when used in combination, extinction becomes more effective. Additionally, the use of reinforcement procedures to strengthen appropriate behaviors is part of best clinical practice.

Future Directions

Extinction is considered a treatment for problem behaviors that is not aversive and acceptable to most staff. It is not as regulated as other more intrusive procedures, such as time-out or overcorrection. Although researchers have investigated the role of clinical treatment with and without implementing extinction procedures, the results remain ambiguous. Identification of behavior classes and/or environmental conditions under which extinction is necessary or optimal in clinical application would be helpful. Clinically, it is important to match the procedure of extinction to certain behavioral characteristics and learners. Clinicians must be mindful of controlling all sources of reinforcement and of monitoring behavioral escalations in bursts.

See Also

► Functional Analysis
► Functional Assessment

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Extraordinary

► Exceptionality

Extreme Male Brain (EMB) Theory

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Definition

Autism spectrum conditions (ASC) have been described as an extreme manifestation of certain traits or as a consequence of an "extreme male brain."

Historical Background

The link between ASC and "maleness" was first proposed by Hans Asperger in his 1944 clinical account where he states, "The autistic personality is an extreme variant of male intelligence... In the autistic individual the male pattern is exaggerated to the extreme." More recent evidence has led to the proposal that ASC may be an exaggeration of certain male-typical characteristics (Baron-Cohen, 2002; Baron-Cohen, Knickmeyer, & Belmonte, 2005).

Current Knowledge

Autism spectrum conditions (ASC) are characterized by impairments in social interaction and communication, alongside unusually restricted, repetitive, stereotyped patterns of behavior, interests, and activities. The American Psychiatric Association uses the term ASD for autism spectrum disorders. The term ASC will be used as those at the higher-functioning end of the autistic spectrum do not necessarily see themselves as having a "disorder," and the profile of strengths and difficulties in ASC can be conceptualized as atypical but not necessarily disordered. ASC remains a medical diagnosis, hence the use of the term "condition," which signals that such individuals need support. Use of the term ASC recognizes that the profile in question does not fit a simple "disease" model but includes areas of strength (e.g., in attention to detail) as well as areas of difficulty and does not identify the individual purely in terms of the latter.

Approximately 1% of children have a diagnosis of ASC. These conditions have a strong neurobiological and genetic component. There is also a clear male to female ratio in the incidence of ASC, estimated at 4:1 for classic autism and over 10:1 in individuals with Asperger syndrome. The cause of the male bias in ASC is not fully understood. Many clinical conditions occur in males more often than females, including autism, dyslexia, specific language impairment, attention-deficit/hyperactivity disorder (ADHD), and early-onset persistent antisocial behavior. Depression, anorexia, and the anxiety disorders show a female bias in sex ratio, raising the question of whether there are sex-linked or sex-limiting factors involved in the etiology of conditions that exhibit a male bias.

ASC in particular have been described as an extreme manifestation of certain sexually dimorphic traits or as a consequence of an "extreme male brain" (EMB) (Baron-Cohen, 2002; Baron-Cohen et al., 2005). Individuals with ASC have been shown to be impaired in empathy (the drive to identify another person's emotions and thoughts, and to respond to these with an appropriate emotion and an area where females show an advantage), while being average or even superior in systemizing (the drive to analyze, explore, and construct a system and an area males show an advantage).

Studies of Empathy and Systemizing

It is widely accepted that males and females show significant differences in their neuroanatomy, cognition, and behavior from an early age. Sex differences in the precursors of empathy are seen from birth, with female babies on average showing a stronger preference for looking at social stimuli (faces) from 24 h after birth (Connellan, Baron-Cohen, Wheelwright, Batki, & Ahluwalia, 2000). Girls have also been found to make more eye contact immediately after birth (Hittelman & Dickes, 1979), at 12 months of age (Lutchmaya, Baron-Cohen, & Raggatt, 2002a) and at 2 and 4 years of age (Podrouzek & Furrow, 1988). Girls on average also exhibit more comforting, sad expressions or more sympathetic vocalizations when witnessing another's distress (Hoffman, 1977). Girls on average also show better quality of social relationships at 48 months, as measured by a subscale of the Children's Communication Checklist. Similar patterns have been observed in adults, with women on average being more likely to report more intimate relationships, having a confidant and receiving social support and visits from friends and family (Baron-Cohen & Wheelwright, 2003).

Using measures that directly assess aspects of empathy, girls are on average better than boys at evaluating the feelings and intentions of characters in a story (Bosacki & Astington, 1999) and differentiating between the appearance and reality of emotion (Banerjee, 1997). There is also a female superiority on the "faux pas" test of social sensitivity (Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999) which measures the recognition of someone saying something that might be hurtful. Sex differences in empathy remain evident in adulthood: for example, women on average score higher than men on the "Reading the Mind in the Eyes" test, which examines subtle mental state and emotion recognition (Baron-Cohen, Wheelwright, & Hill, 2001).

In general, studies have shown that individuals with ASC are also impaired on empathy-related tasks that normally give rise to female superiority, such as the "Social Stories Questionnaire" (Lawson, Baron-Cohen, & Wheelwright, 2004), the "Reading the Mind in the Eyes" task (Baron-Cohen et al., 2001), and the recognition of "faux pas" in short stories (Baron-Cohen et al., 1999). Adults with ASC score lower on the Friendship and Relationship Questionnaire, which assesses empathic styles of relationships (Baron-Cohen &

Wheelwright, 2003). Children with autism perform less well than controls on the "Feshbach and Powell Audiovisual Test for Empathy," a measure of empathy and emotional responsiveness (Yirmiya, Sigman, Kasari, & Mundy, 1992). Children with ASC also show more difficulties passing "theory of mind" tests compared to typically developing children (Happe, 1995).

Studies examining play preferences point toward more interest in mechanical and constructional play in boys, demonstrated by a preference to play with toy vehicles or construction sets, while girls are more likely to choose to play with dolls or toy animals (Berenbaum & Hines, 1992). Males on average also score higher on tasks that require systemizing such as using directional cues in map reading and map making (Kimura, 1999), intuitive physics (Lawson et al., 2004), and the SAT Math Test (Benbow & Stanley, 1983). They are also more accurate on measures of spatial ability such as mental rotation and spatial visualization (Voyer, Voyer, & Bryden, 1995). Finally, males on average score higher on the Embedded Figures Test (EFT) (Witkin, Dyk, Fattuson, Goodenough, & Karp, 1962), which measures attention to detail and field independence – both prerequisites for systemizing (Baron-Cohen, 2002).

Experimental evidence supporting the EMB theory of autism includes findings that individuals with ASC tend to show superior performance compared to typical controls on tasks that involve systemizing and on certain visuospatial tasks that normally give rise to male superiority, such as figure disembedding (Falter, Plaisted, & Davis, 2008; Jolliffe & Baron-Cohen, 1997; Ropar & Mitchell, 2001; Shah & Frith, 1983), block design (Ropar & Mitchell, 2001; Shah & Frith, 1993), and mental rotation (Brosnan, Daggar, & Collomosse, 2009; Falter et al., 2008).

Brosnan et al. (2009) suggest that mental rotation tasks can be separated into rotational and non-rotational components and observed a significant correlation between systemizing and the non-rotational components of the mental rotation task but not the rotational component of the task (Brosnan et al., 2009). Individuals with high-functioning autism (and therefore intact IQ) have also been observed to demonstrate superior accuracy and shorter learning times in tasks that involve maps (Caron, Mottron, Rainville, & Chouinard, 2004).

A recent study by Pierce, Conant, Hazin, Stoner and Desmond (2010) found that toddlers with an ASD as young as 14 months spent significantly more time fixating on dynamic geometric ("systemizable") images, whereas typically developing toddlers showed longer looking times at social stimuli. Further, if a toddler spent more than 69% of his or her time fixating on geometric patterns, then the positive predictive value for accurately classifying that toddler as having an ASD was 100% (Pierce et al., 2010). These findings suggest that these early looking preferences can be found very early in life and used to differentiate toddlers with ASC from typically developing toddlers.

However, the EMB theory has not been shown to apply to all measures showing a male advantage. For example, Falter et al. (2008) found that children with autism do not show superior performance on a measure of targeting ability compared to typically developing boys. It is possible that problems with motor coordination (dyspraxia) in the ASC group may have affected performance on this task. It is worth emphasizing that the EMB theory predicts intact or superior performance on measures of systemizing in ASC and that the EMB theory does not focus on systemizing alone, but on the discrepancy between an individual's empathy and systemizing abilities.

The Empathy Quotient (EQ) and Systemizing Quotient (SQ)

The Empathy Quotient (EQ) and Systemizing Quotient (SQ) were developed in order to examine trends in gender-typical behavior in adults. The EQ and SQ are self-report questionnaires with a Likert format and contain a list of statements about real-life situations, experiences, and interests where empathizing or systemizing skills are required. Findings from the EQ in adults revealed a significant sex difference, with women scoring significantly higher than men. Results from the SQ indicate that men score significantly higher than women (Carroll & Chiew, 2006; Wheelwright et al., 2006). A parent-report version of the EQ and SQ for children between 4 and 11 years of age has also shown similar results with girls scoring significantly higher on the EQ and boys scoring significantly higher on the SQ (Auyeung, Baron-Cohen, Wheelwright, Samarawickrema, & Atkinson, 2009), suggesting that these patterns are present from an early age.

In adults, EQ and SQ scores have also been shown to be better predictors than sex for career choice in science and engineering, or in degree choice (e.g., science vs. humanities), suggesting that typical sex differences in interests or aptitudes may reflect the individual's cognitive style, independent of their sex.

In order to compare an individual's empathizing and systemizing, Goldenfeld, Baron-Cohen and Wheelwright (2005) examined standardized (normalized) scores on the EQ and SQ. The differences between standardized scores demonstrated strong sex differences and led to the definition of empirical "brain types." The five "brain types" describe whether an individual is "balanced" (Type B), better at empathizing (Type E), or better at systemizing (Type S). "Extreme" empathizing (Extreme E) or systemizing (Extreme S) types were also assigned where an individual showed a significant discrepancy in different directions (Goldenfeld et al., 2005; Wheelwright et al., 2006). The assignment of "brain types" based on relative EQ and SQ scores in both children and adults appears to be a useful method of describing differences in sex-typical behavior, with the majority of females toward Type E and the majority of males toward Type S (Auyeung, Baron-Cohen, Wheelwright et al., 2009c; Goldenfeld et al., 2005; Wheelwright et al., 2006).

Findings using the EQ and SQ questionnaires also provide further evidence for the EMB theory of ASC. When the scores obtained from the EQ and SQ are standardized using the method suggested by Goldenfeld et al. (2005), the vast majority of children and adults with high-functioning autism or Asperger syndrome are found to show the Type S or Extreme S "brain types" (Auyeung, Baron-Cohen, Wheelwright et al., 2009c; Goldenfeld et al., 2005; Wheelwright et al., 2006). See Table 1 for a summary of psychological evidence that – irrespective of the direction of sex difference – people with autism show an extreme of the male profile Table 2.

In addition to the evidence at the behavioral level, it has been suggested that characteristics of neurodevelopment in autism such as larger overall brain volumes and greater growth of the amygdala during childhood may also represent an exaggeration of typical sex differences in brain development (Baron-Cohen et al., 2005). Studies using fMRI indicate that typical females show increased activity in the extrastriate cortex during the Embedded Figures Test and increased activity bilaterally in the inferior frontal cortex during the "Reading the Mind in the Eyes" task. Parents of children with ASC also tend to show hyper-masculinization of brain activity, suggesting that hyper-masculinization may be part of the broader autism phenotype.

Extreme Male Brain (EMB) Theory, Table 1 A summary of the psychological evidence for the extreme male brain (EMB) theory

Psychological measure	Autism > male > female	Female > male > autism
Adult systemizing quotient (SQ)	✓	
Child SQ	✓	
Embedded figures test	✓	
Intuitive physics test	✓	
Adult autism spectrum Quotient (AQ)	✓	
Adolescent AQ	✓	
Child AQ	✓	
Childhood autism spectrum Test (CAST)	✓	
Quantitative checklist for autism in toddlers (Q-CHAT)	✓	
Reading the mind in the eyes		✓
adult empathy quotient (EQ)		✓
Child EQ		✓
Faux pas test		✓

Extreme Male Brain (EMB) Theory, Table 2 A summary of the evidence consistent with the EMB theory at the neural level

Brain region	Autism > male > female	Female > male > autism
Total brain volume	✓	
Head circumference	✓	
Grey and white matter	✓	
Amgydala	✓	
Corpus callosum		✓
Perisylvian language areas (Heschl's gyrus/planum temporale)		✓
L > R asymmetry in planum temporale		✓
Lateral frontoparietal cortex		✓

The Role of Social Factors in the Development of Sex Differences

Social interactions undoubtedly play an important role in the development of gender-typical play and toy choices. Gender-based expectations may cause parents, teachers or caregivers to elicit and reinforce expected behavior from children (Stern & Karraker, 1989), thus shaping the child's behavior. It has been shown that infant gender labeling as male or female often elicits sex-stereotypic responses from adults and children (Stern & Karraker, 1989). It has also been suggested that girls are encouraged to be more sensitive and caring toward others than boys (Gilligan, 1982). Findings from studies examining play preferences have indicated that boys are encouraged by parents to play with masculine-typical toys and discouraged from playing with feminine-typical toys (Fagot & Hagan, 1991). Girls, on the other hand, are also encouraged to play with feminine-typical toys but not necessarily discouraged from playing with masculine-typical toys (Fagot & Hagan, 1991). While these factors might influence the behavior exhibited by typically developing children, studies examining eye contact and preference for social stimuli in newborn children provide convincing evidence for a biological basis for some sex differences. It is also not clear how such social factors might apply to the ASC group.

The Role of Prenatal Hormones in the Development of Sex Differences

Though genetic sex is determined at conception, it is the gonadal hormones (i.e., androgens, estrogens, and progestins) that are responsible for differentiation of the male and female phenotypes in the developing human fetus. It is thought that behaviors showing large sex differences are the best candidates for studying effects of hormones on later development (Hines, 2004). The direct sampling of fetal serum or manipulation of fetal hormone levels would be highly dangerous. As a result, researchers have employed indirect methods of measuring prenatal hormone exposure to study effects on later development.

One such indirect measure is the ratio between the length of the 2nd and 4th digit (2D:4D) of the hand. This ratio has been found to be sexually dimorphic, being lower in males than in females. 2D:4D ratio is thought to be fixed by week 14 of fetal life and has been found to reflect fetal exposure to prenatal sex hormones in early gestation (Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer, & Manning, 2004; Manning, 2002). Results from studies of 2D:4D ratios as proxies for fetal testosterone (fT) levels show that children with ASC have more masculinized digit ratios compared to typically developing boys. These patterns have also been observed in the siblings and parents of children with ASC, indicating the possibility of a link between genetically based elevated fT levels and the development of ASC (Manning, Baron-Cohen, Wheelwright, & Sanders, 2001).

The medical condition of Congenital Adrenal Hyperplasia (CAH) leads to abnormally high prenatal and neonatal androgen levels and has provided researchers with an indirect method of examining the effects of elevated androgen exposure. Girls with CAH have more autistic traits (measured using the adult AQ) compared to their unaffected sisters (Knickmeyer et al., 2006a). Given that this condition is usually treated following birth, this suggests their higher AQ scores reflect elevated prenatal androgen levels. These findings should be interpreted with caution, however, since CAH carries a number of related problems (as well as extensive treatment) which may affect the atypical cognitive profiles found in this population.

Some studies have also compared measurements of testosterone in umbilical cord blood with postnatal development. A recent study using umbilical cord blood testosterone measures examined pragmatic language ability in girls followed-up at 10 years of age. Results showed that the higher a girl's free testosterone level at birth, the higher the scores on a pragmatic language difficulties questionnaire (Whitehouse et al., 2010). However, levels of fT are typically at very low levels from about week 24 of gestation, umbilical cord samples can contain blood from the mother as well as the fetus, and hormone levels may vary due to labor itself, so umbilical cord blood testosterone does not allow one to test if outcomes reflect fT per se.

Currently the best method to examine the effect of fT is to sample the amniotic fluid surrounding the fetus via amniocentesis. An advantage of amniotic fluid samples is that amniocentesis is often performed for routine clinical purposes within a relatively narrow time period which coincides with the hypothesized critical period for human sexual differentiation between weeks 8 and 24 of gestation (Hines, 2004). This is also more direct than the 2D:4D method as the hormones themselves can be assayed, rather than relying on a proxy for these.

A number of studies have linked elevated levels of fT in the amniotic fluid with the masculinization of certain behaviors, beginning shortly after birth. Elevated fT has been linked to reduced eye contact in infants (Lutchmaya et al., 2002a), smaller vocabulary in toddlers (Lutchmaya, Baron-Cohen, & Raggatt, 2002b), narrower interests and poorer quality of social relationships at 4 years of age (Knickmeyer, Baron-Cohen, Raggatt, & Taylor, 2005), less empathy at 4 and 8 years (Chapman et al., 2006; Knickmeyer, Baron-Cohen, Raggatt, Taylor, & Hackett, 2006b), more male-typical play behavior (Auyeung et al., 2009a), better performance on the Children's Embedded Figures Test (Auyeung et al., in press), and increased systemizing at 8 years (Auyeung et al., 2006). In addition, fT levels have been found to be positively correlated with number of autistic traits (measured using the Quantitative Checklist for Autism in Toddlers (Allison et al., 2008)) in toddlers between 18 and 24 months of age (Auyeung, Taylor, Hackett, & Baron-Cohen, 2010), as well as in older children (ages 6–10 years old), using two independent dimensional measures of autistic traits (the child version of the AQ and the Childhood Autism Spectrum Test (Auyeung et al., 2009b)). Evidence from typically developing children for effects of fT is summarized in Table 3.

Extreme Male Brain (EMB) Theory, Table 3 Evidence from typically developing children for effects of fT

Evidence from typical children	Key references
Eye contact is inversely related to fT	Lutchmaya et al. (2002b)
Social skills are inversely related to fT	Knickmeyer et al. (2005)
Vocabulary size is inversely related to fT	Lutchmaya et al. (2002c)
Empathy is inversely related to fT	Chapman et al. (2006), Knickmeyer et al. (2005)
Autistic traits are positively associated with fT	Auyeung et al. (2009b, 2010)
Restricted interests are fT is positively associated	Knickmeyer et al. (2005)
Systemizing is positively associated with fT	Auyeung et al. (2006)
Rightward asymmetry in the isthmus of the corpus callosum is positively associated with fT	Chura et al. (2010)

The use of amniotic fluid to measure prenatal hormonal exposure has several limitations. Ideally, it would be best to make direct measurements of testosterone at regular intervals throughout gestation and into postnatal life. However, it would be extremely hazardous to

Extreme Male Brain (EMB) Theory, Table 4 Evidence for testosterone effects in people with ASC

Evidence from people with ASC	Key references
10 sex steroid genes associated with AS or AQ or empathy HSD11B1, LHCGR, CYP17A1, CYP19A1, SCP2, CYP11B1*, ESR1, ESR2, HSD17B4, HSD17B2*	Chakrabarti et al. (2009)
Timing of puberty Boys with ASC enter puberty earlier, girls with ASC enter puberty later	Ingudomnukul, Baron-Cohen, Wheelwright, and Knickmeyer (2007), Knickmeyer et al. (2006c), Tordjman, Ferrari, Sulmont, Duyme, and Roubertoux (1997)
Testosterone related medical conditions in women with ASC and their mothers (e.g., PCOS, breast and ovarian cancers, acne)	Ingudomnukul et al. (2007)
Testosterone related characteristics in women with ASC and their mothers	Ingudomnukul et al. (2007), Knickmeyer, Wheelwright, and Baron-Cohen (2008)
Lower 2D:4D ratio in ASC, and parents	Manning et al. (2001), Milne et al. (2006), Noipayak (2009)
SRD5A1, and AR genes associated with ASC	Henningsson et al. (2009), Hu et al. (2009)

attempt direct measurements from the fetus itself for purely research purposes. It is not possible to obtain repeated samples of fT because amniocentesis itself carries a risk of causing miscarriage (of about 1%). As a result, obtaining amniotic fT measures are opportunistic, when the procedure is being carried out for clinical reasons, with never more than a single measurement of fT at one time-point although it is known that hormones fluctuate during the day and between days, even in fetuses. The representativeness of a single sample of fT thus remains unclear, but would be difficult to explore in an ethical manner.

In addition, given the reported time course of testosterone secretion, the most promising time to measure fT is probably at prenatal weeks 8–24 (Smail, Reyes, Winter, & Faiman, 1981), but this is still a relatively wide range. In addition, research is nonhuman primates has shown that androgens masculinize different behaviors at different times during gestation, suggesting different behaviors may also have different sensitive periods for development. For all these reasons, the inferences that can be drawn about a single measurement of fT are therefore limited. However, where a significant correlation between amniotic fT and a behavior is observed, this should represent a very conservative estimate of the correlation between overall fT levels and that behavior.

Evidence Implicating Testosterone in the Etiology of Autism

Genetic influences are undoubtedly involved with other factors (such as prenatal hormone levels) which lead to the development of ASC. Evidence of a genetic link to ASC is provided by a recent study which shows that genes regulating sex steroids are associated with autistic traits, as measured by scores on the Autism Spectrum Quotient (AQ), in a typical adult sample (Chakrabarti et al., 2009). A parallel study also showed that genes regulating sex steroids are associated with a diagnosis of Asperger syndrome in a case-control sample (Chakrabarti et al., 2009).

Other lines of evidence implicating testosterone in the etiology of ASC are summarized in Table 4:

Conclusions

There is a significant body of evidence connecting the characteristic behaviors of ASC to extremes of certain male-typical behaviors. Evidence includes superior performance on a range of tasks where males typically outperform females but impairment compared to typical males on tasks showing a female advantage. This observation has led to the development of the "extreme male brain" theory of autism. Support for this theory can also be found very early in life, and also in some primate studies suggesting the development of sex-typical behaviors is at least partly biological.

Research using direct measures of potential biological factors such as prenatal hormones as well as multiple measures of empathizing and systemizing, including both observational and behavioral measures are needed to explore the link between these factors in greater detail. Although the findings presented in this chapter lend support to the "extreme male brain" theory of ASC and its link to fT, a thorough evaluation of this theory will require testing not just for associations between fT and autistic traits, but between fT and clinically diagnosed ASC. This remains an active area of research.

Future Directions

Future studies of empathizing and systemizing in children could examine whether the relationships between fT levels (and other biological factors) remain consistent using multiple measures of empathy and systemizing (e.g., observational, experimental). In addition, the replication of the findings related to fT levels in larger sample sizes would assist in identifying any factors that are linked with levels in the extreme ranges. Future studies could assess whether relationships between fT levels and the development of autistic traits are consistent for individuals with a clinical diagnosis of ASC since the current samples only included typically developing children. Considering the current support for a role for fT in the development of autistic traits, it would also be beneficial for future studies to examine the relationships between fT levels, genetic variation, and the development of autistic traits.

The EMB theory of autism has been developed from studies in typically developing and high-functioning individuals with ASC. It would be interesting to extend the scope of this theory with an examination of individuals with more severe forms of ASC. It is also important to assess the validity of "empathizing" and "systemizing" measures by correlating these with performance and everyday measures of functioning, and future studies could further explore how these domains develop and also how they correlate with neural structure and function.

See Also

- ► Broader Autism Phenotype
- ► Cognitive Skills
- ► Empathy
- ► Face Recognition
- ► Friendships
- ► Gender Differences
- ► Social Behaviors and Social Impairment
- ► Social Cognition
- ► Systemizing
- ► Theory of Mind

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