they could not find a correlation between the two. [11] Like the AQ, however, the SQ is a self-report test, so it may not be a reliable measure. In the study involving four-year-olds, the children's mothers were responsible for judging their systemizing tendencies, even though they may interpret items on the test differently from how the researchers would have. [5] Also, the study done at the University of York was probably too small to form a conclusion pertaining to the general population. All in all, the SQ seems to be an inaccurate measure of systemizing, and though some of the studies support Baron-Cohen's hypotheses, their results may be skewed.

Several studies specifically focused on spatial skills, including one that observed the two-dimensional mental rotational abilities in seven-year-old children, who had not yet experienced the hormonal shifts associated with puberty. [13] This study found that, though boys had higher prenatal testosterone levels, girls had faster mental rotational speeds, which conflicts with Baron-Cohen's hypothesis. In addition, mental rotation rate was highest among girls with high prenatal testosterone levels and boys with low fetal testosterone levels. This overall correlation does not support Baron-Cohen's hypotheses.

Individuals with congenital adrenal hyperplasia (CAH) may show the effects of prenatal testosterone levels on various spatial skills. [12] CAH causes abnormally high adrenal androgen levels that begin prenatally. Affected individuals are treated with corticosteroids following birth, so differences between CAH individuals and unaffected individuals may be a result of elevated prenatal testosterone levels. In tasks involving three-dimensional mental rotations, unaffected males performed better than CAH males, who performed better than both CAH and unaffected females. In tasks involving targeting, unaffected and CAH males showed similar performance, while CAH females showed worse performance than males but better performance than unaffected females. There was no observed difference in performance of tasks involving two-dimensional rotation. The general trends in this study indicate that higher fetal testosterone levels are related to improved spatial performance in females and impaired spatial performance in males.

One study failed to find a correlation between digit ratio and spatial ability in women. [14] The study instead found a correlation between spatial ability and sexual orientation, which may also be affected by prenatal androgen levels. Lesbian and bisexual women performed better than heterosexual women on various spatial skills tasks, though they displayed no significant

differences in circulating testosterone levels and were tested at similar times during their menstrual cycle. Previous studies suggest that homosexual and bisexual women experienced higher fetal testosterone levels and have lower 2D:4D than their heterosexual counterparts, though researchers for this particular study did not find significant differences in 2D:4D digit ratio. Among the 20 women identified by the researchers as being non-heterosexual, there was a negative correlation between 2D:4D ratio and sexual orientation. It is possible that the sample size was too small, and the data from the non-heterosexual women coupled with previous research seems to indicate that increased fetal testosterone improves spatial ability in women, which is consistent with many of the studies mentioned previously.

The studies analyzed did not indicate that women with low fetal testosterone levels and men with high fetal testosterone levels cannot be successful engineers. In fact, one study found no correlation between fetal testosterone levels and academic achievement. [9] Many of the studies noted that, although optimal fetal testosterone levels gave individuals an initial advantage in spatial tests, all individuals improved their performance through experience [5, 13]. Thus, individuals wishing to pursue science and engineering careers should not feel disheartened by this study.

Conclusion

Part of this study provides support for Baron-Cohen's hypothesis that fetal testosterone is a link between autism and engineering-related skills. The literature indicates a positive correlation between fetal testosterone levels and the presence and severity of autism, which suggests that one may cause, or contribute to the presence, of the other. However, the relationship between fetal testosterone levels and engineering-related skills has a different trend.

Elevated fetal testosterone correlates with lower systemizing tendencies and spatial abilities in men and higher systemizing tendencies and spatial abilities in women. Since these relationships differ, this study, overall, does not support Baron-Cohen's ideas.

Current research does not adequately support Baron-Cohen's proposed link between autism and engineering skills. This research does not contradict his finding of higher occurrences of autism in families with more engineers, so there may indeed be a link between autism and engineering skills. In the future, researchers should consider other possible links between autism and engineering skills rather than discounting Baron-Cohen's ideas altogether.

In addition, Baron-Cohen should improve his tests, the AQ and SQ. There may be ambiguity in those self-report tests, so he may need to revise them in order to obtain reliable results. By improving the quality of those tests and exploring other possible factors, including estrogen, another sex-related component, he may eventually find a link between autism and engineering-related skills.

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