Disordered eating and negative evaluation anxiety as candidates for the extreme female brain type

Jennifer Ann Bremser
University at Albany, State University of New York, jenna.davis.ua@gmail.com
DISORDERED EATING AND NEGATIVE EVALUATION ANXIETY AS CANDIDATES FOR THE EXTREME FEMALE BRAIN TYPE

by

Jennifer A. Bremser

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I) Abstract

Baron-Cohen proposed an inclusive theory of individual differences in cognitive style by creating a taxonomy of brain types that is based on the distinction between empathizing and systemizing. More males, than females, use a ‘systemizing’ cognitive style whereas more females than males use an empathetic cognitive style. Further, he posited that a small percentage of individuals will manifest the pathological “extremes” of sexually differentiated brain-types. In support this theory, people with autism have superior systemizing skills with deficits in empathizing. While Baron-Cohen (2003) also proposed the existence of an ‘extreme female brain’, he did not specify the form it would take. Using batteries of psychological, sexually dimorphic anthropometric markers of endocrine status, and behavioral measures, a set of four studies provides preliminary evidence that a combination of disordered eating and negative evaluation anxiety provides a candidate model for the extreme female brain type.
II) Introduction

SEXUAL DIFFERENTIATION

The organizational hypothesis of sexual differentiation holds that early in development, the release of sex hormones directs the development of specific neural structures ultimately leading to detectable sexual dimorphisms in physiology and behavior. Darwin (1871) first outlined the phenomenon of sexual selection, which ultimately accounts for the reasons that underlie the existence of sexually dimorphic structures and behavior. From there, Fischer, (1930) provided the framework necessary to work out the proximate mechanisms of sexual differentiation by elucidating the vital role that sex hormones played in the production of sexual dimorphisms. From this position, Jost (1979) worked out a simple chain of events involved in differentiation by demonstrating that genetic sex determines gonadal sex (ovaries or testes), and that gonadal sex determines phenotypic sex.

Sexual differentiation is a two-step process beginning with the development of the gonad. Early in development both XX and XY embryos have undifferentiated gonads comprised of two duct systems, the Mullerian and Wolffian systems, which connect the ‘indifferent’ gonads to the body wall. In mammals, the Sry gene (the sex determining region of Y), is located on the short arm of the Y chromosome. This gene encodes testis determining factor, a product which initiates the cascade of events that leads to the development of the male reproductive system and development of the testis. The fetal testes secrete two critical hormones that further drive masculine development: 1) Testosterone which accelerates development of the Wolffian ducts, a process known as virilization, forming the vas deferens, epidymis and seminal vesicles. 2) Anti-Mullerian
Hormone, which arrests development of the Mullerian ducts, by reabsorbing the tissue that would, in the absence of this hormone, develop into female sex organs—the fallopian tubes, cervix, uterus and inner vagina. In the absence of the Sry gene, these 2 hormones or their receptors, indifferent gonads develop as ovaries, suggesting that the female sexual development is the default pattern. The ovaries secrete very little estrogen prenatally, but the extent to which estrogen exerts an active influence upon feminization is yet to be fully understood (Breedlove & Hampson, 2002; McCarthy, 1997).

The second step involved in sexual differentiation is believed to be strongly, but not exclusively, directed by hormones. In support of this view there are sensitive periods in which the nervous system is maximally affected by exposure to hormones. For example, a newborn female rat exposed to testosterone (T) will not subsequently develop a penis, as the period of sensitivity to genital development has already passed; however, a single administration of T at birth will result in masculinizing effects that have enduring and profound effects on behavior. For instance, a single administration of T results in the absence of species typical female sexual behavior including the loss of ovulation and lordosis (female behavioral display of sexual receptivity).

The cellular mechanisms that govern hormonally-induced sexual differentiation are still under investigation. It has been suggested that one way in which hormones exert their effects is by influencing neurotransmission. McCarthy, Auger, Perrit-Sinal, (2002) propose that the amino acid neurotransmitter GABA and Glutamate function to promote development of sexually differentiated brain areas on the basis that these systems are involved in adult reproductive processes and are a target of steroid modulation. They found sex differences in GABAergic and Glutamtergic neurotransmission in the
dorsomedial and ventromedial hypothalamus of the neonatal brain. Specifically, they found that testosterone in males, leads to increases in GABA and glutamate transmission that correlates with modulation of synapses via changes in glial cell morphology. This is particularly suggestive as it has been shown that GABA, generally thought of as inhibitory, actually depolarizes neurons in the perinatal brain for limited period, by increasing intracellular calcium levels. The excitatory effect of GABA retracts with development and by postnatal day ten, it is inhibitory, but the excitatory effect of increased calcium has been implicated in neurite outgrowth, branching, and synaptogenesis in the hypothalamus. The finding that testosterone positively modulates GABA and glutamate suggests that neuronal excitation may be elevated in steroid-concentrated regions of the male brains compared to females. The finding that increased excitation can promoted in specific brain regions by testosterone during critical periods of development has interesting implications for autism—a neurodevelopmental disorder characterized by excessive brain overgrowth.

SEX DIFFERENCES IN COGNITION

Because of biologically bound differences in parental investment, males and females faced different selective pressures (Trivers, 1972). Reproductive success for females depended on successful parenting whereas as reproductive success for males depended on acquiring and maintaining status. The existence of neural sex differences then, should reflect adaptations to evolutionarily relevant cognitive “ Niches”. For instance, successful hunting would rely on superior spatial orientation skills, attention to detail, tracking, and calculated risk-taking whereas successful parenting would rely on assessing the emotional states of others, recruiting help, impulse control, and the
formation of social bonds. Over time, sex differences would emerge if they produced or were coupled with a fitness advantage.

There are well-documented sex differences in cognition, most notably a male advantage in tasks that measure spatial reasoning skills and a female advantage in verbal abilities. Spatial reasoning skills include a diverse set of functions that enable us to perceive or reason about the positions of objects and their movements in space (Hampson, 2002). The advantage that males possess on tasks involving spatial abilities persists across species and cultures (Geary, 1998). The fact that these sex differences can be observed in childhood, but do not become pronounced until puberty, suggest that the activational effects of sex steroids are involved in their expression. The biggest disparity between men and women exists on tasks that require imagined rotations of objects in space, called mental rotation tasks (MRT). On these tasks, males’ average scores tend to be between 35-40% higher than women’s (Hampson, 2002). Greater spatial rotation skills may reflect the ability to create more accurate mental representations of the physical environment at large. For example, a study looking the ability to learn a route from a fictitious map, found that males learned the route more quickly and made less errors than females. In addition, males relied more on geometrical knowledge of the map and females relied more on landmarks to learn the route. Map learning scores were correlated with performance on mental rotation tasks (Geary, 1998).

Whereas males possess an advantage for representing and rotating objects in space, females outperform males on tasks that involve verbal abilities including enhanced abilities in written communication such as spelling and grammar, the acquisition of speech, verbal fluency, and the ability to comprehend or decode language. The sex
differences observed on verbal abilities are smaller and more variable than differences in
spatial abilities, but still reflect a reliable difference cleaving mens’ and womens’
cognitive functions.

Cognitive and behavioral sex differences increase in frequency over time by way of sexual selection, either because males and females use proficiency in such cognitive
domains as a criteria for mate selection or because these cognitive domains come bundled
with other fitness indicators such as symmetry, waist- and shoulder-to- hip ratios and or
grip strength that reflects an individual’s reproductive potential. Over time, directional
selection for feminine or masculine traits would lead to more exaggerated sex
differences. One prediction that follows is that more “extreme” sex differences are found
in the traits that are most tightly bound to reproductive success such as, traits linked with
fertility in females (a high “E” phenotype) and traits linked with the ability to acquire and
maintain status in males (a “high T” phenotype). If there was directional selection
towards high E/High T phenotypes, than there will be a small subset of the population
who possess the “extremes” of traits. At these “extremes” the trait may no longer confer a
fitness advantage.

THE EVOLUTION OF BRAIN TYPES

Baron-Cohen (2002) proposed an inclusive theory of individual differences in
cognitive style by creating a taxonomy of brain types that is based on the distinction
between empathizing and systemizing. This theory, derived from observed sex
differences in cognition, can account for the skewed sex distributions present in many
forms of psychopathology. It also provides a plausible account of both the proximate and
evolutionary underpinnings of psychopathology. The central argument of this theory is
that males and females have evolved different “brain-types” each specialized to process information in a different way (Baron-Cohen, 2003). For example, he explains females’ advantage on cognitive tasks that involve language and males’ advantage in spatial abilities in terms of broader cognitive styles that were selected because they provided a fitness advantage.

More males, than females, use a ‘systemizing’ cognitive style. Systemizing is the drive to analyze and explore systems to discover the underlying principles that govern a system (Baron-Cohen, 2002; 2003). Systems can be explained by using if-then correlational rules and can be deconstructed in terms of input and output. Performance on spatial rotation tasks, which involve mentally rotating a 2D image of an object, is dependent on good systemizing.

Empathizing, on the other hand, is the drive to identify someone else's emotional state and to respond to that state with the appropriate emotion (Baron-Cohen, 2002). Presumably, empathizing relies upon self-awareness (i.e. awareness of one’s own mental states), the ability to represent the mental states of others (i.e. theory of mind), and the ability to produce an appropriate emotional response to the mental states of other people (i.e. empathy). According to this theory, more females than males use an empathetic cognitive style and because effective communication relies upon making correct inferences, superior empathizing skills may explain the superior communication and language abilities of females (Baron-Cohen, 2002; 2003).

In many instances, both empathizing and systemizing can lead to the same behavioral result. For instance, both systemizers and empathizers could approach a person who is crying with an offer of help but the neurocognitive processes orchestrating
their actions may be very different. Empathizers create a ‘model’ of the other person’s distress based on their own experience then use that model to infer the emotional state of the other person. Then, they respond to the person with the appropriate action as a function of their inference. Systemizers are more likely to understand the situation on the basis of the correlational rules that guide social interactions. For example: If a person is in distress, then it is socially appropriate to offer help or comfort. Arguably, systemizing is not as effective as empathizing when it comes to understanding people, because more often than not, the forces acting on social situations are dynamic and unpredictable.

Baron-Cohen’s distinction of brain types explain why some people are more adept at understanding systems while others are more adept at understanding people.

In the right situation, systemizing and empathizing are both adaptive responses to the complex social and physical environments that characterize human existence. But because selective pressures operated on males and females differently over time, females developed greater empathizing skills and males developed greater systemizing skills. The different adaptive problems facing males (i.e., hunting & tracking, making weapons) and females (i.e., caring for offspring; recruiting help from others) may have lead to the sexual differentiation of the brain. Individuals with a “male brain-type” demonstrate superiority in systemizing and individuals with a “female brain-type” demonstrate superiority in empathizing.

EXTREME MALE BRAIN THEORY OF AUTISM

Autism spectrum conditions (ASC’s) affect an alarming one out of every one hundred and eleven individuals (Center for Disease Control and Prevention, 2009). Autism spectrum disorders represent a class of neurodevelopmental disorders
characterized by a triad of deficits including deficits in communication and language, social development, and the presence of self-stimulatory behaviors (APA, 2000). Accumulating research suggests certain features associated with autism spectrum conditions may provide a model of an 'extreme male brain' (Baron-Cohen, 2002). The first line of evidence supporting this theory is that more males than females are affected by autism. For every one female affected, there are four males (Fombonne, 2003; Wing, 1981). The asymmetry in the prevalence of autism spectrum conditions stands out in even greater relief when looking at asperger's syndrome, which shares two out of the three features of autism—social communication deficits and self-stimulatory behaviors, without the accompanying language or intellectual deficits (APA, 2000). In asperger’s syndrome, the sex ratio is 10: 1 male to female (Wing, 1981). These findings suggest a putative role for the sex hormone testosterone, one type of androgen that is excreted in higher levels in males than in females.

Retrospective studies of amniocenteses in the first trimester of pregnancy show that testosterone levels are significantly elevated in the amniotic fluid of women whose offspring subsequently develop autistic characteristics (Baron-Cohen, Lutchmaya & Knickmeyer 2004). Specifically, amniotic fluid testosterone level is negatively related to eye-contact in boys at 12 months of age, vocabulary development in 18- and 24-month olds, and the quality of social relationships and range of interests in 4 year olds (Baron-Cohen et al., 2004; Knickmeyer, Baron-Cohen, Raggatt, & Taylor, 2005).

There is also evidence that 2D:4D ratios, a somatic marker negatively correlated with prenatal testosterone exposure, are lower in males than females and even lower among individuals with autism (Baker, 1888; Manning, Scutt, Wilson & Lewis-Jones,
1998). In addition, the magnitude of this ratio is correlated with symptom severity (Manning, Baron-Cohen, Wheelright, Sanders, 2001). In a study of 95 families, the 2D:4D ratios of children with autism, their parents and siblings were compared to controls. Children with autism, and their mothers, fathers and siblings had lower 2D:4D ratios than controls, suggesting that a families with lower digit ratios may be at higher risk for autism. In addition, children with the greatest language impairments had the lowest 2D:4D ratios (Manning, et.al, 2001).

Being a female with autism does not offer protection against the consequences of heightened testosterone exposure. In fact, the rates of androgen-related medical conditions, including polycystic ovary syndrome, irregular menstrual periods, excessive body hair (hirsutism) and severe acne are higher among females with ASC’s (Ingudomnukul, Baron-Cohen, Wheelright & Knickmeyer, 2007). Another study found that females with autism spectrum conditions experience a delayed onset of menarche compared to controls, by an average of 8 months (Knickmeyer, Baron-Cohen Hoekstra & Wheelright, 2006). In addition, congenital adrenal hyperplasia (CAH) is characterized by an enzyme deficiency that leads to the over production androgens during prenatal development that continues to post-natal development if not treated (Becker, Breedlove, Crews, & McCarthy, 2002). Females with CAH generally display more masculinized patterns of behavior, including rough-and-tumble play and preferences for boy’s toys. Individuals with CAH provide a natural model to study the effects of greater prenatal testosterone exposure. In a study comparing the prevalence of autistic traits in females with CAH to their unaffected relatives, females with CAH scored higher on the autistic spectrum quotient (AQ), a questionnaire that measures the degree of autistic traits in the
general population. Females with CAH scored notably higher in the areas of limited social development and imagination, providing convergent evidence for the relationship between elevated levels of testosterone autistic characteristics (Knickmeyer, Baron Cohen, Fane, Wheelright, Mathews, Conway, Brook & Hines, 2006).

Collectively, these findings yield consistent, yet indirect evidence supporting a model of elevated testosterone levels during prenatal development in autism, which may persist across the lifespan. In addition to being associated with heightened levels of testosterone, the “extreme male brain” theory of autism rests on the idea that systemizing and empathizing are normally distributed and that a small percentage of individuals will occupy the high and low ends of the distribution. These individuals may manifest the pathological “extremes” of sexually differentiated brain-types. In support of this theory, people with autism have superior systemizing skills (Baron-Cohen, et al., 2003) with deficits in empathizing and other aspects of social communication including language and theory of mind (Baron- Cohen, 2002; 2003).

While Baron-Cohen (2003) also proposed the existence of an ‘extreme female brain’, he did not specify the form it would take. Indeed, he hypothesized that it might not be maladaptive at all stating that, “It is possible that the extreme female brain is not seen in clinics because it is not maladaptive.” (Baron-Cohen, 2003, p. 172); however, given the far-reaching effects of autism and the specific patterns of neuropathology associated with it, this assertion seems unlikely. In the very least, the extreme female brain would have to affect more females than males, be sensitive to the organizational and activational effects of sex steroids, and be associated with superior empathizing, at the expense of systemizing.
Disordered eating clearly affects more women than men (Södersten, Bergh, Zandian, 2006). Therefore, it may have the potential to provide a model of the extreme female brain. Eating disorders, including anorexia and bulimia, are classified by aberrant patterns of eating behavior, a preoccupation with weight, an intense fear of becoming fat or gaining weight and a disturbance in the way one’s body weight or shape is experienced. Arguably, there are more similarities than there are differences between anorexia and bulimia. For instances, 20% of anorexics display bulimic behavior such as recurrent episodes of binge eating and compensatory behaviors in order to prevent weight gain including self-induced vomiting, misuse of laxatives and/or excessive exercise. Because the primary difference in classification depends upon an individual’s weight, (either underweight or normal weight), it has been argued that the difference between the two is only superficial (Södersten, et al., 2006). Thus, it may be beneficial to look at patterns of disordered eating holistically, viewing bulimic behavior is a symptom of anorexia or viewing bulimia is a special type of anorexia. In addition, growing evidence that suggests that disordered eating exists on a continuum; therefore it is useful to consider levels of disordered eating in the general population (Södersten, et al., 2006).

Like autism, the sex ratio in the prevalence of eating disorders is highly skewed. Women are ten times more likely to experience and eating disorders than males (APA, 2000). Similar to ASC’s they are also considered chronic conditions because more than fifty percent of patients receiving treatment relapse within a year and after ten years, less than fifty percent of patients fully recover. Mortality rates among people with anorexia are twelve times higher than the annual death rate due to all other causes of death among females age 15-24, making it the most lethal of all mental illnesses (Sullivan, 1995).
While the role socio-cultural pressures and family dynamics have been emphasized in the past literature, there is increasing evidence that hormones may play an important role in the development and maintenance of eating disorders (Klump, Gobrogge, Perkins, Thorne, Sisk, & Breedlove, 2006). In addition to the female bias in the prevalence of eating disorders, eating disorder symptoms typically appear at puberty and tend to remit later in life when hormone levels rise and decline, respectively (Strober, Freeman & Morrell). Early puberty is a risk factor for both men and women (Zehr, Culbert, Sisk & Klump, 2007) and salivary estradiol is positively correlated to disordered eating during the follicular phase of the menstrual cycle (Klump, 2006). Furthermore, in animal studies, estrogen is negatively related to food intake and positively related to activity levels (Eckel, 2004).

Recently, several studies have shown that prenatal testosterone exposure may actually protect against the development of disordered eating later in life. Klump, et al., (2006) examined 2D:4D ratios as a function of disordered eating and found that lower levels of prenatal testosterone exposure were associated with higher levels of disordered eating. In the same study, circulating estrogen levels were positively correlated with disordered eating. More recently, Quinton, Smith and Joiner (in press) investigated 2D:4D ratios in females diagnosed with eating disorders and found that there were significant differences between those diagnosed with anorexia and bulimia. Participants with anorexia displayed a “low masculinized” digit ratio whereas participants with bulimia displayed a “high feminized” digit ratio with non-clinical controls falling between the two. In addition, among women with eating disorders, 2D:4D was associated with both participants’ current and lowest weight. Consistent with previous research, a
study from the same lab showed that 2D:4D ratios in males were positively correlated with disordered eating (Smith, Hawkeswood & Joiner, 2010).

A unique way to assess the relationship between fetal testosterone and disordered eating is to look at studies of twins. Because twins share the same prenatal environment, females with a male co-twin may be exposed to higher levels of prenatal androgens, including testosterone. Culbert and colleagues (2008) found that the risk of disordered eating was higher among females that shared a female co-twin and lower in females with a male co-twin. However, another study investigating eating disorders in males showed that the risk of developing anorexia was highest for males who shared a female co-twin. Thus, the idea that prenatal testosterone has a protective effect against the development of eating disorders may be overly simplistic. Instead, it may be a combination of protective androgens and pathogenic estrogens that may result in a hormonal profile that is at increased susceptibility to eating disorders (Procopio & Marriott, 2007). Clearly, the links between prenatal testosterone exposure, autism and eating disorders warrants further investigation, particularly in light of Baron-Cohen’s extreme male brain theory of autism and the absence of a plausible “extreme female brain” counterpart.

The increasing complexity of our social lives is another adaptive problem humans coped with over the course of evolution. Dunbar (1992) suggested that the demands of living in groups were powerful enough to prompt the evolution of the neocortex. He demonstrated that group size could be predicted from neocortical volumes among primate species. It is likely that as the social lives of humans became increasingly more complex, there was considerable variation in individuals’ proficiency in social domains. Thus, if sociability was represented on continuum, the low end of the distribution could be
represented as social apathy, while the high end could be represented in the form of social anxiety. This conceptualization of sociability may compliment Baron-Cohen’s characterization of brain types.

Supporting this hypothesis, low sociability manifested as social apathy is consistent with the social deficits that characterize autism, including the avoidance of physical contact and the lack of interest in developing close emotional relationships. Furthermore, the prevalence of anxiety disorders, including social phobia, is high among individuals with eating disorders and not surprisingly, is more prevalent in women than men (Turk, Heimburg, Orsillo, Holt, Gitow, Street, Scheneier & Liebowitz, 1998). A study looking at the co-morbidity of anxiety disorders and anorexia and bulimia found that among a sample of 741 individuals that met criteria for eating disorders, two thirds reported experiencing an anxiety disorder in their lifetime with twenty percent reporting the experience of social phobia. In most cases, anxiety disorders preceded the development of eating disorders and co-morbidity of anxiety serves as a risk factor contributing to a less favorable outcome (Steinhausen, 2002; Kaye, Bulik, Thorton, Barbarich, & Masters, 2004).

In addition to being more prevalent among women, the content and experience of women’s social anxieties also differ from men. Women reported greater fear while talking to authority figures, working while being observed, entering a room while others are already seated, and expressing disagreement or disapproval to people they do not know very well (Turk, et al., 1998). Collectively, these specific fears may reflect a more general fear of negative evaluation by others. Negative evaluation anxiety represents the intolerance for being judged disparagingly or hostilely by others (Watson & Friend,
the fear of negative evaluation is considered an important component to social anxiety. In addition, negative evaluation anxiety is positively associated with disordered eating (Gilbert & Meyer, 2005). The sex differences observed in the prevalence of negative evaluation anxiety and its relationship to disordered eating suggests that, in addition to sexually differentiated aspects of cognition, there may be affective mechanisms, such as the experience of anxiety, that differentiate the male and female brain types.

Using a battery of psychological, morphological, and behavioral measures, the following set of studies will investigate the hypothesis that disordered eating and negative evaluation anxiety provide a candidate model for the extreme female brain type.

III) General Methods and Materials Background

*Psychological, Behavioral and Cognitive Measures*

1. **Eating Attitudes Test (EAT-26)**

The Eating Attitudes Test is the most widely used standardized measure of the characteristics associated with eating disorders (Garfinkel and Newman, 2000). The 40 item full version of EAT was developed to differentiate people with severe eating disorders from those who do not. The EAT-26, developed by Garner, Olmstead, Bohr and Garfinkel (1982), is the short form of the original test. It consists of 26 items taken from the full version. The EAT-26 distinguishes between three factors of disordered eating including dieting, bulimia and food pre-occupation, and oral control. It has strong psychometric properties including good test-retest reliability (r = .84) (Carter and Moss, 1984) and criterion validity (Koslowsky, Scheinberg, Bleich, Mark, Apter, Danon, and Solomon, 1992).
The EAT-26 consists of Likert scale ratings for each item that range from never, rarely, sometimes, often, very often, and always. Scores on the EAT-26 range from 0-78. Although originally designed as a diagnostic tool, the EAT-26 is more currently used to identify various levels of eating disturbances in the general population as there is considerable evidence that eating disorders exist on a continuum rather than in a discrete fashion. A score of 20 is considered the cut-off point for eating disorder, but in the following studies the top 15% of scores for males and females were considered high.

2. Fear of Negative Evaluation Scale (FNE)

The FNE is a self-report measure of social-evaluative anxiety developed by Watson and Friend (1969). Participants respond to 30 true or false statements. It was designed to assess apprehension and distress over negative evaluations by others, the avoidance of evaluative social situations and the expectation that others would evaluate oneself negatively. The FNE is significantly correlated with other measures of social anxiety including the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch and Lushene, 1971) and has been previously associated with eating disorder pathology, specifically with the drive for thinness and level of body dissatisfaction. (Turner, McCanna and Beidel, 1987; Gilbert and Meyer, 2005)

3. Social Comparison Scales

The social comparison scales included a set of self-administered questionnaires that include the physical appearance comparison scale (PACS), a five item scale that assesses a person’s tendency to compare their appearance to the appearance of others. This instrument has fairly good internal consistency (Cronbach’s alpha
= .78) and test-retest reliability (r = .72) (Thompson, Heinberg, & Tanleff, 1991) and the Overweight Preoccupation Scale, a 10 item scale assessing various dieting and body image concerns (Cash, Wood, Phelps, & Boyd, 1991). In addition, a measure of the perception of typical and ideal body configurations for self and opposite sex peers from computer generated images that vary body fat/breast proportions for females and body fat/muscularity proportions for males developed by Frederick (2010).

4. Empathizing Quotient (EQ)

The Empathizing Quotient (EQ) is a forced-choice, self-administered questionnaire created by Baron Cohen and Wheelright (2004), designed to assess empathy. Structurally, it is comprised of 60 items with 40 items assessing empathy and 20 filler items. Responses are given on a four-point scale depending on how strongly participants agree or disagree with statements related to empathy and scoring direction is counterbalanced. Females score significantly higher than males on this instrument and it can be used to correctly identify individuals with asperger’s syndrome. Scores on the EQ range from 0-80. The instrument has high internal consistency with a Cronbach’s alpha of .852 and is considered a valid measure of empathy components (Muncer & Ling, 2006). Empathizing appears to be mostly, but not completely, independent of systemizing (Wheelwright, Baron-Cohen, Goldenfeld, Fine, Smith, Weil & Wakabayashi, 2006).

5. Systemizing Quotient-Revised (SQ-R)

The Systemizing Quotient Revised (SQ-R) is a 75-item forced choice, self-administered questionnaire that measures individual differences in systemizing by
assessing a person’s interest in a broad range of systems, designed by Baron-Cohen and colleagues (Wheelwright, et al., 2006). Responses are given on a four-point scale depending on how strongly participants agree or disagree with statements related to systemizing. Half the items are reverse coded, to reduce response bias. Males score higher than females on the SQ-R, but the sex differences disappear among individuals with autism spectrum conditions. The finding that physical scientists (including individuals with degrees in math, physics, chemistry computer science, geology engineering astrophysics, mineral and material sciences) score higher than biological or social scientists on this measure supports the ecological validity of this measure.

Within the general population, the relationship between SQ-R scores and EQ scores is weak, suggesting that majority of individuals possess a balanced brain type, where there is only a slight tradeoff between dimensions of empathizing and systemizing (Wheelwright, et al., 2006).

6. Schizotypal Personality Questionnaire (SPQ)

The Schizotypal Personality Questionnaire (SPQ) is a 72 item, forced-choice self-report scale of schizotypal personality characteristics (Raine, 1991). It provides an overall measure of individual differences in schizotypal characteristics and includes subscales for all nine schizotypal traits identified in DSM-III-R criteria for schizotypal personality disorder. The SPQ shows evidence of reliability and validity including high internal reliability ($r = 0.91$), test-retest reliability ($r = 0.82$), convergent validity (ranging from 0.59 - 0.81), discriminant validity (0.63) and criterion validity (0.68). The SPQ is not considered a diagnostic tool; however, over half of the participants scoring in the top 10% of the distribution met the diagnosis of
schizotypal personality disorder (Raine, 1991).

7. Reading the Mind in the Eyes Test (RME)

The Reading the Mind in the Eyes Test (RME), developed by Baron-Cohen, Wheelright, Hill, Raste and Plumb (2001) tests participants’ accuracy in the attribution of relevant mental states. Therefore, it is considered a test of theory of mind. Participants are presented with 36 partial face photographs, showing only the eye region of different actors and actresses. The participant is asked to choose which mental state (one target embedded within 3 foils with the same emotional valence) best describes what the actor in the photograph is feeling or thinking. This test measures how well the participant can put themselves into the “mind” of another person or “tune” into their mental state and for this reason it is commonly referred to measure the cognitive components of empathy (Muncer & Ling, 2006). We used a modified version of this test in which the photographs were presented on a computer screen instead of paper. Participants are provided with a glossary of all the mental state terms used in the test, which they are encouraged to consult when necessary. Normative data on the RME suggests a slight, but non-significant female advantage on the task and is inversely correlated with scores on the autism spectrum quotient (Baron-Cohen, et al. 2001).

8. Intuitive Physics Test

The Intuitive Physics Test, is a test developed by Baron-Cohen, Wheelright, Spong, Scahill and Lawson (2001) based on the philosopher Daniel Dennett’s claim that from infancy onwards, humans use folk physics to deduce non-agentive causal forces (Dennett, 1987). The test is a 20 item, multiple-choice task that involves visual
problem solving related to the perception of physical causality developed for individuals over 10 years of age. It is a test of intuitive physics because all problems on the test can be solved from everyday, real world experience and are not problems that are taught as part of any school curriculum where the test was piloted (Baron-Cohen, et al., 2001)

9. **Contagious Yawning**

Yawns that are evoked in the presence of another yawning stimulus are said to be contagious. Seeing and hearing another person yawn or even verbal and textual references to yawning can elicit contagious yawning in about fifty percent of people (Provine, 1989). Platek, Critton, Myers and Gallup (2003) hypothesized that contagious yawning occurs as a consequence of primitive form of empathetic responsiveness, similar to a fixed action pattern, whereby seeing another person yawn produces a corresponding yawn in oneself. The frequency of contagious yawning is inversely proportional to scores on the Schizotypal Personality Questionnaire (SPQ; Paltek et al., 2003). Senju, Maeda, Kikuchi, Hasegawa, Tojo, and Osanai (2007) showed an impairment in contagious yawning among children with autism spectrum conditions, that could not be attributed to differences in IQ, gender or age. The failure to yawn contagiously may represent a neurological deficit in the primitive forms of mental state attribution, which may impede performance on higher order theory of mind tasks.

*Morphological Indicators of Hormone Status*

1. **Waist-to-Hip Ratio (WHR)**

The most notable sex differences in the accumulation of body fat are observed in
the abdominal and gluteofemoral regions. The sexually dimorphic distribution of body fat is influenced by sex hormones, which explains why the differences in body configuration do not appear until puberty (Singh, 1993). Estrogen inhibits fat deposits in the abdominal region and stimulates deposits in the gluteofemoral region of the body. Conversely, testosterone stimulates deposits in the abdominal region and inhibits fat deposits in the gluteofemoral region.

Waist-to-hip ratio (WHR) is considered a reliable index of the distribution of body fat between the upper and lower body (Leibel, Edens & Fried, 1989) and is obtained by finding the ratio between an individual’s waist measurement, defined as the narrowest point between the ribs and the iliac crest and hip measurement, the point of the greatest protrusion of the buttocks. WHR is a stable measure that has high within-person reliability. The loss or gain of up to 22 lbs (10 kg) does not appear to affect body fat distribution. In general, women have lower WHR’s than men; however, after menopause, a woman’s WHR will increase. This is because, as women age, the ratio of androgens to estrogens increases (Kirschner and Samojilik, 1991).

WHR is significantly related to a woman’s health and reproductive function. Among girls with the same body weight, those with lower WHR’s have experienced earlier pubertal endocrine activity. When body weight, height, pubic hair growth, age and pelvic breadth are controlled for, girls with the lowest WHR’s have the highest levels of estrogen and gonadotrophins, luteinizing hormone, and follicle stimulating hormone (DeRidder, Brunin, Zonderland, Thijssen, Bonferer, Blankenstein, Huisveld & Erich, 1990). Also, among married women, low BMI and high WHR is associated with greater trouble becoming pregnant (Kaye, Folsom, Prineas, Potter, Gapstur,
In a prospective study, Zaadstra, Seidell, VanNoord, te Velde, Habbema, Vrieswijk, and Karbaat (1993) found that among women attending a fertility clinic over the course of 2 years, an increase WHR of even 0.1 unit decreased the probably of conception per cycle by 30% even after controlling for age, weight, reason for artificial insemination, cycle length and regularity, smoking and parity. Of all the factors considered, WHR provided the greatest contribution to probability of conception. In addition, a mother’s WHR has consequences for her offspring. Manning, Trivers, Singh, and Thornhill (1999) showed that mothers’ WHR is negatively related to the 2D:4D of their children indicating that as mothers’ WHR increases, their offspring’s’ 2D:4D ratios become more masculinized.

2. **Second- to Fourth-Digit Ratios (2D:4D)**

The ratio between the second digit (index finger) and the fourth digit (ring finger) is a sexually dimorphic trait. Men tend to have lower 2D:4D ratios than women (Manning et al., 1998). Digit length is established in utero as early as the fourteenth week of gestation (Garn, Burdi, Babler, Stinson, 1975). The mechanism which sets 2D:4D is likely due to activity of the homeobox genes Hox a and d which control sexual differentiation of the urinogenital system. These genes may indirectly influence the production of testicular androgens while simultaneously influencing the development of the digits (Kondo, Zakany, Innis, & Doboule, 1997). 2D:4D ratios are associated with a number of sexually differentiated behavioral traits. For instance, low 2D:4D is related to enhanced spatial reasoning, athletic ability and left handedness (Manning & Taylor, 2001; Manning, Trivers, Thornhill & Singh, 2000). High 2D:4D ratios, on the other hand, are associated with verbal fluency (Manning,
and high levels of emotional behavior (Williams, Greenhalgh, & Manning, 2003). In addition, 2D:4D ratios are lower than controls in males and females with congenital adrenal hyperplasia (CAH).

Using amniocentesis during the first trimester of pregnancy, Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer and Manning (2004) found that 2D:4D ratios are associated with high fetal estradiol levels in relation to low fetal testosterone levels. In addition, all relationships between 2D:4D ratios and sex steroids were stronger in the right hand. This is consistent with other findings demonstrating that traits that display between the sexes show a tendency for the male form to be expressed more strongly on the right side. Thus, digits on the right hand may be more sensitive to the effects of fetal sex steroids. Therefore, only right hand 2D:4D measurements were obtained in the study that follows.

3. **HAND GRIP STRENGTH (HGS)**

A number of studies have shown that handgrip strength is a sexually dimorphic trait. Men have consistently greater handgrip strength than women. There is some evidence to suggest that the difference in HGS is the result of higher levels of androgenic hormones (Page, 2005). In addition, Gallup White and Gallup (2007) found grip strength was positively related to shoulder-to-hip ratios in males, which is commonly used as a measure of masculinity in males. Although Gallup et.al (2007) found no relationship between HGS and body morphology in females it is possible that HGS is associated with a more masculine cognitive style.

4. **AGE OF MENARCHE**

The onset of menarche is an indirect assessment of pubertal timing in females.
Puberty is marked by a number of neuroendocrine changes that include increases in testosterone levels in males, and the cyclical secretion of estrogen and progesterone in females. These increases produce enduring, organizational effects on brain and behavior (Sisk & Zehr, 2005). The incidence of disordered eating and anxiety rises dramatically at puberty (Zehr, Culbert, Sisk, & Klump, 2007; Hayward, Killen, Wilson, Hammer, Litt, Kraemer, Haydel, Varady, & Taylor, 1997) while, eating disorders rarely occur prior to puberty and tend to remit later in life (Strober, Freeman and Morrell, 1997). The timing of puberty may be an important factor associated with an increased risk of psychopathology. For example, the degree of pubertal development of girls in the early stages of adolescence was a precursor disordered eating one year later (Keel, Fulkerson, and Leon, 1997). Therefore, age of menarche will be used as a proxy of the onset of pubertal development in females.

IV) Study I

**Disordered Eating and Negative Evaluation Anxiety as the Extreme Female Brain Type**

*Purpose*

Using self-report measures of disordered eating and negative evaluation anxiety and measures of cognitive style (systemizing and empathizing), this study investigated the hypothesis that individuals with high levels of disordered eating and negative evaluation anxiety may aptly represent a model of the ‘extreme female brain’ by showing a cognitive advantage in empathizing and disadvantage in systemizing.
Participants

122 (52 males; 70 females) undergraduate students at the State University of New York at Albany were recruited from psychology courses. Participants’ age ranged from 18-30 (Mean age = 19.4; S.D. = 1.9) and all participants were fluent in English. The methods used in this study were approved by the university Institutional Review Board and conformed to guidelines for the ethical treatment of human subjects. All participants gave informed consent. Participants received course credit in exchange for their participation. Due to the anonymous nature of this study, participants with high levels of disordered eating could not be identified for referral to appropriate medical professionals, but a packet of local resources for treatment and support for individuals with concerns about eating disorders was made available to all participants.

Measures

Participants filled out the following self-report measures independently: EAT-26, FNE, Empathizing (EQ) and Systemizing Quotients (SQ-R) and a brief demographic survey in a group setting. Participants were instructed to sit at least one seat apart from each other in a classroom.

Statistical Analysis

Data from each participant was entered into a spreadsheet and analyzed using SPSS/PAWS version 18.0. An exploratory data analysis revealed that the distribution for scores were normal for every variable except disordered eating. The distribution for scores on the EAT-26 was positively skewed (Kolmogorov-Smirnov Z = 2.006, p = .001). This was corrected by computing the natural logarithmic transformation for this variable [ln(EAT+1)], which resulted in a distribution that did not differ significantly
from normal (Kolmogorov-Smirnov Z = .813, p = .523). The distribution of scores on the FNE was rectangular, which is consistent with what Watson and Friend (1969) report in the original paper; therefore a Spearman rank order correlation was chosen over a Pearson correlation as the preferred method to analyze the relationships between these variables. In addition to examining associations between disordered eating, negative evaluation anxiety and participant’s raw scores on the EQ and SQ-R, a composite variable identified as “Empathizing Bias” was created for each participant by obtaining the z-scores of EQ and SQ-R variables, then subtracting the participants’ SQ-R z-score from the EQ z-score (z-EQ – z-SQ-R = empathizing bias). The empathizing bias reflects the tendency to utilize a cognitive style that favors empathizing over systemizing and its use has been supported in other studies examining possible candidates for the EFB (Brosnan, Ashwin, Walker, & Donahue, 2010). An outlier scoring more than 4 standard deviations away from the mean (X = -.0413, SD = 1.1) for this variable was removed from the subsequent analyses. Sex differences on all variables were examined using multiple t-tests and the alpha level was adjusted accordingly using a Bonferroni correction (.05/6 = .008). Not all participants completed all portions of the questionnaire packet; thus, missing values were excluded pairwise.

Results

Mean values for each variable are displayed in Table 1. As the EFB theory would predict, levels of disordered eating, negative evaluation anxiety, empathizing and empathizing bias were significantly higher among females. Mean scores for each sex are reported in Table 2. Table 3 depicts the correlations among variables. There was a significant positive correlation between disordered eating and negative evaluation anxiety
(r = .329, p ≤ .001) and the bulimia subscale of the EAT-26 and negative evaluation anxiety (r = .310, p ≤ .001). These findings are compatible with a substantial body of previous research demonstrating co-morbidity between eating disorders and social anxiety (Kaye et al., 2004). There was also significant positive correlation between disordered eating and scores on the EQ (r = .272, p ≤ .001), but not the SQ-R. A similar relationship was discovered for negative evaluation anxiety. Participants’ responses on the FNE were positively associated with empathizing and negatively with systemizing, but not significantly. However, both disordered eating and negative evaluation anxiety were positively associated with empathizing bias (r = .173, p ≤ .05 and r = .157, p ≤ .05, respectively).

Discussion

In this study, females scored significantly higher on measures of disordered eating, negative evaluation anxiety, empathizing and empathizing bias. Males only outperformed females on measures of systemizing. These results are consistent with previous research examining sex differences in cognitive styles.

Among male and female participants, disordered eating and negative evaluation anxiety were significantly correlated with a cognitive style that favors empathizing over systemizing demonstrating preliminary evidence that the extreme female brain type may be conceptualized in terms of a phenotype that displays both high levels of disordered eating and negative evaluation anxiety.

In addition, disordered eating accounted for roughly seven percent of the variance in empathizing scores. As scores on the empathizing quotient increase, levels of disordered eating rise. People with greater empathizing skills are likely to be more
sensitive to the pain and suffering of others. An interesting interpretation these data involves looking at rates of vegetarianism among individuals with eating disorders. Numerous studies report a positive association between the presence of vegetarianism and eating disorders (Robinson-O’Brien, Perry, Wall, Story, Neumark-Sztainer, 2009; Yackobovitch-Gavan, Golan, Valeevski, Kreitler, Bachar, Lieblich, Mitrani, Weizman & Stein, 2009; Bas, Karabudak & Kiziltan, 2005). Most of these studies interpret this relationship as evidence confirming the health-conscious, restrictive eating patterns among people with eating disorders; however an alternative hypothesis consistent with the data presented here is that individual differences in empathizing may affect dietary choices vis-à-vis heightened concerns about animal cruelty or animal welfare. Rather than used as a method to reduce caloric intake, vegetarianism may be a by-product of the greater empathizing capacities among individuals with an extreme female brain type. A study by Yackobovitch–Gavan et al., (2009) showed that vegetarianism is not only associated with disordered eating, it can be looked at as a pre-morbid condition that affects the course and outcome of anorexia. In this study, vegetarianism reduced the probability of symptom remission by a factor of greater than 12. If vegetarianism can be viewed as an analogue of empathizing capacities, the corollary hypothesis would be that heightened levels of empathizing would precede disordered eating and may function as an important moderator of eating disorder outcomes. Future research should explore empathizing as a potential variable that influences both the onset and outcome of eating disorders.

This study examined levels of disordered eating in a sample of undergraduate men and women. Using a sample drawn from the general population minimizes the need to
control for the confounding physical, cognitive, and neuropsychological effects that arise as a consequence of an active eating disorder, but also limits the generalizability of these findings to individuals who meet the diagnostic criteria for eating disorders.

V) Study II
Morphological Markers of Feminine Endocrine Status and their Correlates as Evidence for the Extreme Female Brain Theory of Eating Disorders

Purpose

Using sexually dimorphic anthropometric markers of endocrine status, self-report measures of disordered eating, negative evaluation anxiety, cognitive style (systemizing and empathizing), and performance on theory of mind and systemizing tasks, this study examined the hypothesis that females with more feminine characteristics will display higher levels of disordered eating and negative evaluation anxiety and an advantage on tasks that measure the cognitive and subcorticol aspects of empathy (i.e. theory of mind and contagious yawning) while displaying deficits in on tasks involving systemizing. In addition to self-reported measures of systemizing and empathizing, this study includes 2 objective measures of these variables.

Participants

A total of 46 female undergraduate students were recruited from undergraduate psychology courses at the State University of New York at Albany. Participants’ age ranged between 18-22 years (Mean age = 19.1 S.D. = 1.08) and all participants were fluent in English. The participants were not aware of the purpose of the study. All of the methods used in this study were approved by the university Institutional Review Board and conformed to guidelines for the ethical treatment of human subjects. In addition, all
participants gave informed consent and received course credit for their participation. As with Study I, the anonymous nature of this study prevented referrals to the appropriate medical professionals for participants that displayed high levels of disordered eating, but a packet of local resources for treatment and support for individuals with concerns about eating disorders was made available to all participants.

*Anthropometrics*

**Waist-to-Hip Ratio**

Waist-to-hip ratios were obtained using the method employed by Hughes and Gallup (2003). Waist and hip circumference was measured to the nearest 0.5 cm using anthropometric fiberglass body measuring tape by one of two same sex investigators who did not see participants’ responses to other portions of the study. Waist circumference was defined as the smallest girth between the rib cage and the iliac crest. Hip circumference was defined as the largest girth between the waist and thigh. Both female investigators calculated waist-to-hip ratios in 16/46 participants (34%) and inter-rater reliability was high r = .998.

**2D:4D Ratio**

Second- and fourth-digit lengths were recorded by a female investigator using the methods outlined by Manning, Barely, Walton, Lewis-Jones, Trivers, Singh, Thornhill, Rohde, Bereczkei, Henzi, Soler, and Szwed (2000). The length of the second- and fourth-digit of each participant’s right hand was recorded with a digital caliper. Measurements were taken twice for each finger and the average ratio was calculated. Both female investigators calculated 2D:4D ratios for 16/39 (41%) participants.
Hand Grip Strength (HGS)

A female investigator recorded left and right hand grip strength for each participant using a handheld \textit{Lafayette Instruments Model 78010} dynamometer. Each participant was instructed to squeeze the dynamometer with their right hand as tightly as possible then did the same with the left hand, alternating between the two hands until 2 two measurements were obtained for each hand. The average of the two HGS measurements (in kilograms) was used in the subsequent analyses.

Contagious Yawning

After anthropometric measurements were recorded, each participant was instructed to watch a yawning video or slideshow. A female investigator recorded the frequency of contagious yawns for each participant. The initial yawning stimuli contained four, 7-second clips of individuals yawning taken from stimuli used by Gallup and Gallup (2007) and Platek, Critton, Myers, And Gallup (2003) to elicit contagious yawns. The yawning videos were displayed on a computer screen, while the investigator unobtrusively observed participants from outside the room. None of the first thirteen participants yawned contagiously in response to the video stimuli. A new yawning stimulus was created using static images of people yawning. Because the length of the first stimulus may have impeded yawns, the new stimulus lasted four minutes. Images of individuals from multiple ethnic backgrounds and ages yawning were embedded within images of other facial expressions and were displayed in a slideshow format using Microsoft\textsuperscript{©} PowerPoint. The second stimulus also failed to elicit contagious yawns at levels that would be expected from previous research (only 4/25 participants yawned).
Therefore, contagious yawning was excluded as a variable from the subsequent analysis due to an insufficient number of yawns.

*Psychological and Behavioral Measures*

Each participant completed a modified paper/pencil version of the Reading the Mind in the Eyes Test (RME; glossary provided) and the paper/pencil version of the Intuitive Physics Test, per the investigators instructions. In addition, participants filled out the following self-report measures independently: The Social Comparison Scales, EAT-26, FNE, Empathizing (EQ) and Systemizing Quotients (SQ-R), and a demographic survey including reproductive variables and family characteristics privately in a testing room within the laboratory.

*Statistical Analysis*

Data from each participant was entered into a spreadsheet and analyzed using SPSS/PAWS version 18.0. An exploratory data analysis revealed that the distribution for scores were normal for every variable, with the exception of the bulimia subscale of the EAT-26. This variable was positively skewed (Kolmogorov-Smirnov Z = 2.197, p = .000) and was not corrected by computing a natural logarithmic transformation of this variable (Kolmogorov-Smirnov Z = 2.486, p = .000). A Spearman rank order correlation was chosen over a Pearson correlation as the preferred method to analyze the relationship between the bulimia subscale and other study variables. A Pearson correlation was used to investigate the relationships between the other study variables. In all of the subsequent analyses, missing values were excluded pairwise.
Results

Mean values for each variable are displayed in Tables 4, 5 and 6. Levels of disordered eating and negative evaluation anxiety were positively correlated with 2D4D ratios \((r = .310, p \leq .05; r = .419, p \leq .01)\). Figures 1 and 2 show the linear relationship between negative evaluation anxiety, disordered eating and 2D4D. The bulimia subscale of the EAT-26 was also positively correlated with digit ratio (Spearman’s rho \(r = .360, p \leq .05\)) as was the appearance surveillance subscale of the Social Comparison Scales \((r = .356, p \leq .05)\). This relationship is depicted in figure 3. The overweight preoccupation subscale was positively correlated with digit ratio, but not significantly \((r = .237, p = .076)\). Because of the significant correlation between disordered eating and social anxiety \((r = .378, p \leq .01)\), a partial correlation between scores on the EAT-26 and digit ratio, was computed controlling for the influence of negative evaluation anxiety. The relationship between disordered eating and 2D4D was not significant after controlling for negative evaluation anxiety \((r = .178 p = .15)\), nor was relationship between the bulimia subscale and 2D4D \((r = .170, p = .162)\). In addition, a non-significant correlation in the predicted direction was obtained for 2D:4D ratio and empathizing bias \((r = .205, p = 115)\).

As WHR increased, so did participants’ BMI \((r = .423, r \leq .01)\). In addition, WHR was positively correlated with scores on the EAT-26, the bulimia subscale and the overweight preoccupation subscale of the Social Comparison Scales \((r = .393, p \leq .01; r = .375 p \leq .01; r = .380, p \leq .01)\). Notably, WHR accounted for 20\% of the total variance in performance on the Reading the Mind in the Eyes Test \((r = -.449, p \leq .001)\). Figure 4 displays the scatterplot representing this relationship. WHR was also negatively associated with empathizing bias \((r = -.296, p \leq .05)\), suggesting that females with more
accentuated hourglass figures performed better on theory of mind tasks and displayed a
cognitive style that favors empathizing over systemizing. As reported earlier, WHR and
BMI were significantly intercorrelated, therefore, a partial correlation was computed
between WHR and the EAT-26, bulimia subscale, overweight preoccupation subscale,
Reading the Mind in the Eyes Test, and empathizing bias. The relationship between
WHR and scores on the bulimia subscale remained significant \( r = .274, p \leq .05 \);
however, the relationship between scores on the EAT-26 and overweight preoccupation
scale and WHR were not \( r = .245, p = .059; r = .192, p = .111 \), respectively, after
controlling for BMI. The magnitude of the relationship between performance on the
Reading the Mind in the Eyes Test remained substantial even after controlling for BMI \( r
= -.446, p \leq .01 \); however; the negative association between WHR and empathizing bias
was no longer significant after controlling for BMI \( r = -.232, p = .081 \). In addition, there
was a significant negative correlation between WHR and performance on the Intuitive
Physics test \( r = -.257, p \leq .046 \) and a positive correlation between disordered eating and
performance on the RME \( r = .231, p = .066 \).

Non-significant correlations in the predicted directed were obtained for Handgrip
Strength for the right hand and scores on the EQ and RME were in the predicted direction
\( r = -.262, p = .056; r = -.239, p = .069 \), respectively). Contrary to the predictions, scores
on the SQ-R were also negatively correlated with right handgrip strength, but not
significantly \( r -.243, p = .073 \) and scores on the intuitive physics test and systemizing
quotient were correlated with the empathizing quotient \( r = .389, p \leq .01; r = .512 p \leq
.001 \).
Scores on the three subscales of the Social Comparison Scales were highly intercorrelated with scores on the EAT-26 and the FNE providing the further evidence of the construct validity of these scales (see Table 8). In addition, weight difference, a variable comprised of the difference between the highest and lowest reported adult weights, stood out as a good predictor of all other measures of disordered eating. Age of menarche did not predict levels of disordered eating, empathy theory of mind or negative evaluation anxiety.

Discussion

The finding that 2D:4D ratios were positively correlated with disordered eating is consistent with previous research and supports a model in which prenatal exposure to testosterone offsets females risk of disordered eating (Joiner, et al., in press; Culbert et al., 2008, Klump, et al., Procopio & Marriot, 2007). However, this may be the first study to test the hypothesis that negative evaluation anxiety is a plausible candidate for the extreme female brain type. This novel prediction was supported. In fact, negative evaluation anxiety accounted for more variance (17.5%) in 2D:4D ratios than disordered eating. In addition, the significant relationship between 2D:4D and the appearance surveillance subscale provides indicates that the relationship between evaluative anxiety and fetal testosterone is not spurious.

Out of 5 published studies investigating the relationship between digit ratios and disordered eating, this study is the first and only attempt to control for potential covariates. When the effects of negative evaluation anxiety were controlled for, the relationship between disordered eating and digit ratios was no longer significant. One interpretation of this finding is that it is possible that disordered eating arises out of
negative evaluation fears. In our culture, obese people *are* evaluated negatively. The intense fear of becoming fat characteristic of eating disorders, may not be the fear of fat itself, but a fear that arises out of the potential to be evaluated disparagingly by others. Research showing that anxiety often precedes and persists after the development of eating disorders is consistent with this idea.

In this sample, 2D:4D ratios were not correlated with theory of mind, empathizing or systemizing. This is consistent with previous research using a sample from the general population (Voracek & Dressler, 2006); however, Van Honk, Shutter, Bos, Krujit, Lentjes, and Baron-Cohen (2011) recently presented data that showing that oral administration of testosterone dampened performance on the Reading the Mind in the Eyes Test among females with low 2D:4D ratios, but did not affect performance among with higher 2D:4D ratios. This suggests that prenatal exposure to testosterone may make the brain more sensitive to the effects of testosterone later in life. Future investigations concerning 2D:4D should focus on the relationship between the negative evaluation anxiety and testosterone levels among men.

In the present study, performance on the Intuitive Physics Test was inversely related to WHR. This goes against predictions. It is possible that women with low WHR’s may be better at inferring the causal forces that act upon objects However it may be that this test may not actually tap into systemizing skills. It was used as an objective, rather than subjective measure of systemizing, but since all of the problems on these tasks can be solved using everyday experience, it may not be an accurate measure of systemizing ability. Future researchers may want to investigate performance on other potential quantitative measures of systemizing abilities.
Conventionally, the adaptive significance of a low WHR has been viewed in light of its relationship to attractiveness and fertility (van Noord-Zaadstra, et al., 1991; Singh, 1993; Furnham et al., 2002; Swami et al., 2006; Dixson et al., 2007). However, Lassek and Gaulin (2008) conceive that adaptive benefits of low WHR provide a direct cognitive advantage to women and their offspring. WHR accounted for 7% of the variance in mother’s cognitive abilities and about 2.7% of the variance in their offsprings’ abilities as measured by performance on cognitive tests.

In the present study, WHR was negatively correlated with performance on the Reading the Mind in the Eyes Test, suggesting that the cognitive advantages afforded by low WHR’s extend into the realm of social intelligence. In addition, females with more accentuated hourglass figures had cognitive styles that favor empathizing over systemizing. This relationship may be a by-product of greater gluteofemoral fat stores among women with low WHR’s. Gluteofemoral fat is the main source of long-chain polyunsaturated fatty acids that are essential for fetal and infant brain development and comprise roughly 20% of human brain volume (Del Prado, Villapando, Lance, Alfonso, Demmelmar, & Kolestzko, 2000).

Gluteofemoral fat is high in long chains of polyunsaturated chains of fatty acids (Phinney, Stern, Burke, Tang, Miller, & Holman, 1994; Pittet, Halliday, & Bateman, 1979). These chains make up a substantial portion human brain volume and theoretically, women with lower WHR’s would have larger stores of these chains.

In addition, when it comes to making mental state attributions, women with low WHR’s would be at an advantage in a number of evolutionarily significant contexts. First, mental state attribution is an important component to mate selection. Most, but not
all, studies on WHR and attractiveness find that, other things being equal, men prefer women with lower WHR’s. Even congenitally blind men display a preference for low WHR. Because low WHR females would be pursued more aggressively by males seeking both short and long-term mates, there would be increasing pressure on low WHR females' ability to accurately gauge the intentions of prospective mates to ensure that they are in line with hers and to reduce the likelihood that she falls victim to dishonest courtship strategies.

Second, males’ evolved preference for low WHR females could make females displaying this characteristic more susceptible to attacks from intrasexual rivals; because females use more covert, indirect types of aggression, low WHR females with superior theory of mind and empathizing skills could better anticipate the actions of their rivals and attempt to dissuade them by relating to or empathizing with their experience; Alternatively, women with superior theory of mind & empathizing skills could create stronger alliances with other females which could also deter attacks from intrasexual rivals.

Finally, mental state attribution and empathy have obvious implications for child rearing. The primary caretaker hypothesis (Babchuk, Hames, & Thompson, 1985), suggests that females will display evolved adaptations that enhance the probability of survival of their offspring and fast & accurate decoding of facial affect is important to respond to needs of preverbal infants and to infer the intentions of adult con-specifics who could threaten their offspring’s well-being & survival.

Although this relationship was not significant, it interesting to note that the correlations among handgrip strength and measures of empathizing were in the predicted
directed. As grip strength increased, scores on the EQ and Reading the Mind in the Eyes Test decreased. In addition, age of menarche was not significantly correlated with empathizing, disordered eating or negative evaluation anxiety. It is possible that the restricted range obtained in this sample may have obscured relationship for this variable (X = 12.37, SD = 1.29).

VI) Study III

Does disordered Eating Differentially affect males and females?

Purpose

The previous studies have investigated disordered eating and negative evaluation anxiety as candidates for the extreme female brain among undergraduate female and male participants. Using both male and female participants represents an advantage compared to investigations that only focus their analysis on one sex; however, it does not provide insight on how disordered eating differentially affects males and females. In addition, Study 1 explored self-report measures of empathizing and systemizing, but the purpose of the present study is to examine performance on objective, rather than self-report measures, of empathizing and systemizing as a function of disordered eating and negative evaluation anxiety and to further investigate whether patterns of disordered eating differentially affect male and females in a way that is consistent with the EFB theory of disordered eating and negative evaluation anxiety.

Participants

160 (74 males; 86 females) undergraduate students at the State University of New York at Albany were recruited from psychology courses. Participants’ age ranged from 18-30 (Mean age = 19.5; S.D. = 1.9) and all participants were fluent in English. The
methods used in this study were approved by the university Institutional Review Board and conformed to guidelines for the ethical treatment of human subjects. All participants gave informed consent. Participants received course credit in exchange for their participation. Due to the anonymous nature of this study, participants with high levels of disordered eating could not be identified for referral to appropriate medical professionals, but a packet of local resources for treatment and support for individuals with concerns about eating disorders was made available to all participants.

**Measures**

Each participant completed a modified paper/pencil version of the Reading the Mind in the Eyes Test (RME; glossary provided) and the paper/pencil version of the Intuitive Physics Test, per the investigators instructions. Participants also filled out the following self-report measures independently: Social Comparison Scales, EAT-26, FNE, Empathizing (EQ) and Systemizing Quotients (SQ-R) and a brief demographic survey in a group setting. Participants were instructed to sit at least one seat apart from each other in a classroom.

**Statistical Analysis**

Data from each participant was entered into a spreadsheet and analyzed using SPSS/PAWS version 18.0. An exploratory data analysis revealed that the distribution for scores were normal for every variable with the exception of EAT-26 scores which were significantly positively skewed \( \text{Kolmogorov-Smirnov } Z(\text{EAT}) = 2.499, p \leq .001 \). This was corrected by transforming EAT-26 scores into their natural logarithm \( \text{Kolmogorov-Smirnov } Z(\text{nEAT}+1) = 1.03, p = .239 \). In the following analyses, Pearson product correlations were computed to analyze relationships between variables for the entire
sample. Significant relationships were further explored using regression analyses and scatterplots. In addition, correlations were computed separately for each gender. General linear model (GLM) univariate analysis of variance procedures were used to explore the differential effects of disordered eating upon gender.

Results

Descriptive statistics for each variable are presented in Table 9. The significant positive correlation between disordered eating and negative evaluation anxiety was replicated ($r = .344, p \leq .001$). Disordered eating was significantly correlated with scores on the empathy quotient ($r = .292, p \leq .001$), but not the systemizing quotient ($r = .119, p = .073$). As predicted, performance on the Reading the Mind in the Eyes Test was positively related to disordered eating ($r = .103, p = .105$), and performance on the Intuitive Physics test was inversely related to disordered eating, but the relationships were not significant ($r = -.086, p = .143$). In addition, scores on the empathizing quotient were positively correlated with performance on the Reading the Mind in Eyes Test ($r = .179, p \leq .05$), the Appearance Surveillance subscale of the Social Comparison Scale ($r = .256, p \leq .001$), the Fear of Negative Evaluation Scale ($r = .136, p \leq .05$), and contrary to the predictions and previous literature, the Systemizing Quotient-Revised ($r = .292, p \leq .001$).

Further exploration revealed that among female participants, disordered eating was significantly related to performance on the Reading the Mind in the Eyes Test ($r = .245, p \leq .05$). Contrary to the predictions, disordered eating was positively correlated with systemizing but not empathizing ($r = .193, p \leq .05; r = .082, p = .232$, respectively). For females, scores on the empathizing quotient were also significantly correlated with
self-reported levels of systemizing and performance on the Intuitive Physics Test \( (r = .368, p \leq .001; r = .229, p \leq .05) \).

The data for male participants revealed disordered eating was positively correlated with empathizing \( (r = .276, p \leq .01) \) and negatively correlated with the objective, but not self-reported measures of systemizing \( (r = -210, p \leq .05; r = .156, p = .100, \text{respectively}) \). In addition, measures of disordered eating were negatively correlated with performance on Reading the Mind in the Eyes test (see figure #) However, among male participants, scores on the empathizing quotient were related to performance on the Reading the Mind in the Eyes test \( (r = .247, p \leq .05) \). Preoccupation with being overweight was positively correlated with empathizing bias \( (r = .224, p \leq .05) \). Bulimic behavior in males was inversely related to performance on both objective measures of cognitive style (Reading the Mind in the Eyes: \( r = -.292, p \leq .01 \); Intuitive Physics: \( r = -.297, p \leq .01 \)).

GLM procedures were utilized to further investigate the relationship between disordered eating, gender and measures of empathizing. Gender and level of disordered eating (high and low determined by scoring at least one standard deviation above the mean for each gender) were entered as fixed factors with performance on the Reading the Mind in the Eyes Test entered as the dependent variable. A two-way analysis of variance revealed a significant interaction between gender and level of disordered eating \( (F = 9.86, p \leq .01) \). A similar result was obtained when empathizing quotient scores were entered as the dependent variable \( (F = 5.513, p \leq .05) \) revealing that the effects of disordered eating on both objective and self-reported measures of empathizing depend upon gender (see figures 5 & 6).
Discussion

In this study, within a sample of undergraduate men and women, the previously reported association between disordered eating and empathizing was replicated. In addition, empathizing was correlated with an objective measure of theory of mind and two different measures of evaluation anxiety. The present findings are consistent with a model of the extreme female brain type that includes elevated levels of evaluation anxiety and disordered eating in its pathology.

There was a significant interaction between gender, disordered eating and theory of mind. Females with high levels of disordered eating performed better on the Reading the Mind in the Eyes test, but males with high levels of disordered performed worse. This suggests that the consequences of disordered eating depend upon gender. Eating disorders and concerns about weight and body image are more common in women than men. Therefore, high levels of disordered eating in females may be less likely to reach a level of clinical significance. It may be that the cognitive effects associated with disordered eating are more pronounced in males. Consistent with that interpretation, although the rates of autism are higher among males than females, females tend to be more severely impaired (Wing, 1981) and that while moderately high levels of disordered eating are associated with a cognitive advantage on theory of mind tasks, extremely high levels are detrimental, because the physiological consequences of disordered eating are producing cognitive or neuropsychological deficits.

In addition, there was a significant interaction between disordered eating, gender, empathizing. In females, levels of disordered eating did not influence empathizing scores, but males with high levels of disordered eating displayed greater empathizing. This
finding is partially consistent with the idea the disordered eating is associated with the hyper-empathizing that characterizes the extreme female brain type. Supporting this hypothesis, scores on the overweight preoccupation scale were associated with empathizing bias among males and the bulimia subscale of the EAT-26 was inversely related to scores on the intuitive physics test.

The results from male participants provide further support for the extreme female brain theory of disordered eating; however, the results from the female participants are not as clear. In this sample, disordered eating was associated with systemizing ability in females. It may be that the association between systemizing ability and disordered eating reflects a relationship that is learned, rather than a difference in cognitive style that is driven by sexually differentiated brain types. Females with high levels of disordered may be more motivated to perform well, ostensibly because of negative evaluation fears or the drive for perfectionism that is common among individuals with eating disorders (Hewitt, Flett, & Ediger, 1995). Because the rules of systems are fixed, rather than dynamic, it is possible that it easier to acquire the skills needed to become a good systemizer more easily than it would be for an individual to learn how to become a good empathizer, although this is purely speculation.

Nevertheless, the finding that certain aspects of social cognition are differentially affected by disordered eating warrants further investigation as most studies comparing women and men with eating disorders cite more similarities than differences, but have mostly investigated affective (depression and anxiety), rather than cognitive variables (theory of mind and empathizing) that are influenced by disordered eating. (Oliviadra,
VII) Study IV:

Disordered Eating and Negative Evaluation Anxiety as a Function of Schizotypal Personality Characteristics

Purpose

Crespi and Badcock (2008) proposed that Autism and Psychotic Disorders represent the pathological extremes of individual differences in the cognitive dimensions that define the social brain, tracing these differences to the differential effects of imprinted genes. This view compliments the divisions among brain types described by Baron-Cohen, as they divide cognition into “mechanistic” (concerned with things) and “mentalistic” (concerned with people). While schizophrenia does not affect more females than males, females display more positive symptoms of schizophrenia than males (Gur, Petty, Turetsky, & Gur, 1996). Thus, the goal of the present study is to assess schizotypal personality characteristics as a function of disordered eating and negative evaluation anxiety. Demonstrating such an association would support Crespi and Badcock’s (2008) theory and provide additional support for these variables as candidates for the EFB. The present study tests the hypothesis that an EFB profile should be associated with more positive symptoms of schizotypy, including ideas of reference, suspiciousness, and odd beliefs/magical thinking.
Participants

42 (20 males; 22 females) undergraduate students at the State University of New York at Albany were recruited from psychology courses. Participants’ age ranged from 18-22 (Mean age = 19.2; S.D. = 1.2) and all participants were fluent in English. The methods used in this study were approved by the university Institutional Review Board and conformed to guidelines for the ethical treatment of human subjects. All participants gave informed consent. Participants received course credit in exchange for their participation. Due to the anonymous nature of this study, participants with high levels of disordered eating could not be identified for referral to appropriate medical professionals, but a packet of local resources for treatment and support for individuals with concerns about eating disorders was made available to all participants.

Measures

Participants filled out the following self-report measures independently: EAT-26, FNE, Empathizing Quotients (EQ) and the Schizotypal Personality Questionnaire (SPQ) and a brief demographic survey privately in a testing room within the laboratory.

Statistical Analysis

Data from each participant was entered into a spreadsheet and analyzed using SPSS/PAWS version 18.0. An exploratory data analysis revealed that the distribution for scores were normal for every variable with the exception of the bulimia subscale of the EAT-26 which was positively skewed for males only (Kolmogorov-Smirnov Z(bulimia) = 1.514, p ≤ .05). This was not corrected by transforming bulimia scores into their natural logarithm, therefore a Spearman rank order correlation was used for this variable in the following analyses. For all other analyses, Pearson product correlations were computed to
analyze relationships between variables. Significant correlations were investigated further using regression analyses and scatterplots.

**Results**

Descriptive statistics for Study IV are depicted in table 10. Negative evaluation anxiety was significantly correlated with total SPQ scores ($r = .388$, $p \leq .01$). This linear relationship is represented in figure 6. In addition, negative evaluation anxiety was correlated with disordered eating ($r = .280$, $p \leq .05$) and five of the nine SPQ subscales including: *Ideas of Reference*, *Social Anxiety*, *Odd Beliefs* and *Magical Thinking*, *Constricted Affect*, and *Suspiciousness*.

Disordered eating was positively correlated with three of the nine subscales including: *Ideas of Reference*, *Odd beliefs and Magical Thinking*, and *Suspiciousness* (see table ##). In addition, there was a significant positive correlation between scores on the bulimia subscale and positive schizotypal traits including *Ideas of reference* ($r = .280$ $p \leq .05$) and *Suspiciousness* ($r = .391$, $p \leq .01$). In addition, the correlation between empathizing scores and disordered eating obtained in Study III was replicated ($r = .321$, $p \leq .05$). There was also a significant positive correlation between scores on the EAT-26, the bulimic subscale and the empathizing quotient ($r = .321$, $p \leq .05$; $r = .258$ $p \leq .05$, respectively). In males, but not females, there was a significant negative correlation between scores on the EAT-26 and *Constricted Affect* ($r = -.455$, $p \leq .05$).

Schizotypal personality traits were not positively correlated with empathizing, which would be consistent with the results obtained by Brosnan, Ashwin, Walker and Donaghue (2010). In fact, empathizing was negatively correlated with the constricted
affect subscale ($r = -0.286, p \leq 0.05$). Other non-significant correlations were obtained between empathizing and SPQ subscales (see table 11).

Discussion

Schizotypy was significantly associated with negative evaluation anxiety and disordered eating. Five of the nine subscales of the SPQ and SPQ total scores were associated with negative evaluation anxiety. Three of the SPQ subscales were significantly associated with disordered eating. Ideas of reference involve mistaken attributions that causal incidents and external events have direct reference to oneself (APA, 2000). They are essentially mental state misattributions. The tendency to over-attribute relevance to external events may represent a type of hyper-mentalizing that would be predicted EFB theory.

Suspiciousness is the belief that one is being persecuted against or treated unfairly (APA, 2000). The nature of the relationship between suspiciousness, disordered eating, negative evaluation may represent another example of mental state misattribution in which neutral social interactions are interpreted negatively. In addition, the tendency to infer that one is being specifically targeted or treated unfairly may closely approximate negative evaluation fears.

The final subscale that was associated with both disordered eating and negative evaluation anxiety was the odd beliefs and magical thinking subscale, which measures how odd beliefs, such as the belief in telepathy, and magical thinking that influence behavior. Interestingly, telepathy relates to the ability to read other people’s mental states. To a person that excels at theory of mind, telepathy may not be such an odd belief. It is not surprising then, that the extreme female brain type would be associated with a
certain kinds of odd beliefs and magical thinking. In addition, negative evaluation anxiety was associated with the social anxiety and the constricted affect subscales of the SPQ. Although, the social anxiety present in schizotypal personality disorder involves anxiety associated with paranoid fears rather than negative judgments, this finding suggests there is some convergence between the two different types of anxiety.

For males, disordered eating was also negatively related to constricted affect. Constricted affect is characterized by blunted emotional reactivity. This indicates that males with higher levels of disorder eating were more emotionally reactive than males with lower levels of disordered eating. There are gender differences in emotional reactivity that find female are more reactive than males (Muncer & Ling, 2006). Greater emotional reactivity may also be a significant component of empathy. Garnering the appropriate emotional response to other people’s experiences hinges upon being able to “feel” what another person is feeling. This is also supported by the finding in the present study that constricted affect was the only schizotypy variable that significantly correlated with empathizing. Thus, the fact that males responded in a more characteristically feminine way as a function of disordered eating provides further evidence of the relationship between disordered eating and negative evaluation anxiety as potential candidates for the extreme female brain.

Finally, the only published study in the nine years since Baron-Cohen (2002) extended the extreme male brain theory of autism and outlined the existence of different brain types, that investigated potential profile of the EFB was performed by Brosnan, et al., (2010) who investigated psychosis, depression, and general anxiety as a function of empathizing and systemizing abilities. In a sample of 70 undergraduate females, they
found a significant relationship between psychosis, specifically, mania and paranoia, and measures of empathizing, but not systemizing. The relationships between anxiety and depression were not significant. Empathizing bias was also moderately correlated with mania and paranoia. These findings are not inconsistent data presented here, particularly in light of the relationships between negative evaluation anxiety, disordered eating and the suspiciousness and ideas of reference subscales of the SPQ. However, psychosis, by itself, may not fully represent the profile of the EFB. For instance, rates of schizophrenia do not differentially affect females over males.

VIII) General Discussion

The set of studies described above provide preliminary support for the hypothesis that a combination of disordered eating and negative evaluation anxiety are associated with a cognitive style that is consistent with the extreme female brain type.

Across 4 studies there was a significant relationship between disordered eating and negative evaluation anxiety. Among females, disordered eating and negative evaluation anxiety were both associated with second- to fourth-digit ratio, an indirect measure of fetal testosterone levels. More masculinized digit ratios protected against disordered eating and negative evaluation anxiety. While this is the sixth study to report a significant correlation between digit ratio and disordered eating, this is the first time confounding variables, such as negative evaluation anxiety have been controlled for. When the influence of evaluation anxiety was controlled for, the relationship between digit ratio and disordered eating was no longer significant. Previous research has demonstrated that social and evaluative anxiety often precedes the development of eating disorders and that
co-morbidity of anxiety serves as a risk factor contributing to a less favorable outcome (Steinhausen, 2002; Kaye, et al., 2004).

The distinction between social apathy and social anxiety may be a complimentary way to conceive empathizing/systemizing cognitive styles outlined by Baron-Cohen (2002; 2003). Autism, the prevailing model of the extreme male brain type, is characterized by social deficits; however, it is unclear what causes these deficits. The most widely documented neuroanatomical finding in autism research is the hypoactivation of the fusiform gyrus/fusiform face area (FFA) in response to facial stimuli (Grelotti, Gauthier, & Schulz, 2002). The dampened response of the fusiform gyrus faces has been regularly interpreted as a neural dysfunction that contributes to the pronounced social deficits in autism. However, a case study conducted by Grelotti, Klin, Gauthier, Skudlarski, Cohen, Gore, Volkmar, & Schultz (2005) showed normal activation in the FFA in response to pictures of preferred cartoon characters, but not to faces of familiar people in a young boy with autism. This suggests the hypoactivation of the FFA in response to faces, but intact activation in response to preferred objects, is not a sign of dysfunction, rather it is a sign of disinterest. Therefore, it is important to consider the role that apathy plays in the social deficits that characterize autism. Conversely, social anxiety, particularly evaluation anxiety, may represent a salient feature of the extreme female brain type. The intense fear of becoming fat, a defining feature of eating disorders, may not be the fear of fat itself, but a fear that arises from the potential to be evaluated disparagingly by others. Disordered eating, then, may be one way in which negative evaluation fears manifest.

Aside from preventing negative evaluation by others, what possible function does
disordered eating serve? In other words, why is disordered eating the way that negative evaluation fears are expressed? If the extreme female brain results from a deviant pattern of sexual differentiation, whereby the developing brain is exposed to little or no testosterone, the result may be an adult brain that expresses elevated levels of circulating estrogens, progesterone, and even oxytocin. Consistent with this idea, Van Honk, et al., (2011) showed that oral administration of testosterone dampened performance on the Reading the Mind in the Eyes Test among females with low 2D:4D ratios, but did not affect performance among with higher 2D:4D ratios. This suggests that prenatal exposure to testosterone may make the brain more sensitive to the effects of testosterone later in life. It is possible, that the absence of prenatal exposure to testosterone has a similar sensitizing the brain to the activational effects of estrogen, progesterone, and oxytocin. Heightened levels of these hormones at puberty may sensitize the brain to social stimuli at critical periods of development and as a consequence, individuals with an extreme female brain possesses greater levels of empathetic responsiveness. In effect, a person with an extreme female brain may empathize to a fault, which may lead to neglecting their own needs for the needs of others.

Comparable to the heightened sensitivity to sensory stimuli (auditory, visual and tactile) that is common among people with autism, individuals with the extreme female brain may be hypersensitive to social stimuli. Disordered eating may ameliorate the experience of negative evaluation anxiety that results from heightened sensitivity to social stimulation.

An interesting consequence of eating disorders is the profound decrease in the level of estrogen (Sharp & Freeman, 1993). The changes in estrogen levels are responsible for
amenorrhea, one of the defining characteristics in anorexic women. A significant drop in estrogen levels may produce changes in empathizing and theory of mind performance. Consistent with this idea, emotional processing deficits have been linked with eating disorders including the inability to recognize, label and describe emotions in detail and to link feelings with bodily correlates (Garner, Olmsted, & Polivy, 1983; Bourke, Taylor, Parker and Bagby, 1992; Eizaguirre, de Cabezon, de Alda, Olariaga & Juaniz, 2004). These deficits also predict outcomes at 3 years (Speranza, Loas, Wallier, & Corcos, 2007). Also, compared to healthy controls, women with anorexia had difficulty recognizing emotions from facial expressions and vocal tones (Jansch, Harmer & Cooper, 2009; Kucharska-Pietura, Masiak, and Treasure, 2003).

Jones, Harmer, Cowen and Cooper (2008) investigated emotional face processing in female undergraduates with high and low levels of disordered eating. Participants completed the Eating Attitudes Test-26 and the Facial Expression Recognition Task, a computer task in which participants view faces depicting 7 different expressions (anger, disgust, fear, happiness, sadness, surprise, and neutral) at different intensities on a computer screen. The participants with higher levels of disordered eating were significantly less accurate in identifying happy and neutral faces. Among participants with high-levels of disordered eating, there was a tendency to classify more happy faces as neutral, and more neutral faces either angry or sad. In addition, there was some evidence to suggest that their reaction times to recognize disgust were longer, while reaction times to recognize fear were faster than participants with low-levels of disordered eating. When disordered eating reaches clinical levels, the effects of hypermentalizing may manifest as mental state misattributions. This may be because they
are using their own experience to model others and their tendency to classify emotions with a negative bias may be influencing their attributions. For instance, when shown pictures of women who are said to have overeaten, females with high levels of disordered eating inferred more negative feelings to others (Beebe, Holmbeck Schober, Lane, Rosa, 1996).

It is also possible that the physiological and cognitive effects of starvation are producing deficits in performance. In a study looking at performance on the Reading the Mind in the Eyes Test, individuals with anorexia performed worse compared to healthy controls (Russell, Schmidt, Doherty, Young & Tchanturia, 2009). This finding is consistent with the results obtained in Study III, in which males with higher levels of disordered eating performed worse on the Reading the Mind in the Eyes task, but still displayed heightened levels of empathizing. Since eating disorders affect fewer males than females, it is possible that males that scored in the high range had more severe patterns of disordered eating. If so, the detrimental consequences of disordered eating may have inhibited performance.

An alternative interpretation is that low scores on the Reading the Mind in the Eyes task does not represent deficits in theory of mind ability. Instead, the theory of mind errors made by males with high levels of disordered eating may not represent the absence of mental state attributions, but rather an excess that reflects hyper-mentalizing. This interpretation is consistent with the results obtained in Study IV looking at levels of schizotypy in disordered eating. Abu-Akel, (2003) suggests that theory of mind dysfunctions range from having no representation or conceptual understanding of mental states to having a representational understanding of mental states, but a deficit in the
ability to apply this understanding in the correct setting, to the abnormal attribution of mental states. It may be this third class of dysfunction that is being misconstrued as a “deficit,” rather than an excess in previous studies on theory of mind in eating disorders.

Another area for future research to investigate is the role of self-awareness in theory of mind and psychopathology. Most models of theory of mind and empathizing view self-awareness as a closely related construct because we use our own experience to model the experiences of others. Individuals with eating disorders and individuals with autism spectrum conditions show evidence for deficits in self-awareness. In autism, mirror self-recognition, a proxy for self-awareness, is developmentally delayed or absent (Dawson & McKissick, 1984; Spiker & Ricks, 1984).

Recently, a study of individuals with anorexia shows that self-awareness may be actively suppressed in patients with eating disorders. Sachdev, Mondraty, Wen & Gulliford (2009) used fMRI to examine how self-image and non-self images are processed in individuals with anorexia and healthy controls. They found that the processing of non-self images was similar in both groups, but processing of self-images in the anorexic group led to no significant activation of brain regions compared to healthy controls which showed significant activation in the insula and prefrontal cortex. The almost complete absence of activation to self-images could suggest that cognitive, emotional, and perceptual processing may have been suppressed in patients with anorexia and that this could contribute to the body image distortion that characterizes the disorder.

It is possible that individuals with eating disorders actively suppress self-awareness. Heatherton & Baumeister (1991) proposed that binge eating could be motivated by the desire to escape self-awareness. They argue that individuals that engage in binge eating
are acutely sensitive to the demands of others and set extremely high expectations for themselves. When they fail to meet their own expectations, they develop an aversive pattern of high self-awareness, concern over how they appear to others and emotional distress. Binge eating and the loss of inhibition associated with it provide temporary relief from self-awareness.

The observation of theory of mind dysfunctions does not preclude eating disorders from representing the extreme female brain. Rather, it warrants closer examination of the source of the dysfunction. In autism spectrum conditions, theory of mind deficits may be driven by an aberrant pattern of brain development associated with social apathy that is rooted the organizational effects of early testosterone exposure. The theory of mind dysfunction observed in eating disorders maybe driven by aberrant patterns of brain development associated with social anxiety, which is further exacerbated during critical periods of development (i.e., puberty). Further examination of the role of self-awareness and theory of mind as a function of disordered eating may further elucidate the neurocognitive and developmental mechanisms involved. The results of the present studies provide evidence that supports disordered eating and negative evaluation anxiety may provide a candidate model of the extreme female brain. Incorporating the knowledge of empathizing/systemizing distinctions may help guide the development of effective interventions for disorders that rest on the extremes of these variables.
### IX) Tables and Figures

#### Table 1

**Descriptive Statistics for Study I: Measures of Disordered Eating and Negative Evaluation Anxiety and Cognitive Style**

<table>
<thead>
<tr>
<th>Measure (n)</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAT-26 (nLEAT + 1) (121)</td>
<td>9.09 (2.01)</td>
<td>8 (.82)</td>
<td>0-40 (0-3.71)</td>
</tr>
<tr>
<td>Bulimia Subscale (120)</td>
<td>1.13</td>
<td>2.1</td>
<td>1-11</td>
</tr>
<tr>
<td>FNE (119)</td>
<td>12.61</td>
<td>8.21</td>
<td>0-30</td>
</tr>
<tr>
<td>EQ(118)</td>
<td>37.43</td>
<td>11.38</td>
<td>13-69</td>
</tr>
<tr>
<td>SQ-R(116)</td>
<td>57.93</td>
<td>16.75</td>
<td>31-112</td>
</tr>
<tr>
<td>EB(116)</td>
<td>.041</td>
<td>1.11</td>
<td>-2.81-2.51</td>
</tr>
</tbody>
</table>

*Note. EAT-26=Eating Attitudes Test; FNE=Fear of Negative Evaluation; EQ=Empathizing Quotient; SQ-R=Systemizing Quotient-Revised; EB=Empathizing Bias*
Table 2  
*Descriptive Statistics for Study I: Sex Differences in Levels of Disordered Eating, Negative Evaluation Anxiety and Cognitive Style*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Females mean ± sd</th>
<th>Males mean ± sd</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAT-26 (nLEAT + 1)</td>
<td>11.54 ± 9.15 (2.23 ± .85)</td>
<td>5.85 ± 4.47 (1.71 ± .69)*</td>
</tr>
<tr>
<td>Bulimia Subscale</td>
<td>1.47 ± 2.38</td>
<td>.69 ± 1.57</td>
</tr>
<tr>
<td>FNE</td>
<td>14.66 ± 8.50</td>
<td>9.88 ± 6.9 *</td>
</tr>
<tr>
<td>EQ</td>
<td>42.39 ± 10.7</td>
<td>31.13 ± 8.88*</td>
</tr>
<tr>
<td>SQ-R</td>
<td>55.49 ± 14.50</td>
<td>61.04 ± 18.93</td>
</tr>
<tr>
<td>EB</td>
<td>.603 ± .92</td>
<td>-.67 ± .92*</td>
</tr>
</tbody>
</table>

Note. EAT-26 = Eating Attitudes Test; FNE = Fear of Negative Evaluation; EQ= Empathizing Quotient; SQ-R = Systemizing Quotient-Revised; EB= Empathizing Bias  
*p ≤ .008
Table 3
Study I: Spearman rho correlations (n) Between Disordered Eating, Negative Evaluation Anxiety and Cognitive Style

<table>
<thead>
<tr>
<th>Variable</th>
<th>EAT-26 (nlEAT+1)</th>
<th>Bulimia</th>
<th>FNE</th>
<th>EQ</th>
<th>SQ-R</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAT-26 (nlEAT+1)</td>
<td>.552** (120)</td>
<td>.329** (119)</td>
<td>.272** (118)</td>
<td>.091 (116)</td>
<td>.173* (116)</td>
<td></td>
</tr>
<tr>
<td>Bulimia</td>
<td>.310** (118)</td>
<td>.042 (117)</td>
<td>-.008 (115)</td>
<td>.016 (116)</td>
<td></td>
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</tr>
<tr>
<td>FNE</td>
<td>.137 (116)</td>
<td>-.023 (114)</td>
<td>.157* (114)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EQ</td>
<td>.334* (116)</td>
<td>.632** (116)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SQ-R</td>
<td>-.479** (116)</td>
<td></td>
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Note. EAT-26 = Eating Attitudes Test; FNE = Fear of Negative Evaluation; EQ = Empathizing Quotient; SQ-R = Systemizing Quotient-Revised; EB = Empathizing Bias
* p ≤ .05
** p ≤ .001
Table 4  
*Descriptive Statistics for Study II: Anthropometric Markers of Feminine Endocrine Status*

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<tr>
<th>Anthropometric Variables (n)</th>
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<th>Range</th>
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</thead>
<tbody>
<tr>
<td>WHR (46)</td>
<td>.724</td>
<td>.064</td>
<td>.623-.937</td>
</tr>
<tr>
<td>2D:4D (39)</td>
<td>.981</td>
<td>.032</td>
<td>.916-1.070</td>
</tr>
<tr>
<td>Right HGS (40)</td>
<td>25.99</td>
<td>5.53</td>
<td>17.00-39.50</td>
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<tr>
<td>Left HGS (40)</td>
<td>24.03</td>
<td>5.64</td>
<td>14.00-36.50</td>
</tr>
<tr>
<td>BMI (44)</td>
<td>22.834</td>
<td>3.845</td>
<td>16.79-34.93</td>
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Table 5
*Descriptive Statistics for Study II: Objective Measures of Cognitive Style*

<table>
<thead>
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<th>Cognitive Tasks (n)</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td>Reading the Mind in the Eyes (45)</td>
<td>26.44</td>
<td>4.06</td>
<td>19-34</td>
</tr>
<tr>
<td>Intuitive Physics (44)</td>
<td>9.14</td>
<td>2.54</td>
<td>3-15</td>
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Table 6
*Descriptive Statistics for Study II: Psychological Measures*

<table>
<thead>
<tr>
<th>Psychological Measures (n)</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Range</th>
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<tbody>
<tr>
<td>EAT-26 (121)</td>
<td>9.09</td>
<td>8</td>
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<td>EB (116)</td>
<td>.041</td>
<td>1.11</td>
<td>-2.81-2.51</td>
</tr>
<tr>
<td>Social Comparison (42)</td>
<td>5.92</td>
<td>2.28</td>
<td>1-10</td>
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<tr>
<td>Appearance Surveillance (43)</td>
<td>7.53</td>
<td>5.08</td>
<td>1-21</td>
</tr>
<tr>
<td>Overweight Preoccupation (43)</td>
<td>6.51</td>
<td>5.74</td>
<td>0-21</td>
</tr>
</tbody>
</table>

Note. EAT-26 = Eating Attitudes Test; FNE = Fear of Negative Evaluation; EQ = Empathizing Quotient; SQ-R = Systemizing Quotient-Revised; EB = Empathizing Bias
Table 7
*Study II: Pearson Correlations between WHR and Disordered Eating, Cognitive Tasks and Empathizing Bias*

<table>
<thead>
<tr>
<th></th>
<th>EAT-26</th>
<th>Bulimia</th>
<th>OWP</th>
<th>EYES</th>
<th>INPH</th>
<th>EB</th>
<th>WTDIFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHR</td>
<td>.393**</td>
<td>.375*</td>
<td>.380**</td>
<td>-.449**</td>
<td>-.253</td>
<td>.296*</td>
<td>.432**</td>
</tr>
<tr>
<td>WHR/Controlling for BMI</td>
<td>.245</td>
<td>.274*</td>
<td>.192</td>
<td>-.446**</td>
<td>-.193</td>
<td>-.232</td>
<td>.407**</td>
</tr>
</tbody>
</table>

*Note. EAT-26=Eating Attitudes Test; OWP=Overweight Preoccupation Scale; EYES=Reading the Mind in the Eyes Test INPH=Intuitive Physics Test; EB=Empathizing Bias; WTDIFF=Adult weight variability*

* p ≤ .05
** p ≤ .01
Table 8
*Study II: Pearson Correlations (n) between Disordered Eating, Evaluation Anxiety, & Social Comparison*

<table>
<thead>
<tr>
<th>Variable</th>
<th>EAT-26</th>
<th>Bulimia</th>
<th>FNE</th>
<th>AS</th>
<th>OWP</th>
<th>SC</th>
<th>WTDIFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAT-26</td>
<td>.778** (43)</td>
<td>.378** (43)</td>
<td>.506** (42)</td>
<td>.668** (42)</td>
<td>.481** (42)</td>
<td>.514** (43)</td>
<td></td>
</tr>
<tr>
<td>Bulimia</td>
<td></td>
<td>.459** (42)</td>
<td>.456** (42)</td>
<td>.517** (42)</td>
<td>.452** (42)</td>
<td>.432* (43)</td>
<td></td>
</tr>
<tr>
<td>FNE</td>
<td></td>
<td></td>
<td>.542** (43)</td>
<td>.417* (43)</td>
<td>.406* (42)</td>
<td>.296 (42)</td>
<td>.303 (42)</td>
</tr>
<tr>
<td>AS</td>
<td></td>
<td></td>
<td></td>
<td>.521* (43)</td>
<td>.561** (42)</td>
<td>.303 (42)</td>
<td></td>
</tr>
<tr>
<td>OWP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.553** (42)</td>
<td>.666** (42)</td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.297 (42)</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* EAT-26=Eating Attitudes Test; FNE =Fear of Negative Evaluation; AP=Appearance Surveillance; OWP=Overweight Preoccupation; SC=Social Comparison; WTDIFF=Adult Weight Variability

** p ≤ .001
Table 9
Descriptive Statistics for Study III: Measures of Disordered Eating, Social Anxiety and Cognitive Style

<table>
<thead>
<tr>
<th>Measure</th>
<th>Total Sample</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M ± SD</td>
<td>M ± SD</td>
<td>M ± SD</td>
</tr>
<tr>
<td>EAT-26 (nlEAT + 1)</td>
<td>9.4 ± 8.8</td>
<td>6.25 ± 6.37</td>
<td>12.12 ± 9.77</td>
</tr>
<tr>
<td>Bulimia Subscale</td>
<td>1.25 ± 2.43</td>
<td>.85 ± 2.16</td>
<td>1.6 ± 2.61</td>
</tr>
<tr>
<td>WTDFF</td>
<td>27.96 ± 17.7</td>
<td>31.25 ± 16.3</td>
<td>25.11 ± 18.42</td>
</tr>
<tr>
<td>FNE</td>
<td>12.75 ± 7.56</td>
<td>10.57 ± 6.5</td>
<td>14.64 ± 8.29</td>
</tr>
<tr>
<td>AS</td>
<td>6.67 ± 4.4</td>
<td>5.4 ± 3.76</td>
<td>7.76 ± 4.62</td>
</tr>
<tr>
<td>OWP</td>
<td>6.25 ± 5.63</td>
<td>4.16 ± 4.3</td>
<td>8.05 ± 6.01</td>
</tr>
<tr>
<td>INPH</td>
<td>9.66 ± 2.63</td>
<td>10.35 ± 2.5</td>
<td>9.07 ± 2.63</td>
</tr>
<tr>
<td>EYES</td>
<td>25.76 ± 3.94</td>
<td>25.17 ± 4.12</td>
<td>26.25 ± 3.73</td>
</tr>
<tr>
<td>EQ</td>
<td>35.77 ± 11.2</td>
<td>28.86 ± 8.89</td>
<td>41.04 ± 10.44</td>
</tr>
<tr>
<td>SQ-R</td>
<td>56.83 ± 17.52</td>
<td>59.43 ± 18.65</td>
<td>54.62 ± 16.28</td>
</tr>
<tr>
<td>EB</td>
<td>.018 ± 1.07</td>
<td>.05 ± 1.00</td>
<td>-.01 ± 1.125</td>
</tr>
</tbody>
</table>

Note. EAT-26=Eating Attitudes Test; WTDFF=Adult Weight Variability; FNE =Fear of Negative Evaluation; AP=Appearance Surveillance; OWP=Overweight Preoccupation; INPH=Intuitive Physics Test; EYES=Reading the Mind in the Eyes test; EQ=Empathizing Quotient; SQ-R=Systemizing Quotient-Revised; EB=Empathizing Bias
Table 10

Descriptive Statistics for Study IV: Disordered Eating, Negative Evaluation Anxiety and Schizotypal Personality Characteristics

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAT-26</td>
<td>11.52</td>
<td>10.8</td>
<td>0-60</td>
</tr>
<tr>
<td>Bulimia Subscale</td>
<td>1.9</td>
<td>2.9</td>
<td>0-15</td>
</tr>
<tr>
<td>FNE</td>
<td>15.93</td>
<td>9.2</td>
<td>1-38</td>
</tr>
<tr>
<td>EQ</td>
<td>31.83</td>
<td>9.1</td>
<td>16-62</td>
</tr>
<tr>
<td>SPQ-Total</td>
<td>27.08</td>
<td>12.67</td>
<td>0-58</td>
</tr>
<tr>
<td>Ideas of Reference</td>
<td>4.02</td>
<td>2.21</td>
<td>0-8</td>
</tr>
<tr>
<td>Social Anxiety</td>
<td>4.05</td>
<td>2.4</td>
<td>0-8</td>
</tr>
<tr>
<td>Odd Beliefs/Magical Thinking</td>
<td>1.6</td>
<td>1.62</td>
<td>0-7</td>
</tr>
<tr>
<td>Unusual Perceptual Experiences</td>
<td>2.64</td>
<td>2.13</td>
<td>0-7</td>
</tr>
<tr>
<td>Eccentric/Odd Behavior</td>
<td>2.26</td>
<td>2.23</td>
<td>0-7</td>
</tr>
<tr>
<td>No Close Friends</td>
<td>2.86</td>
<td>2.29</td>
<td>0-8</td>
</tr>
<tr>
<td>Odd Speech</td>
<td>3.57</td>
<td>2.43</td>
<td>0-9</td>
</tr>
<tr>
<td>Constricted Affect</td>
<td>2.88</td>
<td>1.69</td>
<td>0-7</td>
</tr>
<tr>
<td>Suspiciousness</td>
<td>3.55</td>
<td>2.2</td>
<td>0-8</td>
</tr>
</tbody>
</table>

Note. *n = 42 EAT-26=Eating Attitudes Test; FNE=Fear of Negative Evaluation; EQ=Empathizing Quotient; SPQ-Total=Total scores on the Schizotypal Personality Questionnaire
Table 11
Study VI: Significant Correlations Between Disordered Eating, Social Anxiety, and Schizotypal Personality Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>SPQ-Total</th>
<th>Ideas</th>
<th>Anxiety</th>
<th>Odd/Magical</th>
<th>Percept</th>
<th>Odd Behavior</th>
<th>No Close Friends</th>
<th>Odd Speech</th>
<th>Constrict</th>
<th>Suspicious</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAT-26</td>
<td>.112</td>
<td>.263*</td>
<td>-.056</td>
<td>.257*</td>
<td>-.089</td>
<td>-.300</td>
<td>.041</td>
<td>-.098</td>
<td>-.074</td>
<td>.333*</td>
</tr>
<tr>
<td>Bulimia</td>
<td>.182</td>
<td>.280*</td>
<td>.021</td>
<td>.221</td>
<td>-.079</td>
<td>.078</td>
<td>.099</td>
<td>.137</td>
<td>.105</td>
<td>.391**</td>
</tr>
<tr>
<td>FNE</td>
<td>.388**</td>
<td>.312*</td>
<td>.454**</td>
<td>.243</td>
<td>.134</td>
<td>-.089</td>
<td>.200</td>
<td>.084</td>
<td>.323*</td>
<td>.293*</td>
</tr>
<tr>
<td>EQ</td>
<td>-.249</td>
<td>.027</td>
<td>-.265*</td>
<td>.018</td>
<td>-.176</td>
<td>-.223</td>
<td>.303</td>
<td>-.246</td>
<td>-.286*</td>
<td>.057</td>
</tr>
</tbody>
</table>

Note. EAT-26=Eating Attitudes Test; FNE =Fear of Negative Evaluation; EQ=Empathizing Quotient; SPQ-Total=Total scores on the Schizotypal Personality Questionnaire

*p ≤ .05

**p ≤ .01

Figure 1.
The Linear Relationship Between Negative Evaluation Anxiety and Digit Ratio

Figure 2.

Negative Evaluation Anxiety as a Function of 2D4D

$R^2\,\text{Linear} = 0.175$
The Linear Relationship Between Disordered Eating and Digit Ratio

Disordered Eating as a Function of 2D4D Ratio

\[ r^2 \text{ Linear} = 0.096 \]
Figure 3.
The Linear Relationship Between Appearance Surveillance and Digit Ratio

[Diagram showing the linear relationship between Appearance Surveillance and 2D4D, with a correlation coefficient of R² = 0.127]
Figure 4.
*The Linear Relationship Between Waist-to-Hip Ratio and Theory of Mind*

*Reading the Mind in the Eyes as a Function of WHR*

R² Linear = 0.201
Figure 5.
The Interaction Between Disordered Eating, Gender and Theory of Mind
Figure 6.
The Interaction Between Disordered Eating, Gender and Empathizing

![Graph showing the interaction between disordered eating, gender, and empathizing quotient. The x-axis represents disordered eating levels (low, high), and the y-axis represents mean scores on the empathizing quotient. The graph compares males and females.](image)

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Figure 7.

*The Linear Relationship Between Evaluation Anxiety and Schizotypy*
References


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systemizing quotient-revised (SQ-R) and Empathy Quotient (EQ). Brain Research, 1079, 47-56.


