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The Children's Empathy Quotient and Systemizing Quotient: Sex Differences in Typical Development and in Autism Spectrum Conditions

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Abstract Children's versions of the Empathy Quotient (EQ-C) and Systemizing Quotient (SQ-C) were developed and administered to $n = 1{,}256$ parents of typically developing children, aged 4–11 years. Both measures showed good test–retest reliability and high internal consistency. As predicted, girls scored significantly higher on the EQ-C, and boys scored significantly higher on the SQ-C. A further sample of $n = 265$ children with Autism Spectrum Conditions (ASC) scored significantly lower on the EQ-C, and significantly higher on the SQ-C, compared to typical boys. Empathy and systemizing in children show similar patterns of sex differences to those observed in adults. Children with ASC tend towards a 'hyper-masculinized' profile, irrespective of sex.

Keywords Empathizing · Systemizing · Autism · Sex differences

Introduction

It is widely accepted that males and females show significant differences in their neuroanatomy, cognition and behavior from an early age (Baron-Cohen et al. 2005; Geary 1995; Kimura 1999). Baron-Cohen (2002) suggests that in addition to the traditional concepts of verbal and spatial ability, the dimensions of 'empathizing' and 'systemizing' might also aid the understanding of human sex differences. Empathizing (the drive to identify another person's emotions and thoughts and to respond to these with an appropriate emotion) is held to be generally stronger in females, whilst systemizing (the drive to analyze, explore and construct a system) is held to be generally stronger in males.

Sex Differences in Empathizing and Systemizing

Sex differences in the precursors of empathy are seen from birth, with female babies showing a stronger preference for looking at social stimuli (faces) from 24 h after birth (Connellan et al. 2000). Girls have also been found to make more eye contact immediately after birth (Hittelman and Dickes 1979), at 12 months of age (Lutchmaya et al. 2002) and at 2 and 4 years of age (Podrouzek and Furrow 1988). Girls have been shown to exhibit more comforting, sad expressions or more sympathetic vocalizations when witnessing another's distress (Hoffman 1977). Girls also show better quality of social relationships at 48 months, as measured by a subscale of the Children's Communication Checklist (Knickmeyer et al. 2005). Similar patterns have been observed in adults, with women being more likely to report more intimate relationships, having a confidant and receiving social support and visits from friends and family (Baron-Cohen and Wheelwright 2003; Umberson et al. 1996).

Using measures that directly assess aspects of empathy, girls are better than boys at evaluating the feelings and intentions of characters in a story (Bosacki and Astington 1999) and differentiating between the appearance and reality of emotion (Banerjee 1997). There is also a female

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superiority on the 'faux pas' test (Baron-Cohen et al. 1999) which measures the recognition of someone saying something that might be hurtful. Sex differences in empathy remain evident in adulthood: for example, women score higher than men on the 'Reading the Mind in the Eyes' Test, which examines subtle mental state and emotion recognition (Baron-Cohen et al. 2001; Baron-Cohen et al. 1997b).

Studies examining play preferences point towards 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 and Hines 1992; Liss 1979; Servin et al. 1999; Smith and Daglish 1977). Males also score higher on tasks that require systemizing such as using directional cues in map-reading and map-making (Beatty and Tröster 1987; Galea and Kimura 1993; Kimura 1999), intuitive physics (Lawson, Baron-Cohen and Wheelwright 2004) and the SAT-Math Test (Benbow and Stanley 1983). They are also more accurate on measures of spatial ability such as mental rotation (Johnson and Meade 1987; Kerns and Berenbaum 1991; Masters and Sanders 1993) and spatial visualization (Kerns and Berenbaum 1991). Finally, males score higher on the Embedded Figures Test (EFT) (Berlin and Languis 1981; Nebot 1988; Witkin et al. 1962), which measures attention to detail and field independence—considered to be prerequisites for systemizing (Baron-Cohen 2002).

Factors That Influence the Development of Sex Differences

Social interactions undoubtedly play an important role in the development of gender-typical play and toy choices. Some findings have indicated that boys are encouraged by parents to play with masculine-typical toys and discouraged from playing with feminine-typical toys (Fagot 1978; Fagot and 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 1978; Fagot and Hagan 1991).

Whilst social influences are likely to be very important, investigations examining sex differences in children at a very early age indicate the possibility of a partly biological mechanism for some of these sex differences. For example, gender-typical toy preferences have been observed in children as young as 12 months (Servin et al. 1999; Snow et al. 1983). The possibility of a biological effect is also highlighted by similar gender-typical toy preferences observed in nonhuman primates (Alexander and Hines 1994).

The Adult 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 (Baron-Cohen et al. 2003; Baron-Cohen and Wheelwright 2004). 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 higher than men (Baron-Cohen and Wheelwright 2004; Carroll and Chiew 2006; Wheelwright et al. 2006). Results from the SQ indicate that men score significantly higher than women (Baron-Cohen et al. 2003; Carroll and Chiew 2006; Wheelwright et al. 2006). 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) (Billington et al. 2007; Focquaert et al. 2007), 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 et al. (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 appears to be a useful method of describing differences in sex-typical behavior, with the majority of females towards Type E and the majority of males towards Type S (Goldenfeld et al. 2005; Wheelwright et al. 2006).

Autism and the Extreme Male Brain

Autism Spectrum Conditions (ASC) are characterized by impairments in social interaction and communication, alongside unusually restricted, repetitive, stereotyped patterns of behavior, interests and activities (APA 1994). Two studies in UK populations of children estimated the prevalence of ASC to be 116.1 per 10,000 and 94 per 10,000 (Baird et al. 2006; Baron-Cohen et al. 2009). These conditions have a strong neurobiological and genetic component (Stodgell et al. 2001). There is also a clear male to female ratio in the incidence of ASC, estimated at 4:1 for classic autism (Chakrabarti and Fombonne 2005) and as high as 10.8:1 in individuals with Asperger Syndrome (Gillberg et al. 2006).

The cause of the male bias in ASC is not fully understood. However, one theory suggests these conditions might include 'hyper-masculinization' of certain behaviors. This Extreme Male Brain (EMB) theory of autism (Baron-Cohen 2002; Baron-Cohen and Hammer 1997) proposes that individuals with ASC are impaired in empathy whilst being average or even superior in systemizing. Experimental evidence supporting the EMB theory of autism includes findings that individuals with ASC are superior to typical controls on tasks that involve systemizing (Lawson et al. 2004) and on certain visuo-spatial tasks that normally give rise to male superiority, such as mental rotation (Falter et al. 2008), figure disembedding (Falter et al. 2008; Jolliffe and Baron-Cohen 1997; Ropar and Mitchell 2001; Shah and Frith 1983) and block design (Ropar and Mitchell 2001; Shah and Frith 1993). 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 et al. 2004).

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. However, 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.

Individuals with ASC are also impaired on empathy-related tasks that normally give rise to female superiority, such as the 'Social Stories Questionnaire' (Lawson et al. 2004), the 'Reading the Mind in the Eyes' task (Baron-Cohen et al. 1997a) and the recognition of 'faux pas' in short stories (Baron-Cohen et al. 1999). Adults with ASC score lower on the Friendship Questionnaire, which assesses empathic styles of relationships (Baron-Cohen and 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 et al. 1992). Children with ASC also show more difficulties passing 'theory of mind' tests compared to typically developing children (Happe 1995).

Findings using the Adult 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 individuals with high functioning autism or Asperger Syndrome are found to show the Type S or Extreme S 'brain types' (Goldenfeld et al. 2005; Wheelwright et al. 2006).

Objectives

The current study investigates whether sex differences identified using the EQ and SQ in adults can also be observed in children. The Adult EQ and SQ were adapted for parental report and completed by parents of ($n = 1{,}256$) typically developing children. In addition, the adapted versions of the questionnaires were completed by parents of ($n = 265$) children with ASC, to establish if, like their older counterparts, they constitute an extreme of Type S in the 'brain types' defined by Goldenfeld et al. (2005).

Method

Instrument Development

The primary instruments for this study were the adapted versions of the adult EQ and SQ questionnaires. These are shown in Appendix 1 and are referred to as the EQ-Child (EQ-C) and SQ-Child (SQ-C). In the study reported here, the EQ-C and SQ-C were combined into one questionnaire for ease of administration. This was designed to be a parent-report questionnaire, to avoid inaccuracies related to a child's reading and comprehension abilities. Where possible, questions were phrased to ask about engagement and/or preference for activities in which both boys and girls would typically participate. In order to tap into the extreme ends of the spectrum, some items ask about relatively rare behaviors (such as bullying or reactions to the death of a movie character).

Scoring

The combined questionnaire has 55 items, with four alternatives for each question. The parent indicates how strongly they agree with each statement about their child by ticking one of several options: 'definitely agree', 'slightly agree', 'slightly disagree', or 'definitely disagree'. Questionnaires with five or more blank items were considered incomplete, and these data were discarded in subsequent analyses ($n = 7$). The 55 items were split into 27 EQ-C questions and 28 SQ-C questions:

1. For the EQ-C, a 'slightly agree' response scores one point and 'definitely agree' scores two points on the following items: 1, 6, 14, 18, 26, 28, 30, 31, 37, 42, 43, 45, 48 and 52. A response of 'slightly disagree' or 'definitely disagree' scores zero points. 'Slightly disagree' scores one point and 'definitely disagree'

scores two points on the following items: 2, 4, 7, 9, 13, 17, 20, 23, 33, 36, 40, 53 and 55. A response of 'slightly agree' or 'definitely agree' scores zero points. The maximum attainable score for this domain is 54.

2. For the SQ-C, a 'slightly agree' response scores one point and 'definitely agree' scores two points on the following items: 5, 8, 10, 12, 19, 21, 24, 25, 29, 34, 35, 38, 39, 41, 44, 46, 49 and 50. A response of 'slightly disagree' or 'definitely disagree' scores zero points. 'Slightly disagree' scores one point and 'definitely disagree' scores two points on the following items: 3, 11, 15, 16, 22, 27, 32, 47, 51 and 54. A response of 'slightly agree' or 'definitely agree' scores zero points. The maximum attainable score for this domain is 56.

Pilot Study

22 children (12 males, 10 females) aged 5-11 years ($M = 8.1$, SD $= 1.79$) were recruited for a pilot study. Ceiling and floor effects were not observed in this sample, and a broad range of total scores for empathizing and systemizing were obtained. The pilot study also showed good variability in responses for each item. For all questions except items 21 and 23, the full range of possible responses was observed. Items 21 and 23 were retained as it was agreed that they could still act to differentiate between children in the much larger sample of the main study. Participants were given the opportunity to express any comments they had about the questionnaire. No revisions were found to be necessary.

Participants

Questionnaires were completed by mothers of children between 4 and 11 years in age ($M = 7.90$, SD $= 1.77$), comprising 2 groups:

Group 1 consisted of typically developing children with $n = 1{,}256$ (675 girls, 581 boys) who were participating in a large epidemiological study of social and communication skills in primary schools in and around Cambridge, UK (Baron-Cohen et al. 2009; Scott et al. 2002; Williams et al. 2005). Parents of children with special needs are often included in mainstream UK primary education, and only parents of children who previously reported their child had no special needs or disabilities were contacted for this study. A total of 2,776 parents were contacted, resulting in a 45% response. Results from a sub-sample of 85 typically developing children (38 girls, 47 boys) reported elsewhere showed that IQ was not correlated with EQ-C or SQ-C (Auyeung et al. 2006; Chapman et al. 2006). In the current study, IQ data were therefore not collected, allowing for the inclusion of a larger sample.

Group 2 consisted of $n = 265$ (46 girls, 219 boys) children with ASC, diagnosed by psychiatrists or an appropriate clinician (e.g., clinical psychologists) using established criteria (APA 1994; ICD-10, 1994). Only children with a diagnosis of autism ($n = 69$, mean age $= 8.02$ (SD $=$ 2.11)) or Asperger Syndrome/high functioning autism ($n = 196$, mean age $= 8.09$, (SD $= 2.11$)) were included in the study. Mothers of children with ASC were recruited via the Cambridge University Autism Research Centre website (www.autismresearchcentre.com) and completed the questionnaire online. Information such as the date of diagnosis, and the clinic which made the diagnosis was also collected.

Results

Internal Consistency

Cronbach's alpha coefficients were calculated and showed high coefficients for empathy items ($\alpha = 0.93$) as well as for systemizing items ($\alpha = 0.78$).

Test–Retest Reliability

Six months after initial contact, $n = 500$ participants were asked to complete a second copy of the EQ-C and SQ-C in order to examine test–retest reliability, resulting in 258 test–retest pairs (133 girls, 125 boys). For the EQ-C, the intra-class correlation between the two tests was 0.86 (single measures) ($p < 0.001$). The intra-class correlation for the SQ-C between the two tests was 0.84 (single measures) ($p < 0.001$). These additional responses were not included in subsequent analyses of results.

EQ-C and SQ-C Correlations

A correlation was performed for all groups together, yielding a small but significant negative correlation between EQ-C and SQ-C score ($r = -0.13$, $p < 0.001$). When looking at the typically developing and ASC groups separately, the correlation between EQ-C and SQ-C score was no longer significant, with ($r = -0.02$, $p > 0.05$) and ($r = -0.07$, $p > 0.05$) respectively.

Sex Differences

Table 1 shows means and standard deviations of the EQ-C and SQ-C scores by group.

Examination of scoring patterns in the typically developing children revealed significant sex differences. Girls scored higher on the EQ-C, whilst boys scored higher on the SQ-C. No significant differences in EQ-C and SQ-C

Table 1 Mean scores for EQ-C and SQ-C by group

	EQ-C Total		SQ-C Total	
	M	SD	M	SD
Typical Group ($n = 1{,}256$)	37.7	9.81	24.11	8.02
Typical Girls ($n = 675$)	40.16	8.89	22.64	7.94
Typical Boys ($n = 581$)	34.84	10.07	25.81	7.79
ASC Group ($n = 265$)	13.97	6.82	27.43	9.20
ASC Girls ($n = 46$)	15.43	6.27	26.11	9.11
ASC Boys ($n = 219$)	13.66	6.90	27.71	9.22

Table 2 Effect sizes (*d*)

	EQ-C Total	SQ-C Total
Typical Girls vs. Typical Boys	0.56	0.40
ASC Girls vs. ASC Boys	0.27	0.17
Typical Boys vs. ASC Group	2.80	0.38

scores were found between boys and girls in the ASC group. These children were therefore combined into a single group in subsequent analyses. See Table 2 for effect sizes (*d*) found by comparing scoring patterns for typical boys, typical girls and children with ASC. Effect sizes provide a standardized measure for the difference between scoring patterns of each group, and are independent of group size. An effect size between .2 and .4 is considered to be small. A value between .5 and .7 is considered a medium effect size and a value greater than .8 is considered a large effect size (Cohen 1988).

The EQ-C

Figure 1 shows EQ-C scores by group (girls, boys and children with ASC). A wide range of scores was obtained for each group. Analysis of EQ-C scores for all groups showed that the distribution was not significantly skewed (skewness <1). For the girls, Fig. 1 suggests the possibility of a small ceiling effect. However, because there was clear differentiation between the groups and only a small proportion of girls reached the maximum score, no further action was taken. A one-way between subjects ANOVA was conducted to examine if group (typical girls, typical boys and ASC) differences existed. There was a significant difference between groups ($F_{(2,1518)} = 806.89$, $p < 0.001$). Post hoc Tukey HSD tests showed significant differences between all three groups (all $p < 0.001$) with typical girls scoring the highest ($M = 40.16$, SD = 8.89), followed by typical boys ($M = 34.84$, SD = 10.07) and the ASC group scoring the lowest ($M = 13.97$, SD = 6.82) (see Fig. 1).

The SQ-C

Figure 2 shows SQ-C scores by group (girls, boys and children with ASC). Analysis of SQ-C scores showed that the distribution was also not significantly skewed (skewness <1). For each group, a wide range of scores was obtained and no floor or ceiling effects were observed. Differences between the groups were analyzed using a one-way between subjects ANOVA. The ANOVA revealed a significant main effect for ASC diagnosis ($F_{(2,1518)} = 42.16$, $p < 0.001$). Tukey HSD pairwise comparisons revealed significant differences between the groups (all $p < 0.001$), with the ASC group scoring the highest ($M = 27.43$, SD = 9.20), followed by typical boys ($M = 25.81$, SD = 7.79) and typical girls scoring the lowest ($M = 22.64$, SD = 7.94).

Brain Types

By comparing an individual's performance on the EQ-C and SQ-C using standardized scores, it is possible to evaluate each child's relative ability to empathize or systemize. Standardized scores were calculated for both EQ-C and SQ-C according to the formulae suggested by Goldenfeld et al. (2005):

E (standardized) = [(EQ-C observed − ⟨EQ-C mean for typical population⟩)/maximum possible score for EQ-C]

S (standardized) = [(SQ-C observed − ⟨SQ-C mean for typical population⟩)/maximum possible score for SQ-C]

The typically developing group mean scores were: EQ-C ($M = 37.70$; SD = 9.81) and SQ-C ($M = 24.11$; SD = 8.02). The standardized E and S variables were used to produce a difference score (D). This new variable was defined as follows:

D (difference between the normalized SQ-C and EQ-C scores) = (S−E)/2

Using the method suggested by Goldenfeld et al. (2005) for adult EQ and SQ data, 'brain types' were numerically assigned according to the percentiles of the typically developing group on the 'D' scale. The lowest scoring 2.5% were classified as Extreme Type E. Participants who scored between the 2.5th and 35th percentiles were classified as Type E. Those scoring between the 35th and 65th percentile were classified as Type B. Type S was defined by scores between the 65th and 97.5th percentile, and the top 2.5% were classified as Extreme Type S. See Table 3 for the proportion of participants from the sample with each brain type. Table 3 also shows comparable data for adult females, adult males and adults with ASC (from Wheelwright et al. 2006).

A one-way between subjects ANOVA was used to test for group differences in D scores. Results showed a

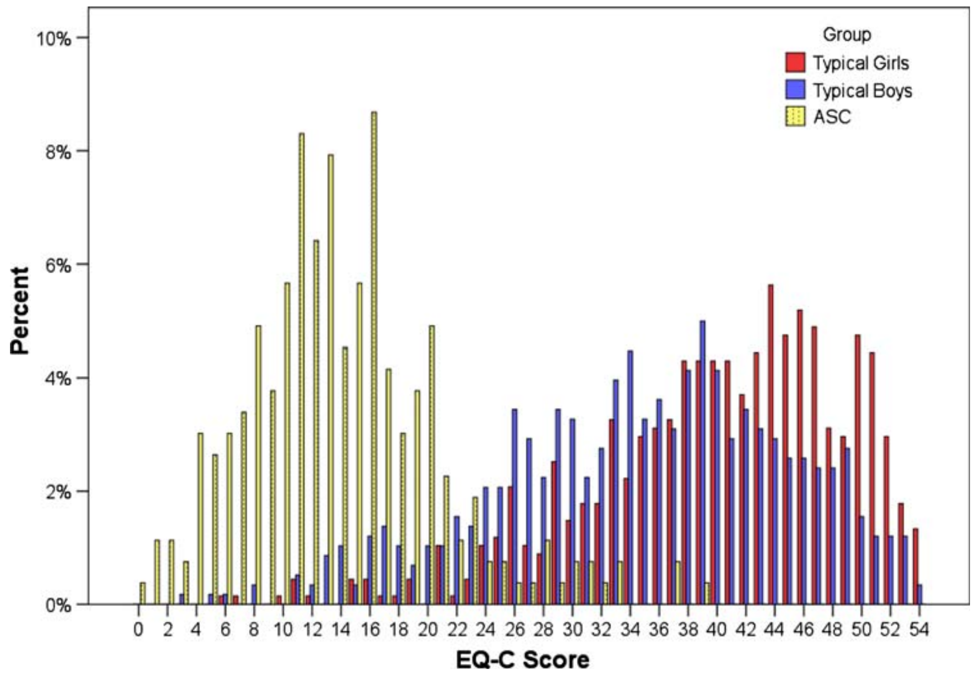

Fig. 1 Group scoring patterns on the EQ-C. *Note*: Girls with ASC did not score differently than boys with ASC, therefore boys and girls with ASC have been combined

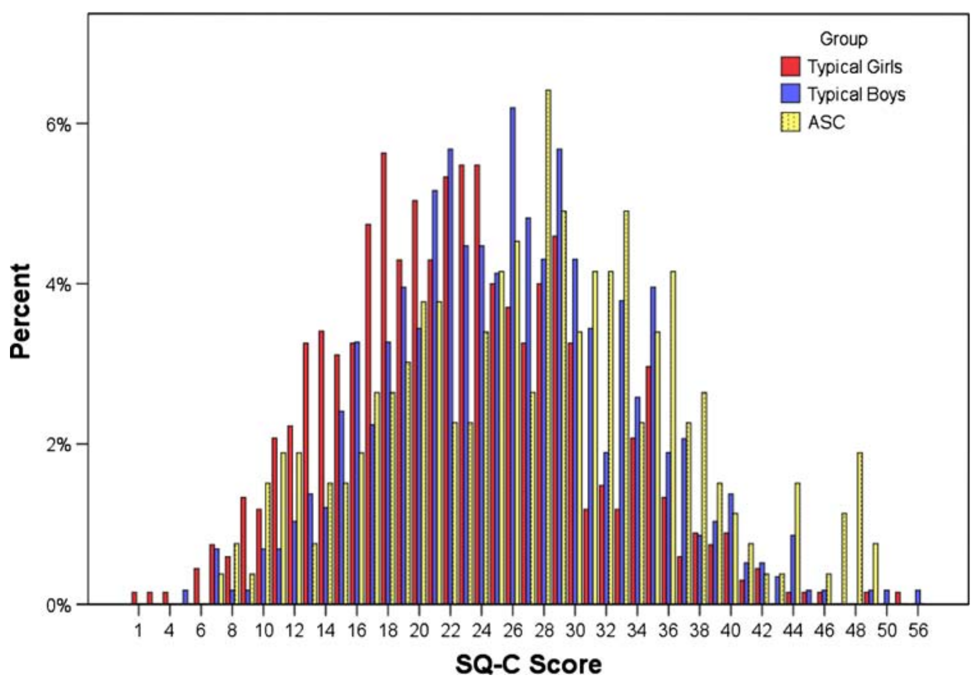

Fig. 2 Group scoring patterns on the SQ-C. *Note*: Girls with ASC did not score differently than boys with ASC, therefore boys and girls with ASC have been combined

significant effect of group ($F_{(2,1518)} = 642.01$, $p < 0.001$). Tukey HSD post hoc tests show that all groups differed significantly (all $p < 0.001$) from each other with typical girls ($M = -0.36$, $SD = 0.11$) tending towards the Extreme E or Type E 'brain types', followed by typical boys ($M = 0.04$, $SD = 0.12$), and children with ASC ($M = 0.25$, $SD = 0.11$) showing a tendency to fall in the Type S or Extreme S 'brain types'.

Figure 3 shows a visual representation of the 'brain types'. Note that the boundaries were based on percentiles calculated from the typically developing sample, consistent with the definitions suggested by Goldenfeld et al. (2005). Note the clear separation between individual girls, boys and children with ASC in the figure. Starting in the top left hand corner and progressing towards the lower right corner (increasing D score), it can be seen that the highest

Table 3 Percent of children with each 'brain type' measured in *D* (difference score between EQ and SQ)

Brain type	*D* Percentile (per)	Brain type boundary	Group					
			Typical girls $n = 675$	Typical boys $n = 581$	ASC children $n = 265$	Typical women[a] $n = 1{,}038$	Typical men[a] $n = 723$	ASC adults[a] $n = 125$
Extreme E	per < 2.5	$D < -0.205$	4.0	0.5	0	4.3	0.1	0
Type E	$2.5 \leq$ per < 35	$-0.205 \leq D < -0.050$	41.9	20.3	0	44.8	15.1	0
Type B	$35 \leq$ per < 65	$-0.050 \leq D < 0.037$	31.7	29.5	1.9	29.3	30.3	6.4
Type S	$65 \leq$ per < 97.5	$0.037 \leq D < 0.260$	21.2	45.6	50.9	20.7	49.5	32.0
Extreme S	per $\geq$ 97.5	$D \geq 0.260$	1.2	4.1	47.2	0.9	5.0	61.6

[a] Data from Wheelwright et al. 2006

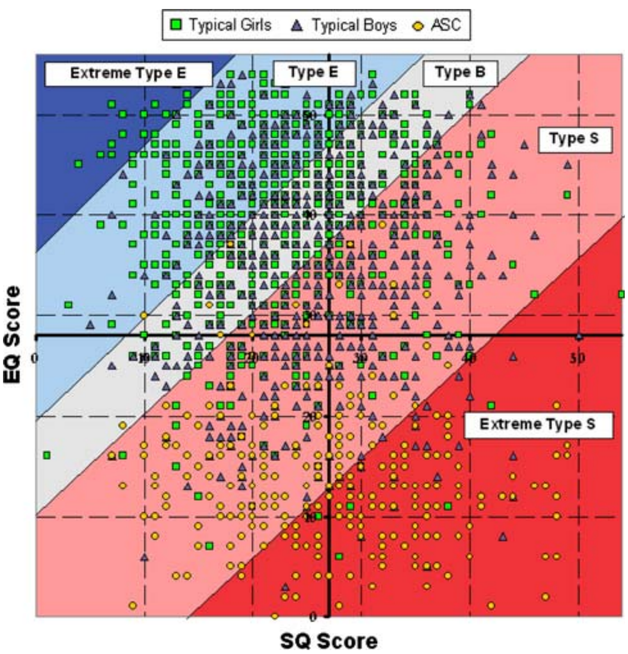

Fig. 3 'Brain types' translated into raw scores on the EQ-C and SQ-C

concentration of participants changes from typical girls to typical boys, and children with ASC.

Discussion

In the present study, the Children's Empathy Quotient (EQ-C) and Systemizing Quotient (SQ-C) were completed by parents of $n = 1{,}256$ typically developing children and also by $n = 256$ parents of children with Autism Spectrum Conditions (ASC). In the typically developing group, both measures showed a broad range of responses, high internal consistency and good test–retest reliability.

Girls scored higher than boys on the EQ-C, where sex was shown to have a medium effect size ($d = 0.56$) on score (see Table 2). The results from the EQ-C support previous studies demonstrating sex differences in childhood, suggesting that girls exhibit more empathic behavior than boys (Hoffman 1977). Children with ASC scored much lower than typically developing children on the EQ-C. The group differences in EQ-C scores showed a large effect size ($d = 2.80$) between typically developing boys and children with ASC, suggesting that the EQ-C questionnaire is capable of detecting the poor empathizing typically associated with ASC.

On the SQ-C, boys were found to score significantly higher than girls. A smaller effect size ($d = 0.40$) was found for SQ-C score, with boys scoring higher than girls. Sex differences in SQ-C scores are also consistent with studies demonstrating a male advantage for visuo-spatial ability and a preference for 'systems'. Children with ASC had even higher scores on this measure than boys ($d = 0.38$) and results are in line with studies showing increased ability on tasks such as figure disembedding (Falter et al. 2008; Jolliffe and Baron-Cohen 1997; Ropar and Mitchell 2001; Shah and Frith 1983) and block design (Ropar and Mitchell 2001; Shah and Frith 1993). The scoring patterns observed therefore support the idea that whilst individuals with ASC do not empathize to the same extent as the typical population, they may be more likely to engage in behaviors or activities which involve systems and processes.

Examination of Figs. 1 and 2 also shows that the scoring distributions differ significantly between the EQ-C and SQ-C questionnaires. For the EQ-C, scores obtained by the typically developing group were consistently high. It is possible that many of the behaviors examined by the EQ-C are common within the typically developing population, or that the wording of questions within this study induces a positive bias in the reporting of social behaviors by parents. The scoring patterns here also resemble those previously seen in adults (Wheelwright et al. 2006), suggesting that both the adult and child versions of the EQ measure similar behaviors.

The patterns in EQ-C and SQ-C responses described above are also consistent with findings in adults (Baron-Cohen and Wheelwright 2004; Carroll and Chiew 2006; Lawson et al. 2004; Wheelwright et al. 2006), where individuals with ASC score lower than boys on measures of empathic behavior, whilst also scoring higher on measures which require systemizing. Similarly, no significant sex differences were found within the ASC group for either EQ-C or SQ-C scores, replicating a lack of sex differences on equivalent measures of empathy and systemizing in adults with ASC (Wheelwright et al. 2006).

In order to compare an individual's ability to empathize and systemize, results from the EQ-C and SQ-C were compared using a standardized difference measure (D). The standardized data show significant differences in scoring patterns for girls, boys and children with ASC. The distribution of D scores in Fig. 3 indicates that when individual behavior patterns are examined along the dimensions of empathizing and systemizing, children within the ASC group tend to exhibit a hyper-masculinized profile, irrespective of sex. The vast majority of children with ASC were found to exhibit the Type S (50.9%) or Extreme S (47.2%) 'brain types' defined by Goldenfeld et al. (2005).

The standardized scores also showed that the proportion of each group (girls, boys, children with ASC) with each 'brain type' closely resembled results from the adult population (Goldenfeld et al. 2005). This is consistent with the idea that 'brain types' are determined at an early age. However, it is important to note that these cognitive 'brain types' have not yet been confirmed using neuroimaging techniques, and it will be important for future research to examine how these measures relate to brain structure and function.

A comparison between individual scores on each questionnaire revealed a small but significant correlation coefficient between EQ-C and SQ-C scores ($r = -0.13$, $p < 0.001$). However, the correlation between EQ-C and SQ-C scores for the typically developing ($r = -0.03$, $p > 0.05$) and ASC ($r = -0.07$, $p > 0.05$) groups was no longer significant when the groups were examined separately. These low correlations suggest that the behaviors measured by the EQ-C and SQ-C questionnaires are largely independent of one another.

If the EQ-C and SQ-C are used as measures of autistic tendencies, the low correlations observed between these instruments are somewhat consistent with findings by Ronald et al. (2005) who report a weak correlation between social (similar to the current study's measure of Empathy) and nonsocial (similar to Systemizing) behaviors associated with autism. However, other work has suggested that autistic traits are explained by a single, continuously distributed factor (Constantino et al. 2004; Constantino and Todd 2003). Further research needs to be conducted investigating the psychometric properties of measures specifically designed as screening tools (or diagnostic measures) for autism to confirm whether characteristics of autism are continuously distributed or explained by multiple underlying factors.

The origins of the gender-typical behaviors examined in this study are not clear. There is no doubt that social and environmental factors play a large role in the development of behavior in boys and girls. Gender-based expectations may cause parents, teachers or caregivers to elicit and reinforce expected behavior from children (Stern and 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 and Karraker 1989). It has also been suggested that girls are encouraged to be more sensitive and caring towards others than boys (Gilligan 1982). Whilst these factors might influence the behavior exhibited by typically developing children, it is not clear how such social factors might apply to the ASC group.

Studies examining eye contact (Hittelman and Dickes 1979) and preference for social stimuli (Connellan et al. 2000) in newborn children provide convincing evidence for a biological basis for some sex differences. Some studies have suggested that prenatal exposure to hormones may contribute to these differences in children (Auyeung et al. 2006; Chapman et al. 2006; Grimshaw et al. 1995; Knickmeyer et al. 2005). However, other studies have produced inconsistent results in this area (Finegan et al. 1992; Hines et al. 2003; Resnick et al. 1986). 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.

Limitations and Future Directions

Researchers have stressed the importance of context when examining sex differences (Hyde 2005), and a questionnaire-based study limits the measurement of such variables. Against the drawbacks of parental report, an advantage of the questionnaire method used here is that mothers have the opportunity to judge their children's traits, skills, strengths and weaknesses in a variety of contexts over an extended period of time, whilst other methods may only observe the child in a single laboratory session. Future research could compare parental scores with ratings from teachers or a healthcare professional.

Independent verification of diagnoses for children with Autism Spectrum Conditions was not possible. Participants with a diagnosis were recruited from the Cambridge University Autism Research Centre's database of volunteers. Parents provide diagnostic information and complete the questionnaires online and data including the date of diagnosis and name of clinic where their child received the diagnosis were collected. Similarly, the collection of IQ data for such a large sample of children was also beyond the scope and resources of this study. Whilst IQ was found to be unrelated to EQ-C or SQ-C scores in a sub-sample of typically developing children (Auyeung et al. 2006; Chapman et al. 2006), this could not be confirmed in the ASC group.

How representative the participants from this study are of the general population is not known. It will be important for future studies to examine the relationships between socioeconomic status, parental attitudes about gender-typical behavior and other family and school factors to further explore how these variables might contribute to scores on these measures.

Conclusions

The Empathy Quotient (EQ) and Systemizing Quotient (SQ) aim to evaluate the extent to which individuals empathize and systemize. Children's versions of the Empathy (EQ-C) and Systemizing (SQ-C) Quotients were developed and administered to large samples of typically developing children and to individuals with ASC. These adapted questionnaires showed good test–retest reliability and high internal consistency. The distribution of scores showed good variation on both measures, and on average girls scored higher than boys on the EQ-C and boys scored higher than girls on the SQ-C. Children with ASC scored significantly higher on the SQ-C, and significantly lower on the EQ-C compared to typical boys, providing further support for the notion that individuals with ASC show a 'hyper-masculinized' cognitive profile. When standardized (normalized) scores were used to compare an individual's performance on measures of empathy and systemizing, the results were very similar to those previously observed in adults, suggesting that cognitive 'brain types' are present from an early age.

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The Combined EQ-C and SQ-C

Please complete by ticking the appropriate box for each statement

		Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree
1.	My child likes to look after other people.				
2.	My child often doesn't understand why some things upset other people so much.				
3.	My child doesn't mind if things in the house are not in their proper place.				
4.	My child would not cry or get upset if a character in a film died.				
5.	My child enjoys arranging things precisely (e.g. flowers, books, music collections).				
6.	My child is quick to notice when people are joking.				
7.	My child enjoys cutting up worms, or pulling the legs off insects.				
8.	My child is interested in the different members of a specific animal category (e.g. dinosaurs, insects, etc).				
9.	My child has stolen something they wanted from their sibling or friend.				
10.	My child is interested in different types of vehicles (e.g. types of trains, cars, planes, etc).				
11.	My child does not spend large amounts of time lining things up in a particular order (e.g. toy soldiers, animals, cars).				

12.	If they had to build a Lego or Meccano model, my child would follow an instruction sheet rather than "ploughing straight in".				
13.	My child has trouble forming friendships.				
14.	When playing with other children, my child spontaneously takes turns and shares toys.				
15.	My child prefers to read or listen to fiction rather than non-fiction.				
16.	My child's bedroom is usually messy rather than organised.				
17.	My child can be blunt giving their opinions, even when these may upset someone.				
18.	My child would enjoy looking after a pet.				
19.	My child likes to collect things (e.g. stickers, trading cards, etc).				
20.	My child is often rude or impolite without realizing it.				
21.	My child knows how to mix paints to produce different colors.				
22.	My child would not notice if something in the house had been moved or changed.				
23.	My child has been in trouble for physical bullying.				
24.	My child enjoys physical activities with set rules (e.g. martial arts, gymnastics, ballet, etc).				
25.	My child can easily figure out the controls of the video or DVD player.				
26.	At school, when my child understands something they can easily explain it clearly to others.				
27.	My child would find it difficult to list their top 5 songs or films in order.				
28.	My child has one or two close friends, as well as several other friends.				
29.	My child quickly grasps patterns in numbers in math.				
30.	My child listens to others' opinions, even when different from their own.				
31.	My child shows concern when others are upset.				
32.	My child is not interested in understanding the workings of machines (e.g. cameras, traffic lights, the TV, etc).				
33.	My child can seem so preoccupied with their own thoughts that they don't notice others getting bored.				
34.	My child enjoys games that have strict rules (e.g. chess, dominos, etc).				
35.	My child gets annoyed when things aren't done on time.				
36.	My child blames other children for things that they themselves have done.				
37.	My child gets very upset if they see an animal in pain.				
38.	My child knows the differences between the latest models of games-consoles (e.g. X-box, Playstation, Playstation 2, etc) or other gadgets.				
39.	My child remembers large amounts of information about a topic that interests them (e.g. flags of the world, football teams, pop groups, etc).				
40.	My child sometimes pushes or pinches someone if they are annoying them.				
41.	My child is interested in following the route on a map on a journey.				
42.	My child can easily tell when another person wants to enter into conversation with them.				

43.	My child is good at negotiating for what they want.				
44.	My child likes to create lists of things (e.g. favorite toys, TV programs, etc).				
45.	My child would worry about how another child would feel if they weren't invited to a party.				
46.	My child likes to spend time mastering particular aspects of their favorite activities (e.g. skate-board or yo-yo tricks, football or ballet moves).				
47.	My child finds using computers difficult.				
48.	My child gets upset at seeing others crying or in pain.				
49.	If they had a sticker album, my child would not be satisfied until it was completed.				
50.	My child enjoys events with organized routines (e.g. brownies, cubs, beavers, etc).				
51.	My child is not bothered about knowing the exact timings of the day's plans.				
52.	My child likes to help new children integrate in class.				
53.	My child has been in trouble for name-calling or teasing.				
54.	My child would not enjoy working to complete a puzzle (e.g. crossword, jigsaw, word-search).				
55.	My child tends to resort to physical aggression to get what they want.				

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