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Research Report

Predicting Autism Spectrum Quotient (AQ) from the Systemizing Quotient-Revised (SQ-R) and Empathy Quotient (EQ)

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ABSTRACT

Background: Empathizing is a specific component of social cognition. Empathizing is also specifically impaired in autism spectrum condition (ASC). These are two dimensions, measurable using the Empathy Quotient (EQ) and the Autism Spectrum Quotient (AQ). ASC also involves strong systemizing, a dimension measured using the Systemizing Quotient (SQ). The present study examined the relationship between the EQ, AQ and SQ. The EQ and SQ have been used previously to test for sex differences in 5 'brain types' (Types S, E, B and extremes of Type S or E). Finally, people with ASC have been conceptualized as an extreme of the male brain. *Method:* We revised the SQ to avoid a traditionalist bias, thus producing the SQ-Revised (SQ-R). AQ and EQ were not modified. All 3 were administered online. *Sample:* Students (723 males, 1038 females) were compared to a group of adults with ASC group (69 males, 56 females). *Aims:* (1) To report scores from the SQ-R. (2) To test for SQ-R differences among students in the sciences vs. humanities. (3) To test if AQ can be predicted from EQ and SQ-R scores. (4) To test for sex differences on each of these in a typical sample, and for the absence of a sex difference in a sample with ASC if both males and females with ASC are hyper-masculinized. (5) To report percentages of males, females and people with an ASC who show each brain type. *Results:* AQ score was successfully predicted from EQ and SQ-R scores. In the typical group, males scored significantly higher than females on the AQ and SQ-R, and lower on the EQ. The ASC group scored higher than sex-matched controls on the SQ-R, and showed no sex differences on any of the 3 measures. More than twice as many typical males as females were Type S, and more than twice as many typical females as males were Type E. The majority of adults with ASC were Extreme Type S, compared to 5% of typical males and 0.9% of typical females. The EQ had a weak negative correlation with the SQ-R. *Discussion:* Empathizing is largely but not completely independent of systemizing. The weak but significant negative correlation may indicate a trade-off between them. ASC involves impaired empathizing alongside intact or superior systemizing. Future work should investigate the biological basis of these dimensions, and the small trade-off between them.

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1. Introduction

1.1. *Empathizing: a specific component of social cognition*

Social cognition is too broad a construct to be useful. This is because social information derives from very different ***sources*** (e.g., faces, voices, actions), and the information conveyed may be of different *types* (e.g., emotional, intentional, bodily cues, social rules). Finally, the demands of a situation may require different psychological *processes* (e.g., emotion–recognition, attribution of intent, identity recognition, lip-reading or gaze-following). For this reason, research has tended to focus on *specific* aspects of social cognition.

Empathizing is one such specific component of social cognition. Empathizing is defined as the drive to identify another person's emotions and thoughts, and to respond to these with an appropriate emotion (Baron-Cohen, 2003). We refer to it as a drive rather than an ability, but we recognize that it may be a mix of these, since our ability tends to reflect how strong our drive is in a particular area. When we use the term 'drive', we also do not make any claim as to how much of this stems from innate or experiential factors, since there have been insufficient studies into the heritability of empathy. It is also apparent that one's level of empathy can be influenced by a range of situational factors (e.g., fatigue, threat, alcohol or mood can all temporarily reduce one's empathy), individual differences (e.g., sex, females tending to score better on tests of empathy) (Baron-Cohen and Wheelwright, 2004) and neurological conditions (e.g., autism and psychopathy both entail reduced empathy (Baron-Cohen, 1995; Blair, 1995). The key feature we wish to highlight is that empathizing is a *dimension* along which individuals differ. For this reason, the Empathy Quotient (EQ), a self-report questionnaire, has been developed to measure such individual differences (Baron-Cohen and Wheelwright, 2004). Other empathy measures (such as the Interpersonal Reactivity Index) have also been used (see Baron-Cohen and Wheelwright for a review of these).

The value of isolating empathizing as a specific component for study within social cognition is three-fold. First, neuroimaging studies reveal a unique set of brain regions involved in recognizing other's emotions and mental states (Baron-Cohen et al., 1994, 1999; Brothers, 1990; Frith and Frith, 2001), key among these being the medial- and orbito-frontal cortex and the amygdala. Secondly, sex differences in the general population suggest that both experiential, hormonal and even genetic factors underpin empathizing (Hughes and Cutting, 1999; Knickmeyer et al., 2005). Thirdly, and as mentioned earlier, the neurodevelopmental condition of autism involves a specific impairment in empathy (Baron-Cohen and Wheelwright, 2004). The study of empathizing therefore holds the promise not only of casting light on this most important of human characteristics, but on sexual dimorphism in the brain and the neural basis of a major medical condition.

1.2. *The Autism Spectrum Quotient*

The diagnosis of an autism spectrum condition (ASC) involves difficulties in social development and communication, alongside the presence of unusually strong repetitive behavior or 'obsessive' interests (A.P.A., 1994; I.C.D-10, 1994). Autistic traits are found not only at a high level in people with such diagnoses but are also found on a continuum at lower levels throughout the population. This continuum is revealed using a second instrument, the Autism Spectrum Quotient (AQ), which measures such individual differences (Baron-Cohen et al., 2001). There are other instruments that have been developed to measure autistic traits (see Baron-Cohen et al., 2001 for a review) but the AQ is specifically designed for self-report by adults with an IQ in the average range or above.

1.3. *Systemizing*

ASC not only involves difficulties in empathy, but also involves a strong drive to 'systemize' (Baron-Cohen, 2002). Systemizing is defined as the drive to analyze, understand, predict, control and construct rule-based systems. It is of interest that while a female advantage is seen on the EQ, a male advantage is seen on the self-report questionnaire that measures individual differences in systemizing, the Systemizing Quotient (SQ) (Baron-Cohen et al., 2003). While many tests are relevant to systemizing (such as map-reading, intuitive physics or mathematics), the value of the SQ is that it cuts across these separate examples of systemizing to look at an individual's interest in a *range* of systems. Finding opposite patterns of sex differences on the EQ and SQ suggests that empathizing and systemizing are independent of each other. However, given that ASC appears to involve both strong systemizing and impaired empathizing suggests that there may be important neurobiological links between these.

To date, only one study has used both the SQ and EQ in the same sample (Baron-Cohen et al., 2003), and no study so far has used all 3 questionnaires (SQ, EQ, AQ) on the same individuals to understand how these relate to each other. One aim of the present study is to test if an individual's AQ score can be predicted from their EQ and SQ scores. If it can be, this suggests that ASC is determined by the specific combination of these two dimensions.

1.4. *The E–S and EMB theories*

The Empathizing–Systemizing (E–S) theory of typical sex differences (Baron-Cohen, 2002) proposes that more females than males show the profile of empathizing being stronger than systemizing (E > S, also referred to a Type E), and more males than females show the opposite profile (S > E, or Type S). The 'extreme male brain' (EMB) theory (Baron-Cohen, 2002) holds that the cognitive profile seen in ASC is an extreme of that seen in typical males. That is, they should have the profile S >> E (or Extreme Type S). Furthermore, if this applies to ASC as a whole, then the typical sex difference in the general population should not be found.

These predictions have been confirmed (Baron-Cohen et al., 2003; Baron-Cohen and Wheelwright, 2004). On the EQ, females in the general population score 47.2 (SD = 10.2), which is significantly higher than the male mean of 41.8 (SD = 11.2), while people with ASC score significantly lower than typical males, with a mean score of 20.4 (SD = 11.6). On the SQ, typical males score a mean of 30.3 (SD = 11.5), which is significantly higher than the mean for typical females of 24.1 (SD = 9.5). People with an ASC score significantly higher than typical males with a mean of 35.7 (SD = 15.3). Finally, on the AQ (Baron-Cohen et al., 2001), not surprisingly, people with ASC have the highest AQ scores (mean 35.8, SD = 6.5), but consistent with predictions, typical males score higher (mean = 17.8, SD = 6.8) than typical females (mean = 15.4, SD = 5.7).

1.5. *Aims*

The study reported below had 5 aims:

(1) To improve the SQ as an instrument. This is because items in the original SQ were drawn primarily from traditionally male domains. To counter this, new items were added to the SQ to create the SQ-Revised (or SQ-R), including more items that might be relevant to females in the general population. This design feature allowed us to test if systemizing scores are higher among males even with the inclusion of items selected from traditionally female domains.
(2) We also tested SQ-R as a function of degree-subject studied in the typical sample, as a means of validating the SQ-R, predicting that physical scientists should score higher than those in the humanities (since physical science always involves systemizing, while the humanities vary more in how much systemizing is required). These first two aims are primarily methodological.
(3) To investigate the relationship between the EQ, SQ-R and AQ in both a typical and an ASC sample. In particular, we wanted to test whether AQ score could be predicted from EQ and SQ-R score, and whether the EQ and SQ-R were fully independent of each other or whether there was a trade-off between them. This aim is more conceptual, since it raises the question of whether the number of autistic traits an individual has is ultimately a function of one's position on the empathizing and systemizing dimensions.
(4) To confirm previous sex differences reported using the SQ, AQ and EQ (but now using the SQ-R) in the typical sample, and to test if such sex differences are absent in the ASC sample. This is of interest for theoretical reasons, if ASC involves hyper-masculinization of both males and females.
(5) To calculate the proportion of people scoring in each of 5 defined 'brain types': Type S, Type E, Extreme Type S, Extreme Type E and the balanced brain, Type B (E = S), as a direct test of the E–S and the EMB theories.

2. Results

2.1. *Typical group*

The data obtained for Group 1 were examined first. Mean scores for SQ-R, AQ and EQ by sex and degree subject are presented in Table 1. The distribution of SQ-R scores approximated to a normal distribution: the kurtosis and skewness statistics were, across the whole of Group 1, 0.186 and 0.398, respectively. The internal consistency of the SQ-R was checked using Cronbach's alpha. The value of 0.903 is high, indicating good internal consistency. A factor analysis on the SQ-R extracted 18 factors with an eigen value greater than 1. Examination of the items in each factor suggested that these were not psychologically meaningful clusters and, given the high value for Cronbach's alpha, it was thought more appropriate to analyze the SQ-R as a single scale without any specific subscales. The mean score for males and females separately was calculated for each item on the SQ-R. In the original version of the SQ, males had a higher mean on 86.8% of the items, and females on 13.2% of the items. This disparity between the sexes was improved in the SQ-R: males had a higher mean on 68.0% of the items and females had a higher mean on 32.0% of the items.

Table 1 – Means and SDs for SQ-R, AQ and EQ for Group 1

Degree	Sex	*n*		SQ-R	AQ	EQ
Physical science	Male	294	Mean	65.4	19.4	35.9
			SD	17.5	6.4	11.0
	Female	159	Mean	59.9	18.0	44.7
			SD	19.4	5.7	11.3
Biological science	Male	125	Mean	62.0	16.7	41.6
			SD	17.8	5.8	11.5
	Female	290	Mean	52.0	15.6	48.5
			SD	19.2	5.8	11.4
Social science	Male	115	Mean	61.9	16.2	41.4
			SD	18.8	5.0	11.0
	Female	181	Mean	51.2	15.0	48.7
			SD	19.7	5.1	10.8
Humanities	Male	189	Mean	53.7	15.7	40.5
			SD	20.6	6.0	11.7
	Female	408	Mean	48.4	14.6	48.7
			SD	17.9	5.3	11.2

2.1.1. *Effects of sex and degree*

Previous research has shown that there is a relationship between sex and degree subject and scores on both the AQ and EQ questionnaires (Baron-Cohen and Wheelwright, 2004; Baron-Cohen et al., 2001). These effects were therefore tested in this sample. Separate ANOVAs were conducted on the AQ and EQ with between-subject factors of Degree (physical science vs. biological science vs. social science vs. humanities) and Sex (males vs. females). For the AQ, there was a significant main effect of Degree ($F(3,1753) = 32.9$, $P < 0.0001$) and also of Sex ($F(1,1753) = 16.0$, $P < 0.0001$). The Degree by Sex interaction was not significant ($F(3,1753) = 0.083$, $P = 0.97$). Post hoc Tukey tests indicated that physical scientists scored higher on the AQ than the other 3 degree groups ($P < 0.0001$) and that biological scientists scored higher than students studying humanities ($P < 0.05$). There were no other significant differences. For the EQ, there were also significant main effects of Degree ($F(3,1753) = 16.9$, $P < 0.0001$) and Sex ($F(1,1753) = 177.8$, $P < 0.0001$). The Degree by Sex interaction was not significant ($F(3,1753) = 0.57$, $P = 0.64$). Post hoc Tukey tests indicated that physical scientists scored lower than the other 3 degree groups ($P < 0.0001$). There were no other significant differences.

As there is a relationship between sex and degree subject on both the AQ and EQ, the 2 questionnaire scores were included as covariates in the analysis of SQ-R. Hence, an ANOVA with between-subject factors of Degree (physical science vs. biological science vs. social science vs. humanities) and Sex (males vs. females) was performed on the SQ-R, covarying for AQ and EQ scores. Both covariates had a

Table 2 – Means and SDs for SQ-R, AQ and EQ for the ASC group and typical group

Group	Sex	n		SQ-R	AQ	EQ
ASC	Male	69	Mean	77.8	35.9	18.7
			SD	22.9	7.8	9.8
	Female	56	Mean	76.4	37.4	18.5
			SD	25.1	8.2	10.1
	Total	125	Mean	77.2	36.5	18.6
			SD	23.8	8.0	9.9
Typical group	Male	723	Mean	61.2	17.4	39.0
			SD	19.2	6.2	11.6
	Female	1038	Mean	51.7	15.5	48.0
			SD	19.2	5.6	11.3
	Total	1761	Mean	55.6	16.3	44.3
			SD	19.7	5.9	12.2

significant effect: AQ ($F(1,1751) = 182$ $P < 0.0001$), EQ ($F(1,1751) = 51.2$, $P < 0.0001$). There was a significant main effect of Degree ($F(3,1751) = 18.4$, $P < 0.0001$) and Sex ($F(1,1751) = 83.9$, $P < 0.0001$), with males scoring higher than females. Post hoc pairwise comparisons, using Bonferroni correction to adjust for multiple comparisons, indicated that physical scientists scored the highest, there was no difference between social scientists and biological scientists, while students studying humanities scored lowest of all ($P < 0.05$ for all comparisons). The interaction between Degree and Sex was not significant ($F(3,1751) = 2.12$, $P = 0.1$).

2.2. *Predicting AQ from SQ-R and EQ*

The relationship between SQ-R, EQ and AQ was specifically examined in Group 1 by first testing the correlations between each pair of questionnaires. The correlations were all significant at the $P < 0.01$ level. There was a strong negative correlation between the AQ and EQ ($r = -0.50$), a moderate positive correlation between the AQ and SQ-R ($r = 0.32$) and a weak, but significant, negative correlation between the SQ-R and the EQ ($r = -0.09$).

In order to investigate the relationship between the SQ-R, EQ and AQ further, a factor analysis was carried out on the total scores from each questionnaire. One factor with an eigen value greater than 1 was extracted, which accounted for 54.7% of the total variance. This factor accounted for 76.1% of the variance in the AQ scores, 58.3% in the EQ and 30.0% in the SQ-R. The AQ had a strong positive loading on the factor (0.87), the EQ had a strong negative loading (–0.76) and the SQ-R had a positive loading (0.55). These results suggest that it is most appropriate to produce a model which predicts AQ score based on EQ and SQ-R scores. It was decided to retain sex in the model but not degree subject to increase its applicability. The model was produced by running a univariate ANOVA on AQ score, with a single factor of sex, and covarying for EQ and SQ-R. As expected, both covariates had a significant effect: SQ-R ($F(1,1757) = 219.4$ $P < 0.0001$), EQ ($F(1.1757) = 598.9$, $P < 0.0001$) and there was a significant main effect of Sex ($F(1.1757) = 18.9$, $P < 0.0001$).

Using the parameters generated in the model, for males, AQ score can be estimated using the formula AQ = [0.089SQ-R − 0.25EQ + 21.6], while for females AQ = [0.089SQ-R − 0.25EQ + 22.7].

2.3. *Results from the ASC group*

Table 2 presents the mean AQ, EQ and SQ-R scores for the ASC group and the typical group. Fig. 1 shows the distribution of SQ-R in the ASC group and typical males and females separately. The 3 groups have overlapping but distinguishable

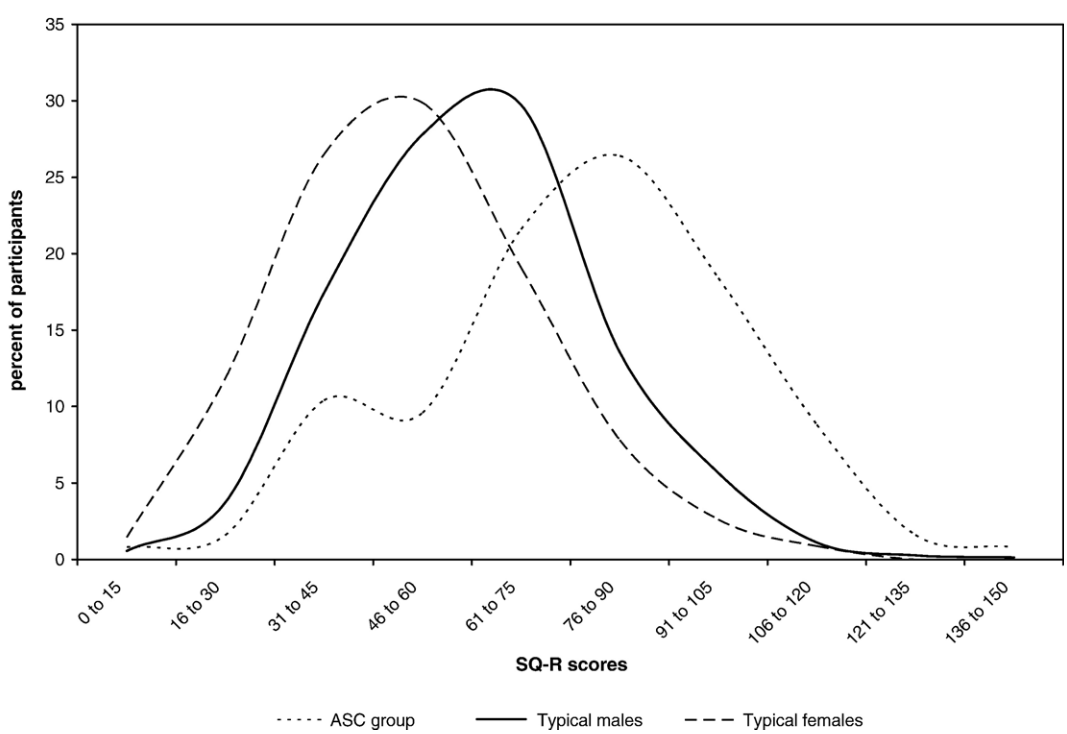

Fig. 1 – Distribution of SQ-R scores in the ASC group, typical males and typical females.

distributions, which is an improvement on the distributions for the original version of the SQ (Baron-Cohen et al., 2003). The mean age of the typical group was 21.0 years (SD = 2.6 years), which is significantly younger than the ASC group mean of 37.6 years (SD = 13.1 years) (t = 43.1, df = 1884, $P < 0.0001$). Age was therefore included as a covariate in the ANOVA on the SQ-R, with Group and Sex factors. There were significant main effects of Group ($F(1,1881) = 34.8$, $P < 0.0001$) and Sex ($F(1,1881) = 9.5$, $P < 0.01$), and the Group by Sex interaction was also significant ($F(1,1881) = 4.7$, $P < 0.05$). The age covariate had a significant effect ($F(1,1881) = 9.9$, $P < 0.01$). Inspection of the means suggests that the interaction arises because there was no difference on SQ-R scores between the males and females with ASC. This prediction was confirmed by an independent **t** test ($t = 0.33$, $df = 123$, $P = 0.74$).

2.3.1. *Predicting AQ from SQ-R and EQ*

The relationship between SQ-R, EQ and AQ was first examined in the ASC group by testing the correlations between each pair of questionnaires. All the correlations were significant at the $P < 0.01$ level, in the expected directions: $r = -0.51$ for the AQ and EQ, $r = 0.36$ for the AQ and SQ and $r = -0.29$ for the EQ and SQ.

In order to investigate the relationship between the SQ-R, EQ and AQ in the ASC group further, a factor analysis was carried out on the total scores from each questionnaire. One factor with an eigen value greater than 1 was extracted, which accounted for 53.9% of the total variance. This factor accounted for 78.7% of the variance in the AQ scores, 59.1% in the EQ and 23.7% in the SQ-R. The AQ had a strong positive loading on the factor (0.89), the EQ had a strong negative loading (–0.77) and the SQ-R had a positive loading (0.49). These results are similar to those found in Group 1 and suggest that it is most appropriate to produce a model which predicts AQ scores based on EQ and SQ-R scores. The model was produced by running a univariate ANOVA on AQ score, with a single factor of sex, covarying for EQ and SQ-R. As expected, both covariates had a significant effect: SQ-R ($F(1,121) = 8.5$, $P < 0.01$), EQ ($F(1,121) = 31.9$, $P < 0.0001$) and there was no significant main effect of Sex ($F(1,121) = 1.6$, $P = 0.21$). Since the main effect of sex was not significant, there was no need to produce different formulae for estimating AQ score in males and females with ASC.

Using the other parameters generated in the model, AQ score in the ASC group can be estimated using the formula: AQ = [0.077SQ-R – 0.36EQ + 38.1].

In previous research, there have been insufficient numbers of males and females with ASC to test whether there is any difference between the sexes on the AQ and EQ. With the current sample, independent **t** tests were carried out for each questionnaire separately and no significant difference between males and females was found for either questionnaire ($t = -1.04$, $P = 0.30$ for the AQ, $t = 0.12$, $P = 0.90$ for the EQ, $df = 123$ for both).

2.3.2. *Percentage of each group showing each 'brain type'*

To calculate the proportion of people scoring in each of 5 defined 'brain types' predicted by the E–S theory (Baron-Cohen et al., 2003) (Type S, Type E, Extreme Type S, Extreme Type E and Type B), we used a method reported elsewhere (Goldenfeld et al., in press). First, the SQ-R and EQ scores were standardized for the whole of Group 1 (n = 1761) using the following formulae S = [(SQ-R – <SQ-R>)/150 and E = (EQ – <EQ>)/80]. That is, we first subtracted the typical population mean (denoted by <…>) from the scores, then divided this by the maximum possible score (150 for the SQ-R, and 80 for the EQ). The means were 55.6 (SQ-R) and 44.3 (EQ). The original EQ and SQ-R axes were then rotated by 45°, essentially factor analyzing S and E, to produce two new variables, D and C. We normalized by the factors of 1/2 as is appropriate for an axis rotation. These new variables are defined as follows:

$D = (S - E)/2$ (i.e., the difference between the normalized SQ and EQ scores) and $C = (S + E)/2$ (i.e., the sum of the normalized SQ and EQ scores).

Because variable D is a measure of the difference between an individual's empathizing and systemizing scores, it allows us to determine an individual's brain type: a positive score indicates brain Type S, or Extreme Type S, a negative score indicates brain Type E, or Extreme Type E, and a score close to zero indicates brain Type B. In numerical terms, these brain types were assigned according to the percentiles of Group 1 on the D axis. The lowest scoring 2.5% on the D axis was classified as Extreme Type E and the top 2.5% was classified as Extreme Type S. Those scoring between the 35th and 65th percentile were classified as Type B. Participants who scored between the 2.5th and 35th percentiles were Type E, and Type S was defined by scoring between the 65th and 97.5th percentile.

Table 3 shows the percent of participants from both Group 1 and 2 with each brain type. Group 1 is divided into males and females while Group 2 is not, since there are no sex differences on the EQ and SQ-R for this group. Fig. 2 shows the results translated back into raw scores on the SQ-R and EQ tests so that individual brain types can be classified. Note that the D

Table 3 – Percent of participants with each brain type. *D* is the difference score between EQ and SQ

Brain type	D percentile (per)	Brain type boundary	Group		
			ASC group, n = 125	Typical males, n = 723	Typical females, n = 1038
Extreme Type E	per < 2.5	$D < -0.21$	0	0.1	4.3
Type E	2.5 ≤ per < 35	$-0.21 \le D < -0.041$	0	15.1	44.8
Type B	35 ≤ per < 65	$-0.041 \le D < 0.040$	6.4	30.3	29.3
Type S	65 ≤ per < 97.5	$0.040 \le D < 0.21$	32.0	49.5	20.7
Extreme Type S	per ≥ 97.5	$D \ge 0.21$	61.6	5.0	0.9

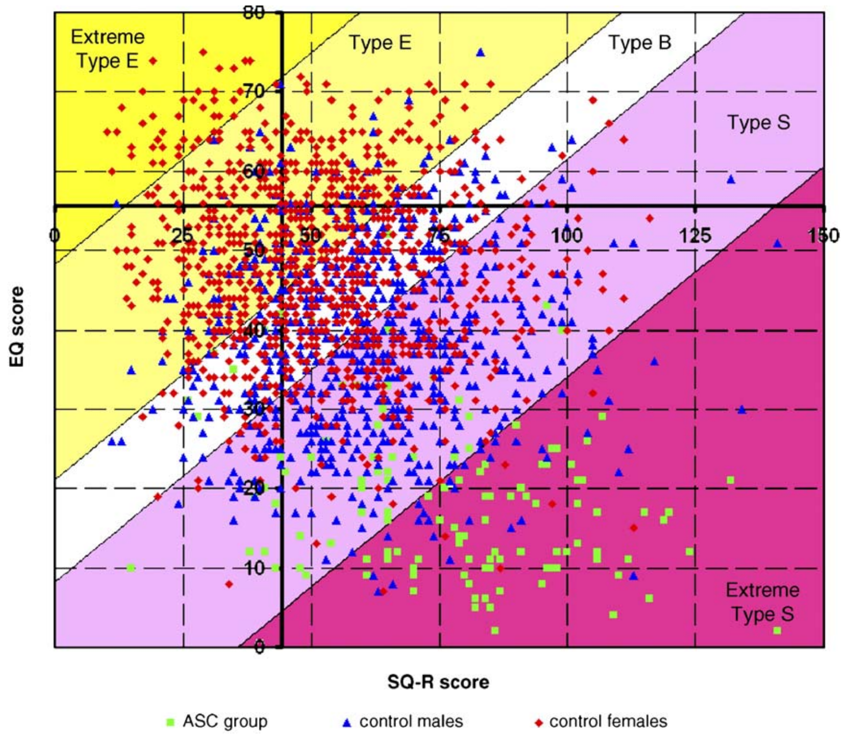

Fig. 2 – SQ-R and EQ scores for all participants with the proposed boundaries for different brain types.

axis, which is not shown, runs from the top left hand corner to the bottom right hand corner. Starting in the top left hand corner and passing along this axis, it can be seen that the highest concentration of participants changes from typical females to typical males and finally to participants from the ASC group. This observation is supported by inspection of Table 3: a larger proportion of typical females have a Type E brain, a larger proportion of typical males have a Type S brain and most people with ASC have an Extreme Type S brain.

This finding was supported by running a one-way ANOVA on the *D* scores, comparing the ASC group, typical males and typical females. There was a significant main effect of Group, $F(2,1883) = 510.2$, $P < 0.0001$ and post hoc Tukey tests confirmed that people with ASC had the highest *D* scores (mean = 0.24, SD = 0.11), followed by typical males (mean = 0.05, SD = 0.092) with typical females having the lowest *D* scores (mean = –0.04, SD = 0.099) (all Ps < 0.0001). These results indicate that, on average, people with ASC have a much stronger drive to systemize than to empathize, typical males also systemize to a higher level than they empathize, while typical females empathize to a higher level than they systemize.

To test whether EQ and SQ are a 'zero sum game' (which would be the case if **C** scores [the sum of the normalized EQ and SQ-R scores] did not differ between groups, despite there being group differences on the EQ and SQ), a one-way ANOVA was performed on the **C** scores. There was a significant main effect of Group ($F(2,1883) = 66.0$). Post hoc Tukey tests indicated that typical females had the highest **C** score (mean = 0.01, SD = 0.092), followed by typical males (mean = –0.015, SD = 0.10) with the ASC group scoring the lowest (mean = –0.089, SD = 0.86) (all $P < 0.0001$). This suggests that empathizing and systemizing are largely independent of one another.

3. Discussion

This study attempts to better understand one aspect of social cognition—empathy. It does this by investigating the relationship between scores on the Empathy Quotient (EQ), Systemizing Quotient-Revised (SQ-R) and Autism Spectrum Quotient (AQ) in both a large sample of typical participants, and a sample of adults with autism spectrum conditions (ASC). A revised version of the SQ, the SQ-R, was used which was an improvement on the previously reported SQ as it was less male-biased. AQ score was successfully predicted from EQ and SQ-R scores. This means that the position of an individual on the autism spectrum, as defined by the number of autistic traits an individual possesses, is a function of their empathizing and systemizing scores.

In the typical group, there was a strong negative correlation between the AQ and EQ, and a moderate positive correlation between the AQ and SQ-R. The negative correlation between the EQ and SQ-R was significant, but relatively weak. This suggests that there is only a weak trade-off between empathizing and systemizing in the normal population. In the ASC group, however, the negative correlation between EQ and SQ-R was much greater, and on par with the other correlations, suggesting that there may be a stronger trade-off between empathizing and systemizing in this group. This needs to be better understood.

The relationship between EQ and SQ-R was also examined by calculating the percentage of participants scoring in the 5 defined brain types. The E–S theory predicts that more typical females should have Type E (E > S) brains and more typical males should have Type S (S > E) brains. The EMB theory predicts that most people with ASC should have Extreme Type

S (S >> E) brains. These predictions were supported by the data: the largest proportion (45%) of typical females had a Type E brain, the largest proportion (50%) of typical males had a Type S brain and the largest proportion (62%) of adults with an ASC had an Extreme Type S brain. The same proportion (30%) of typical males and females had a Type B (E = S) brain. The percentages of each group showing each 'brain type' closely match those figures reported previously (Goldenfeld et al., in press) based on EQ and SQ data from a smaller general population (non-student) sample, and a group of people with ASC. It is striking that, in the present study, in the typical group, more than twice as many males as females had a Type S brain, and more than twice as many females as males had a Type E brain.

When the standardized EQ and SQ-R scores were combined, typical females achieved the highest combined score, followed by typical males, with the ASC group scoring lowest. Our earlier study (Goldenfeld et al., in press) found no difference in the combined score of the males and females, interpreting this in terms of differences in EQ and SQ-R scores 'compensating' each other. Needless to say, it is important to replicate all of these results in a general population sample. However, previous studies have not found a difference between student and general population samples on the EQ, SQ and AQ (Baron-Cohen and Wheelwright, 2004; Baron-Cohen et al., 2001, 2003).

In a direct comparison of the ASC group and typical group, the ASC group scored higher on the SQ-R than the typical group. Within the ASC group, there was no sex difference on the SQ-R, the EQ or AQ. This is in contrast with the typical group where the predicted sex differences were all found, i.e., males scored higher on the SQ-R and AQ, but lower on the EQ, than females. The EMB theory does not make any predictions about whether there should be sex differences in an ASC sample, but the absence of the typical sex difference in the ASC group suggests that both males and females with ASC are hyper-masculinized. Naturally, to move from the typical male range of SQ-R scores to the AS range involves a smaller shift than to move from the typical female range of SQ-R scores into the AS range. This could explain why there are more males than females diagnosed with ASC. It would be of interest to test if there is an equivalent dose–effect in candidate biological mechanisms (Baron-Cohen et al., 2005) needed to produce autism in males than in females.

Within the typical group, similar results were found in terms of sex differences and university-degree differences as have been reported in previous studies (Baron-Cohen et al., 2001, 2003; Baron-Cohen and Wheelwright, 2004). Males scored higher on the AQ and lower on the EQ than females. Students studying physical sciences scored higher on the AQ and lower on the EQ than students studying other degrees. In addition, on the AQ, biological scientists scored higher than students studying humanities. On the SQ-R, males scored higher than females, even taking into consideration AQ and EQ scores. Again allowing for the effect of AQ and EQ, physical scientists scored the highest on the SQ-R, there was no difference between social and biological scientists and students studying humanities scored the lowest. These results would be predicted on the basis of assumptions about the level of systemizing needed for different degree subjects.

We conclude that empathizing appears to be largely (but not completely) independent of systemizing. The fact that the number of autistic traits an individual possesses can be predicted in terms of their empathizing and systemizing scores suggests that empathizing and systemizing may be linked in important ways. Future research needs to examine this link. For example, they may share a common biological mechanism. A recent candidate biological mechanism is fetal testosterone, which has a positive correlation with empathizing but a negative correlation with systemizing (as indexed by 'narrow interests') (Knickmeyer et al., 2005). Future research should test the neural basis of empathizing and systemizing using fMRI in samples that are drawn from the EQ and SQ continua.

4. Experimental procedures

4.1. Participants

Group 1, later referred to as the typical group, consisted of 1761 members of Cambridge University, comprising 723 males and 1038 females. Average age was 21.0 years (SD = 2.58 years). 85.5% of the sample described themselves as right-handed, 10.8% were left-handed and 3.7% were ambidextrous. They were recruited via several routes including email, post, newspaper adverts and notices around the university, and invited to complete the 3 questionnaires online via a website constructed by the authors. An incentive to participate was offered, in that everyone who completed all three questionnaires was entered into a draw to win a prize. Only participants who completed all three questionnaires were included in the final analysis. Participants who reported a history of psychiatric difficulties (depression, ASC, bipolar illness, psychosis or anorexia) were excluded from the analysis. Participants indicated their undergraduate degree subject and these were classified as physical sciences,[1] biological sciences,[2] social sciences[3] and humanities.[4]

Group 2 consisted of 125 adults, 69 males and 56 females, with a diagnosis on the autism spectrum. Of these 125, 110 had Asperger Syndrome (AS) and 15 had high-functioning autism (HFA). These are distinguished primarily in terms of age at which language development began (phrase speech before 3 years old being required for AS, and after 3 leading to a diagnosis of HFA, assuming the social and obsessional criteria are also met). The mean age of Group 2 was 37.6 years (SD = 13.1 years). 73.8% of the sample

[1] Physical sciences included: mathematics, physics, physical natural sciences, chemistry, computer science, geology, communications, engineering, manufacturing engineering, chemical engineering, mineral science, material science, astrophysics, astronomy and geophysics.

[2] Biological sciences included: experimental psychology, neurophysiology, biochemistry, molecular biology, biological anthropology, biology, neuroscience, medicine, veterinary medicine, anatomy, genetics, pharmacology, physiology, plant sciences and zoology.

[3] Social sciences included: geography, economics, commerce, social and political sciences, archaeology, anthropology, land economy, international relations and management.

[4] Humanities included: classics, languages, drama, education, law, architecture, philosophy, oriental studies, English, linguistics, theology, history, history and philosophy of science, history of art and music. We acknowledge that some humanities (such as law or linguistics) or social sciences (such as economics) involve more systemizing than others, but these ways of dividing degree subjects may still capture some important differences between the highly lawful physical sciences and less lawful domains.

described themselves as right-handed, 9.5% were left-handed and 16.7% were ambidextrous. All participants were diagnosed by experienced clinicians according to DSM-IV or ICD-10 criteria.

4.2. Instruments

Full details about the construction of the AQ and EQ are available elsewhere (Baron-Cohen and Wheelwright, 2004; Baron-Cohen et al., 2001). The EQ was developed because other instruments purporting to measure empathy also include items unrelated to empathy. The AQ and SQ are the only self-report instruments of their kind, for use in the adult population. The SQ used in the present study was a modification of the one described earlier (Baron-Cohen et al., 2003), and the modifications are described below. All three questionnaires were self-administered on-line, and have a forced choice format. Participants are asked to indicate whether they 'strongly agree', 'slightly agree', 'slightly disagree' or 'strongly disagree' with a statement. Approximately half the items on each questionnaire are worded so that a high scorer will agree with the item, to avoid response bias. The AQ consists of 50 questions, each of which scores one point if the participant chooses the 'autistic trait' response, or zero otherwise. The EQ comprises 40 items, with 2 points available for a 'strongly' response and 1 point for an appropriate 'slightly' response.

4.3. Modifications of the SQ

The original version of the SQ comprised 40 scoring items and 20 filler items. The SQ-R initially had 80 scoring items, and this is the version that all participants completed. The 80-item version of the questionnaire was piloted on 10 typical males and 10 typical females, to check that all items were easily comprehensible. Following data collection, 5 items were removed from the questionnaire because they were too similar to other items in the SQ-R, AQ or EQ. 2 out of the 5 items were from the original version of the SQ. Therefore, the final version of the SQ-R had 75 items. It is shown in Appendix A. The 37 new items were items 1, 2, 3, 5, 8, 10, 11, 13, 19, 20, 21, 22, 23, 27, 28, 30, 31, 34, 36, 38, 39, 40, 42, 44, 48, 49, 55, 56, 57, 59, 61, 62, 65, 68, 71, 72 and 75, and were included to provide a greater coverage of social systems and domestic systems, not just mechanical or abstract systems.

4.4. Scoring the SQ-R

On the following 39 items, 'strongly agree' responses score two points and 'slightly agree' responses score one point: 1, 2, 4, 5, 7, 9, 11, 12, 13, 14, 16, 18, 19, 20, 21, 23, 25, 27, 29, 30, 32, 36, 38, 41, 42, 43, 46, 50, 53, 55, 60, 61, 62, 66, 68, 69, 72, 74 and 75. On the following 36 items, 'strongly disagree' responses score two points and 'slightly disagree' responses score one point: 3, 6, 8, 10, 15, 17, 22, 24, 26, 28, 31, 33, 34, 35, 37, 39, 40, 44, 45, 47, 48, 49, 51, 52, 54, 56, 57, 58, 59, 63, 64, 65, 67, 70, 71 and 73. Since there were 75 items and each could be scored with a maximum of 2 points, the maximum score on the instrument was 150 and the minimum was zero.

4.5. Procedure

All participants completed the EQ, SQ-R and AQ online, using a custom-designed website. After registering on the website and providing some basic information, participants were invited to fill out the three questionnaires, which were labeled as Adult Questionnaires A–C. For each questionnaire, participants were instructed to read each statement very carefully and rate how strongly they agreed or disagreed by selecting the appropriate option opposite each question. Participants could choose in what order to complete the questionnaires and, as they could log in and out of the site, all three questionnaires did not have to be completed in the same session.

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Appendix A. The SQ-R

	Strongly agree	Slightly agree	Slightly disagree	Strongly disagree
1. I find it very easy to use train timetables, even if this involves several connections.				
2. I like music or book shops because they are clearly organised.				
3. I would not enjoy organising events e.g. fundraising evenings, fetes, conferences.				
4. When I read something, I always notice whether it is grammatically correct.				
5. I find myself categorising people into types (in my own mind).				
6. I find it difficult to read and understand maps.				
7. When I look at a mountain, I think about how precisely it was formed.				
8. I am not interested in the details of exchange rates, interest rates, stocks and shares.				
9. If I were buying a car, I would want to obtain specific information about its engine capacity.				
10. I find it difficult to learn how to programme video recorders.				
11. When I like something I like to collect a lot of different examples of that type of object, so I can see how they differ from each other.				
12. When I learn a language, I become intrigued by its grammatical rules.				
13. I like to know how committees are structured in terms of who the different committee members represent or what their functions are.				
14. If I had a collection (e.g. CDs, coins, stamps), it would be highly organised.				
15. I find it difficult to understand instruction manuals for putting appliances together.				

Appendix A ***(continued)***

	Strongly agree	Slightly agree	Slightly disagree	Strongly disagree
16. When I look at a building, I am curious about the precise way it was constructed.				
17. I am not interested in understanding how wireless communication works (e.g. mobile phones).				
18. When travelling by train, I often wonder exactly how the rail networks are coordinated.				
19. I enjoy looking through catalogues of products to see the details of each product and how it compares to others.				
20. Whenever I run out of something at home, I always add it to a shopping list.				
21. I know, with reasonable accuracy, how much money has come in and gone out of my bank account this month.				
22. When I was young, I did not enjoy collecting sets of things e.g. stickers, football cards, etc.				
23. I am interested in my family tree and in understanding how everyone is related to each other in the family.				
24. When I learn about historical events, I do not focus on exact dates.				
25. I find it easy to grasp exactly how odds work in betting.				
26. I do not enjoy games that involve a high degree of strategy (e.g. chess, Risk, Games Workshop).				
27. When I learn about a new category, I like to go into detail to understand the small differences between different members of that category.				
28. I do not find it distressing if people who live with me upset my routines.				
29. When I look at an animal, I like to know the precise species it belongs to.				
30. I can remember large amounts of information about a topic that interests me e.g. flags of the world, airline logos.				
31. At home, I do not carefully file all important documents e.g. guarantees, insurance policies.				
32. I am fascinated by how machines work.				
33. When I look at a piece of furniture, I do not notice the details of how it was constructed.				
34. I know very little about the different stages of the legislation process in my country.				
35. I do not tend to watch science documentaries on television or read articles about science and nature.				
36. If someone stops to ask me the way, I'd be able to give directions to any part of my home town.				
37. When I look at a painting, I do not usually think about the technique involved in making it.				
38. I prefer social interactions that are structured around a clear activity, e.g. a hobby.				
39. I do not always check off receipts etc. against my bank statement.				
40. I am not interested in how the government is organised into different ministries and departments.				
41. I am interested in knowing the path a river takes from its source to the sea.				
42. I have a large collection e.g. of books, CDs, videos etc.				
43. If there was a problem with the electrical wiring in my home, I'd be able to fix it myself.				
44. My clothes are not carefully organised into different types in my wardrobe.				
45. I rarely read articles or webpages about new technology.				
46. I can easily visualise how the motorways in my region link up.				
47. When an election is being held, I am not interested in the results for each constituency.				
48. I do not particularly enjoy learning about facts and figures in history.				
49. I do not tend to remember people's birthdays (in terms of which day and month this falls).				
50. When I am walking in the country, I am curious about how the various kinds of trees differ.				
51. I find it difficult to understand information the bank sends me on different investment and saving systems.				
52. If I were buying a camera, I would not look carefully into the quality of the lens.				
53. If I were buying a computer, I would want to know exact details about its hard drive capacity and processor speed.				
54. I do not read legal documents very carefully.				
55. When I get to the checkout at a supermarket, I pack different categories of goods into separate bags.				
56. I do not follow any particular system when I'm cleaning at home.				
57. I do not enjoy in-depth political discussions.				
58. I am not very meticulous when I carry out D.I.Y or home improvements.				
59. I would not enjoy planning a business from scratch to completion.				
60. If I were buying a stereo, I would want to know about its precise technical features.				
61. I tend to keep things that other people might throw away, in case they might be useful for something in the future.				
62. I avoid situations which I cannot control.				

(continued on next page)

Appendix A *(continued)*

	Strongly agree	Slightly agree	Slightly disagree	Strongly disagree
63. I do not care to know the names of the plants I see.				
64. When I hear the weather forecast, I am not very interested in the meteorological patterns.				
65. It does not bother me if things in the house are not in their proper place.				
66. In maths, I am intrigued by the rules and patterns governing numbers.				
67. I find it difficult to learn my way around a new city.				
68. I could list my favourite 10 books, recalling titles and authors' names from memory.				
69. When I read the newspaper, I am drawn to tables of information, such as football league scores or stock market indices.				
70. When I'm in a plane, I do not think about the aerodynamics.				
71. I do not keep careful records of my household bills.				
72. When I have a lot of shopping to do, I like to plan which shops I am going to visit and in what order.				
73. When I cook, I do not think about exactly how different methods and ingredients contribute to the final product.				
74. When I listen to a piece of music, I always notice the way it's structured.				
75. I could generate a list of my favourite 10 songs from memory, including the title and the artist's name who performed each song.				

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