

Investigating the Role of Hormones in Theory of Mind

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Theory of mind (ToM) represents the ability to make inferences about the intentions, beliefs, emotional states, and likely future behavior of other individuals. It appears that, on average, girls and women have a small advantage on many ToM tasks over boys and men. The current study was designed to investigate if circulating levels of sex hormones affect ToM abilities. Study one used an experimental group of 17 women who began taking estrogen-containing oral contraceptives (OC) during the study compared to a control group who did not begin using OC. Results indicate that estrogen supplementation, at least synthetic estrogen, does not enhance ToM abilities. Study two measured circulating levels of testosterone in 57 men and 29 women via salivary assay and related them to ToM skills. Results indicate that while there is no relationship for females' level of testosterone and ToM skills ($r = .10$); males with higher T levels did make more errors ($r = -.19$). A different pattern for males with the highest T levels was observed. Specifically, males nearing 2 SD 's above the mean T levels made fewer errors ($r = .20$). For most males (the middle three SD 's of T levels), higher levels of testosterone are strongly associated with more errors on tests that measure ToM skills, $r(47) = .33, p = .02, R^2 = .11$. Reasons and theoretical implications for the overall pattern of hormonal effects are discussed.

Theory of Mind (ToM) refers to a person's ability to think about, make intelligent inferences about, and accurately gauge another person's mind set and emotions. A person with an excellent ToM would be good at guessing what another person is thinking and would be more aware of other's feelings and motives. Theory of Mind can be considered as a module within the human mind, that is to say that there may be some set of pathways in the brain or regions of the brain that are dedicated to reading the intent and mind set of other persons (Abbas, 2006). Such an ability would very likely be useful in terms of surviving in a social society, and some (Geary, 2004; Humphrey, 1976) have argued that a

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ToM would have been naturally “selected for” in the course of human evolution. The discussion is not purely academic; it may have implications for understanding certain disorders. It has been argued by some that persons with autism lack a ToM entirely, while those with Asperger Syndrome (which is often thought of as a milder form of autism) have an impaired ToM. Simon Baron-Cohen, a leading researcher in this area, has argued that autism (and Asperger Syndrome) is an imbalance between two types of intelligence such that sufferers lack an ability to understand people but have an overdeveloped ability to understand and think about systems, movement and mechanical thinking.

If Baron-Cohen is correct, the sex difference in these skills and interests may be of even more interest. It has long been observed that girls and women report and illustrate more “empathic” behaviors, while boys report and show more interest in mechanical objects. For example, pre-school girls are more able to imagine other’s feelings, the drawings of males contain more mechanical objects (Iijima, Arisaka, Minamoto, & Arai, 2001); males score better on spatial reasoning and mechanical aptitude tests (Geary, 1998; Kimura 1999). Of course, these differences may be cultural and/or they may be enhanced by cultural experiences. While determining whether differences in empathic thinking are all cultural, all biological or some combination of the two is not the primary focus of the proposed research, it is worth noting that some studies have documented a sex difference in the first week of life in that male infants spend significantly more time looking at a mechanical object moving, while female infants spend significantly more time gazing at a human face (Connellan et al., 2000). Whether biological or social, the empathic style and focus on other’s feelings is often considered to be more female, while a mechanical, analytical style of thought is, at least somewhat more male.

It is the position of the current authors that this sex difference is relatively small and often of little practical import at the individual level (many women are more analytic than men), but the data are relevant to the idea that ToM is a module that males are, on average less able to use. Furthermore, according to the DSM, the essential features of autism: impaired social interaction, deficits in social communication, and “stereotyped patterns of behavior” such as “preoccupation with parts of objects”(APA, p. 75), are features very much related to ToM. As might be expected, there is a very pronounced sex difference in the cases of autism and Asperger syndrome (males account for at least five times the number of females diagnosed, DSM, 2000). Some leading researchers (Baron-Cohen & Hammer, 1997) have even argued persuasively that Asperger syndrome and autism actually represent very extreme forms of the “male brain.”

The current project is an investigation of the role of sex hormones in ToM abilities. If ToM is a skill that has a sex difference, as prior research has shown; and if a complete lack of ToM is an extreme and pathological exaggeration of this sex difference, then it may be that levels of sex hormones will relate to a person's ability on ToM tasks. Specifically two studies were conducted. Study One investigated the possible role of circulating levels of estrogen, and Study Two investigated the role of circulating levels of testosterone.

STUDY ONE; ESTROGEN AND THEORY OF MIND

Method

Participants This study involved women undergraduates from a large mid-western university. The experimental group consisted of 24 women who were planning to begin oral contraceptive (OC) use in the near future. Of the 24 women, 17 completed the study. Three dropped out stating they had decided not to participate or they no longer met selection criteria, perhaps indicating they decided not to start using OC. Four were dropped for missing one of the data collection sessions. The control group consisted of 36 women who reported no plans to begin taking oral contraceptives; 29 completed the study.

ToM Test The *Test of the Eyes* (Baron-Cohen, 1997) is presented as a series of photographs of the eyes of thirty-six different actors. Each photograph is shown on a separate page, and the actor is showing a specific emotion or feeling. Around each photograph are four different mood-describing adjectives. The participants are asked to choose which of the feelings or moods the person in the photo is portraying. The score is the number of correctly identified feelings or moods.

Testing the ability to read another's intent by viewing the eyes, called "*Reading the Mind in the Eyes*" test (or "*Test of the Eyes*") was chosen because it is the most commonly used paper and pencil measure of Theory of Mind abilities (Richell, et al., 2003; Stone et al., 2003; Voracek & Dressler, 2006; Keleman, Erdelyi, Pataki, Benedek, Janka & Keri, 2005), because it has been shown to reliably differentiate populations who are recognized as impaired on the ability to infer other's emotional states, and because women have been shown to score significantly higher than men on this measure (Baron-Cohen, 2002; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), indicating it is sensitive enough to pick up not only large differences (such as between those with and without Autism or Schizophrenia) but also variations among normal persons. The original procedure (Baron-Cohen, 1997) was revised in 2001 and the new version has been shown to reliably discriminate between groups thought to vary on ToM abilities, specifically those with Asperger's and high functioning autism, but also

those with schizophrenia (Keleman et al., 2005) and schizotypal characteristics (Meyer & Shean, 2006). Baron-Cohen et al (2001) report that the test discriminated 15 targets from 239 controls. Using fMRI, it has been shown that males and females not only have differences in their overall performance, but use different brain regions when completing the *Test of the Eyes* (Baron-Cohen et al, 2006), suggesting a basic sex difference in approach to the task. The test has been shown to measure a skill that is independent of both language ability and general intelligence (Senju, Tojo, Konno, Dairoku, & Hasegawa, 2002). It is of interest to note that performance on the *Test of the Eyes* has been shown to be improved by administering the hormone oxytocin, which is associated with social recognition and attachment (Domes, Heinrich, Michel, Berger & Herpertz, 2007). All in all, it can be said that this test is tapping those skills that are needed to accurately gauge another's mindset and recognize social intent.

Procedure The control group was administered the *Test of the Eyes* twice, approximately four weeks apart. The one month delay helped to ensure that the endogenous levels of estrogen would be near the same level (the level of estrogen changes markedly across a typical month). The experimental group also took the *Test of the Eyes* on a similar schedule. The women in the experimental group began taking oral contraceptives after the fourth week, but the exact date varied based on the day their menstrual cycle commenced (as required when one begins the use of oral contraceptives). Each woman in the experimental group took the *Test of the Eyes* for the second time within one week of commencing the use of OC. Thus, all participants took the *Test of the Eyes* twice, with the experimental group commencing the use of OC between testing time one and testing time two. Test-retest reliability for the sample was $r = .67$.

Results

The women who received oral contraceptives did not perform statistically better after commencing OC (session 1 mean errors = 9.29; session 2 mean errors = 9.0; $t(16) = .36$; *ns*). The control group also did not show a difference between testing time one and two (session 1 mean errors = 8.96; session 2 mean errors = 8.29; $t(27) = .17$, *ns*). The central test was whether there was a difference in change that occurred between test session one and test session two for the two groups. There was no difference, $t(43) = -.35$; *ns*), thus our hypothesis was not supported.

STUDY TWO; TESTOSTERONE AND THEORY OF MIND

Methods

Participants This study involved undergraduates from a large mid-western university. Fifty-seven male participants and 29 female

participants provided a saliva sample and completed Baron-Cohen's *Test of the Eyes*.

Procedure Participants were tested in small same-sex groups. Each participant rinsed his or her mouth upon arriving and provided a sample about 30 minutes later while completing the survey questions. The *Test of the Eyes* was given as part of a larger battery of questions, which is not part of the current study. Participants had been instructed not to eat or drink for 30 minutes prior to arriving, and all saliva samples were frozen within the hour. Saliva samples were by un-stimulated passive drool. Samples were assayed by an independent lab (Salimetrics, LLC) and all collection and storage procedures were in accord with those recommended by Granger et al. (2004).

Results

Sex Differences Descriptive statistics showed an overall mean level of testosterone of 96 pg/ml ($SD = 51$), with positive skew (skewness = .77). Males had a mean testosterone level of 112.4 pg/ml ($SD = 48$) while females had a mean of 61 pg/ml ($SD = 39$), $t(84) = 4.98, p < .001$. The split-half reliability for participants on the *Test of the Eyes* was $r = .55$. Females scored higher on the *Test of the Eyes*, that is they made fewer errors as a group, consistent with prior research (mean number correct Males = 24.5; Females = 27.5, $t(84) = 3.3, p = .001$).

Testosterone and ToM Errors The relationship between testosterone and accurate ToM skills was assessed via regression between circulating testosterone levels and score on Baron-Cohen's *Test of the Eyes*. For female participants, the number of errors on the *Test of the Eyes* was not related to circulating testosterone levels, $r = .01, ns$. For male participants, there was an overall non-significant trend for higher levels of circulating testosterone to be associated with a higher number of errors on the *Test of the Eyes*, $r = .19, p = .15$, two-tailed. However, when males with the highest T levels were separately analyzed ($n = 8$), an opposite pattern emerged. For these males, there was a very weak, statistically non-significant trend for more testosterone to be associated with fewer errors ($r = -.20$). Males whose T levels were nearer the mean (the middle three standard deviations in our sample, $n = 49$) revealed a moderate relationship for higher T levels to be associated with more errors when assessing other's intent based on viewing of the eyes, $r = .33, p < .05$. Analysis of variance (ANOVA) was conducted. The level of testosterone was a significant predictor of performance on the ToM task, with T levels accounting for 11% of the variance in the error rate on the *Test of the Eyes*, $F(1,47) = 5.7, p = .02, \eta^2 = .11$.

DISCUSSION

Theory of mind (ToM) is a salient human cognitive competency, and represents the ability to make inferences about the intentions, beliefs, emotional states, and likely future behavior of other individuals (Baron-Cohen, 1995; Gopnik & Wellman, 1994). The ability to infer emotional states and to predict the actions of those with whom one comes in contact would likely aid in survival and may contribute to such diverse human behaviors as empathy, forethought, and social intelligence (Geary, 2004; Humphrey, 1976). It appears that, on average, girls and women have at least some advantage on many ToM tasks over boys and men (Banerjee, 1997; Happé, 1995). Given that girls and women also have an advantage over boys and men in most other areas of social cognition, such as skill at reading facial expressions, and that these differences are influenced by prenatal hormones (Baron-Cohen, 2002; Geary, 1998), it is reasonable that the expression of ToM abilities might be moderated by circulating levels of hormones.

Although use of OC has been shown to influence some social behaviors and abilities in which sex differences are found (Chavanne & Gallup, 1998; Gangestad & Thornhill, 1998), the present results suggest that the hormones contained in oral contraceptives might not influence ToM abilities, at least as these are assessed by the *Test of the Eyes*. However, there are some caveats.

It might be assumed that synthetic estrogens would enhance ToM abilities, if the female advantage in this area is influenced by circulating estrogens. However, the synthetic estrogens are not biochemically identical to natural estrogens (Ferin, Jewelewicz, & Warren, 1993). For example, the ethinyl estradiol found in OC is more readily absorbed from the gastro-intestinal track, and the daily dose schedule combined with the half-life is likely to result in greater daily fluctuation of estrogen levels than would occur in a woman with naturally high levels of estrogen. In some domains the use of OC has been found to disrupt normal estrogen functions as these relate to social behavior (Chavanne & Gallup, 1998; Gangestad & Thornhill, 1998; Geary, DeSoto, Hoard, Sheldon & Cooper, 2001). Given this, although our findings provide no support for the hypothesis, the possibility that naturally occurring estrogens may still influence ToM abilities should be acknowledged.

The principal finding of study two is that within the typical male range of testosterone, T levels were moderately related to errors in assessing the emotion depicted in photograph of the eyes. It is of interest that males with the highest T levels seem to diverge from the overall tendency of males with higher T levels to score worse on the *Test of the Eyes*. This type of pattern is not without precedent, of course. For example, although testosterone is associated with enhanced performance

on tests of spatial skills, very high testosterone has a different effect, actually impeding performance, if anything (Kimura, 1999). For the current results, it may be relevant that males were tested in small same-sex groups. In this study, participants provided a sample 30 minutes after arriving, after they had been filling out the questions. This was done in effort to minimize the effect of eating or drinking just before samples were given (even though they were instructed not to eat before hand). Perhaps some males may actually feel more competitive than other males on this task, and these males may have higher testosterone. The challenge hypothesis states that the act of competing with other males will itself raise males' T levels (Feree, Wikelski & Anderson, 2004). It could be that highly competitive males felt challenged to perform well and were motivated to outperform other males, and this elevated motivation raised their T levels (resulting in higher T levels when T was collected). It has in fact been shown that change in level of testosterone is an independent difference variable that predicts performance on some tasks (Mehta & Josephs, 2006). Thus, the performance on the ToM task may best be understood as a combination of individual variation in the level of testosterone (the hypothesis investigated in the present study), how competitive one felt during the test, and individual variation in how much one's T level changes during a competitive task. Males who had a large increase in T level might have performed especially well. Unfortunately, our methods did not allow us to test this idea, and our participants were not queried on how motivated they were or on how competitive they felt. Future research attempting to address this issue should consider including a measure of how competitive participants felt during the test, as well as pre- and post- measures of testosterone.

Nonetheless, these results are important because they offer preliminary support for the idea that circulating levels of testosterone may relate to a persons' ability to accurately gauge the mind set of another. Specifically, for males within typical ranges of testosterone, high testosterone seems to be associated with lower Theory of Mind skills and less ability to understand the feelings of others. These results are relevant to the question of why sex differences exist on these skills, supporting the idea that at least some of this difference may be biologically based, consistent with research (reviewed above) that sex differences regarding interest in others and empathy are present at birth and are in part biologically wired into the human species. The idea that ToM may be a module that varies among individuals and is sexually dimorphic has generated a lot of interest among basic scientists as well as those studying disorders like Asperger Syndrome and autism. Specifically, Baron-Cohen's idea that Autism may be an extreme form of

a normal male-type brain is supported by a relationship with testosterone levels to ToM skills.

Many sex differences in behavior have been shown to be mediated by testosterone, but it is worth recalling that many sex differentiated behaviors are affected by either testosterone or estrogen levels, but not both. Future studies should attempt to replicate this finding with a larger male sample while controlling for competitive feelings, or analyze the type of errors males with high testosterone are making in regards to their guesses about what emotion a person is feeling. Males with higher T levels may be making different types of errors, perhaps perceiving dominance that others do not see, but other than this error, be highly accurate. As a whole, these results suggest that circulating levels of testosterone, but not estrogen, may be related to ToM skills.

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