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Empathizing and systemizing in males, females, and autism: a test of the neural competition theory

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Summary:

Sex differences exist in empathizing (females showing a stronger drive than males), and this contrasts with sex differences in systemizing (males showing a stronger drive). Systemizing occurs when one analyses or constructs a system according to rules that govern that system. In this chapter we re-analyse data from the Empathy Quotient (EQ) and Systemizing Quotient (SQ) to test if empathy and systemizing "compete" in the brain. We conclude that they do, because there is no difference between the sexes in the measure of C (combined scores). This suggests that females' relatively high empathizing score compensates for their less developed systemizing score, and conversely males' high systemizing score compensates for their less well-developed empathizing score. Whilst many psychiatric conditions entail an impairment in empathy, autism and Asperger Syndrome (AS) may be specific in entailing an impairment in empathy alongside a heightened drive to systemizing, controlling for IQ and sex. This difference-score (between EQ and SQ) is tested for its power to classify individuals with AS. Finally, we propose a classification of 5 different 'brain types' based on such difference scores, which broadly correspond to the male- and female-typical brain, the extremes of these, and a final brain type which is 'balanced' (no difference between EQ and SQ). Future research should test the neural basis of these 5 cognitively-defined brain types in order to understand their developmental and anatomical characteristics further.

This book focuses on empathy impairments in psychiatric conditions. It is hard to think of a single psychiatric condition that does not reduce empathy to some extent. This may be a bi-product of the turning inwards of attention, of the focus on oneself, which tends to characterize anyone with a psychiatric condition. Because empathy impairment is not syndrome-specific, it is too blunt a notion. In this chapter, we focus on the subtle individual differences in empathy within the general population. In particular, we consider sex differences in empathy. Finally, we look at individuals with autism spectrum diagnoses, not just in terms of their empathy difficulties but in contrast with their intact or even superior drive to systemize. As will become apparent, we argue that it is the relative size of the discrepancy between these two domains (empathy and systemizing) that leads to useful distinctions in our understanding of different types of mind.

Empathizing and systemizing: sex differences

Two key modes of thought are systemizing and empathizing (Baron-Cohen, 2002). Systemizing is the drive to understand the rules governing the behaviour of a system and the drive to construct systems that are lawful. Systemizing allows one to predict and control such systems. Empathizing is the drive to identify another person's thoughts or emotions, and to respond to their mental states with an appropriate emotion. Empathizing allows one to predict another person's behaviour at a level that is accurate enough to facilitate social interaction. A growing body of data suggests that, on average, females are better than males at empathizing, and males are better than females at systemizing (Geary, 1998; Maccoby, 1999). In this chapter, we review evidence that these abilities strongly differentiate the male and female brain type, and re-analyse some published data to show that these abilities compete, so that despite sex differences in cognitive style, there is no overall sex difference in cognitive ability.

Autism

Individuals with autism spectrum conditions have severe social difficulties and an 'obsessional' pattern of thought and behaviour (A.P.A, 1994)**.** Such diagnostic features may arise as a result of their significant disabilities in empathizing (Baron-Cohen, O'Riordan, Jones, Stone and Plaisted, 1999; Baron-Cohen and Wheelwright, 2003; Baron-Cohen, Wheelwright, Hill, Raste and Plumb, 2001) as well as their stronger drive to systemize (Baron-Cohen, Wheelwright, Scahill, Lawson and Spong, 2001; Jolliffe and Baron-Cohen, 1997). Such a cognitive profile, together with significant sex bias in incidence rate, is compatible with the theory that autism is an extreme of the male brain (Baron-Cohen, 2002; Baron-Cohen, 2003).

The EQ and SQ

In order to quantify systemizing and empathizing, two self-report questionnaires have been developed (Baron-Cohen, Richler, Bisarya, Gurunathan and Wheelwright, 2003): the Systemizing Quotient (SQ) and the Empathy Quotient (EQ). In that study, these two questionnaires were tested in two groups: Group 1 comprised 114 males and 163 females randomly selected from the general population. Group 2 comprised 33 males and 14 females diagnosed with Asperger Syndrome (AS) or high-functioning autism (HFA). The mean scores of this study confirmed both the sex-difference in the general population (i.e., a male superiority in systemizing and a female superiority in empathizing), and the extreme male brain theory of autism.

Full details about the construction of the SQ and EQ questionnaires are available elsewhere (Baron-Cohen, Richler, Bisarya, Gurunathan and Wheelwright, 2003; Baron-Cohen and Wheelwright, 2004). The EQ and SQ were designed to be short, easy to complete, and easy to score. They have a forced-choice format, and are self-administered. Both the SQ and EQ comprise 60 questions, 40 assessing systemizing or empathizing (respectively), and 20 filler (control) items. Approximately half the items are worded to produce a "disagree" response, and half an "agree" response, for the systemizing/empathizing response. This is to avoid a response bias either way. Items are randomised. An individual scores 2 points if they strongly display a systemizing/empathizing response, and 1 point if they slightly display a systemizing/empathizing response.

In this chapter, we have re-analysed the data reported in the earlier study (Baron-Cohen, Richler, Bisarya, Gurunathan and Wheelwright, 2003) to test for a correlation between the scores for each individual on these tests. The maximum score on both questionnaires was 80. We plotted the raw scores from all individuals (from both groups) on a single chart, whose axes were labelled by the SQ and EQ scores, as shown in Figure 1a. The means of each test were taken from Group 1 in the earlier data set, and in this way represent a sex-blind mean of the general population. As can be seen, the results cluster in the SQ-EQ space and do not randomly fill the chart. This suggests that it may not be possible to score anywhere in SQ-EQ space, and that there may be constraints operating, such that SQ and EQ are not independent.

Do the EQ and SQ 'sex' the brain? A re-analysis of the 2003 dataset

We separated out the scores from the three groups: males from the general population (henceforth, male controls), females from the general population (female controls), and individuals with AS/HFA, as shown in colour in Figure 1b. Inspection of this plot strongly suggests 3 distinct populations. To explore the variations around the mean, we transformed the raw SQ and EQ scores into the two new variables: $S \equiv (SQ - \langle SQ \rangle) / 80$ and $E \equiv (EQ - \langle EQ \rangle) / 80$, i.e. we first subtracted the control population mean (denoted by $\langle \ldots \rangle$) from the scores, then divided by the maximum possible score, 80. The means were: 26.66 (SQ) and 44.01 (EQ). To reveal the differences between the populations we essentially factor analysed the results by performing a rotation of the original SQ and EQ axes by 45°. We normalised by the factors of ½ as is appropriate for an axis rotation. These new variables are defined as follows:

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

D scores represent the difference in ability at systemizing and empathizing for each individual. A high D score can be attained either by being good at systemizing or poor at empathizing, or both. C scores test if systemizing and empathizing stand in a reciprocal, competitive relationship with each other, such that as one scores higher on one of these dimensions, one scores lower on the other. Competition might arise at the neural level (since space is limited in the cortex (Kimura, 1999)) or might arise because both depend on some other biological resource (e.g., the hormone foetal testosterone (Knickmeyer, Baron-Cohen, Raggatt and Taylor, 2005). If systemizing and empathizing are reciprocal, one would expect no difference in C scores between the sexes. These new D and C axes are shown in dotted lines on Figure 1b.

Insert Figure 1a and b here

Figure 1b shows that the data have approximate boundaries that lie parallel to the C axis; in other words, the data vary significantly along the D dimension, but much less so along the C dimension. Our rotation was chosen to exhibit precisely this feature, but what was unexpected was that the rotation of 45° had such a natural interpretation, as explained below. Figure 1b suggests that the male control data have greater weight than the female data on the positive D axis, and the AS/HFA group has weight even further to the right along that axis than the male controls. By contrast, there is no significant trend along the C axis.

To explore this further, we have plotted the cumulative distributions of our data along the D and C directions, making separate plots for control male, control female and AS/HFA groups. We define the cumulative distribution $\Sigma_D(D)$ along the D direction as the fraction of data points whose D value is less than D' irrespective of the C value (see Figure 2a). Similarly, we define the cumulative distribution $\Sigma_C(C)$ along the C direction as the fraction of data points whose C value is less than C', irrespective of the D value (see Figure 2b).

Insert Figure 2a and 2b here

The means and standard deviations of the C and D scores for the different populations are as follows: D scores: control females = -0.039 (0.006); control males = 0.055 (0.011); AS/HFA = 0.21 (0.018). C scores: control females = 0.007 (0.011); control males = -0.0 (0.012); AS/HFA = -0.092 (0.010).

Figure 2a shows the cumulative distribution along the D direction, Σ_D, plotted for the three different groups: control female, control male and AS/HFA. The cumulative distributions are widely spaced apart, much further than the fluctuations in the raw data, indicating that these groups really do represent three distinct populations and are not sampled from the same underlying distribution. We quantified this observation by performing a between-subjects single-factor analysis of variance (ANOVA). There was a significant effect of group ($F(2, 321) = 121$, $p < 0.0001$). Post-hoc Tukey tests confirmed that all 3 groups differed significantly from one another.

Figure 2b shows the cumulative distribution along the C direction, Σ_C, plotted for the three different groups: control female, control male and AS/HFA. It is apparent that the control male and control female plots are indistinguishable up to the sample fluctuations, but both are well separated from the plots for the AS/HFA group. We have quantified this observation by performing a between-subjects single-factor analysis of variance (ANOVA). As expected, there was a significant effect of group ($F(2, 321) = 16.2$, $p < 0.0001$). Post-hoc Tukey tests confirmed that there was no significant difference between control males and females, but both of these groups were significantly different from the AS/HFA group.

Interpretation

These results indicate that the control male and female groups show distinct and significant differences in their cognitive style. The male group scores higher than the female group along the D dimension (relatively higher systemizing and lower empathizing), but there is no difference between the sexes in the measure of C (combined scores). Apparently, females' relatively high empathizing ability compensates for their less developed systemizing ability, and conversely males' high systemizing ability compensates for their less well-developed empathizing skills. The AS/HFA group has a lower C score. This is because, although they outperform both male and female controls on the systemizing measure, this does not compensate for their much lower scores on the empathizing measure.

A taxonomy of brain types, based on the difference between empathy and systemizing

Previously, a classification of brain types was proposed (Baron-Cohen, 2002), based in part on the empirical evidence suggesting that, as a group, males score higher on the SQ, but lower on the EQ, relative to females (Baron-Cohen, Richler, Bisarya, Gurunathan and Wheelwright, 2003). These data also suggested the possibility of a weak inverse relation between SQ and EQ scores. This inverse relationship is fully exposed by the analysis presented here. In particular, because the sex-differences are only discernable along the D dimension, regions of similar brain type are bounded by lines that are parallel to the C axis, or in terms of the original raw data, lines that lie parallel to the lower-left to upper-right diagonal of the SQ-EQ plot. Since there is no unique way to break up the results of our data analysis into identifiable groups along the D dimension, we propose a classification based upon the cumulant plot of Figure 2a. This generates 5 brain types, as follows:

(1) A significant proportion of individuals in the general population is likely to have a 'balanced' brain (or be of Type B), that is, their E and the S are not significantly different to each other. This can be expressed as $E \approx S$. In practice, we defined this as individuals whose D score lay between the median of the control male and female populations.

(2) A proportion of the general population is likely to have an ‘extreme S’ Type brain, that is, having a D score larger than the median of the AS/HFA group. This can be expressed as S>>E.

(3) A proportion of the general population is likely to have an ‘extreme E’ Type brain, symmetrically opposite to the extreme S Type brain. This can be expressed as E>>S. (We are not aware of any known clinical group which corresponds to this).

(4) The S Type brain can then be defined as those individuals who lie between the Type B and the extreme Type S brains. This can be expressed as S>E.

(5) The E Type brain can then be defined as those individuals who lie between the Type B and the extreme Type E brains. This can be expressed as E>S.

These 5 brain type definitions are based upon median scores, rather than *a priori* criteria based upon the mean and standard deviation. This obviates the need to make special assumptions about the form of the distributions. Table 1 shows the percentage of each of the 3 groups of individuals falling into each of the 5 Types of brain, using the median definitions above.

Insert Table 1 here.

Table 1 also shows that similar results were obtained by using a classification based upon the control males and females and simply taking a range of percentiles that separated out the tails of the distribution and the centre.

These natural groupings can be defined in terms of the deviations of the SQ and EQ scores from the means over the control populations. Thus, the balanced (B) brain type refers to individuals whose scores are close to the respective means, while S and E are brain types where the deviation from the mean is much greater in S (E) than for E (S). Similarly, extreme S and extreme E are extreme forms of brain types S and E respectively.

With the median definitions as given in Table 1, we note that there are significant sex differences in the populations of the different brain types. In the balanced brain type, males and females are present in virtually equal proportions. However, in S-type brains, males outnumber females by a factor of nearly 3:1. In E-type brains, females outnumber males by about the same factor. Finally, among the extreme S-type brains, individuals diagnosed with AS/HFA outnumber males by a factor of nearly 10. Unfortunately, there are not enough data to make any determination of sex-related trends within the AS/HFA group. We hope that future studies will be able to address this interesting question. These trends, rather than the precise boundaries we have chosen between the brain types, are the key differences that our SQ and EQ studies expose, and are not very sensitive to whether the median or percentile classification is used.

In order to present these results in a practical form, we show in Figure 3 our results for the different brain types (using the median definitions), translated back into raw scores on the SQ and EQ tests. Figure 3 can be directly used to classify an individual's brain type as represented by their responses to the SQ and EQ tests.

Insert Figure 3 here

The brain basis of empathy: further distinctions?

Philosophical (Stein, 1989) and evolutionary (Brothers, 1990; Levenson, 1996; Preston and de Waal, 2002) accounts have suggested that empathizing is not a unitary construct. Possible constituent fractions include Cognitive Empathy (CE) (attributions about other's mental states); Emotional Contagion (EC) ('the tendency to automatically mimic and synchronise facial expressions, vocalizations, postures and movements with those of another person, and, consequently, to converge emotionally' (Hatfield, Cacioppo and Rapson, 1992); and Sympathy (SY): involves a 'concern mechanism' (Nichols, 2001) that is often associated with an prosocial/altruistic behavioural component. Our current self-report measure (EQ) provides a composite score of all these three components of empathy (Baron-Cohen and Wheelwright, 2004; Lawrence, Shaw, Baker, Baron-Cohen and David, 2004). Example questions tapping on to these individual components are as follows:

a) CE: I often find it difficult to judge if something is rude or polite.
b) EC: I get upset if I see people suffering on news programmes.
c) SY: I really enjoy caring for other people.

Current experiments are underway in our lab to test the neurophysiological validity of such conceptual dissociations of empathy. Such a dissociation could help in characterising the nature of observed 'empathy deficits' in clinical conditions like autism and psychopathy (Russell and Sharma, 2003). Neuroimaging experiments have implicated different brain areas for performing tasks that tapped on to one or more of these 'fraction's of empathy. Traditional 'theory of mind' (Cognitive Empathy) tasks have consistently shown activity in medial prefrontal cortex, superior temporal gyrus and the temporo-parietal junctions (Frith and Frith, 2003; Saxe, Carey and Kanwisher, 2004). Studies of Emotional Contagion have demonstrated involuntary facial mimicry (Dimberg, Thunberg and Elmehed, 2000) as well as activity in the 'mirror neuron'-rich regions of the brain (Decety and Jackson, 2004; Wicker and al, 2003). Sympathy has been relatively less investigated, with one study implicating the left inferior frontal gyrus, among a network of other structures (Decety and Chaminade, 2003). While it would be somewhat phrenological to expect classical double-dissociations among these individual fractions of empathy, the clinical significance of such a finding cannot be underplayed. Our current fMRI studies of the brain basis of EQ and SQ scores may shed light on the neural nature and conceptual significance of the observed dependence between these two non-orthogonal psychometric personality measures.

Conclusions

We have shown that a re-analysis of the data from an earlier study using the Empathy Quotient (EQ) and Systemizing Quotient (SQ) (Baron-Cohen, Richler, Bisarya, Gurunathan and Wheelwright, 2003) reliably sexes the brain when analysed blind. In addition, although females show stronger empathizing and males show stronger systemizing, their *combined* scores do not differ, suggesting that empathizing and systemizing compete neurally in the brain. This also leads to the gratifying conclusion that, overall, neither sex is superior. We also confirm earlier reports that people with Asperger Syndrome (AS) or high functioning autism (HFA) have stronger systemizing scores than normal, but our new analysis shows that this did not compensate for their weaker empathy: thus their combined scores do not equal those of the normal groups. This result lends support to the extreme male brain theory of autism, and confirms that autism spectrum conditions arise from a cognitive deficit in empathizing.

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Table 1. Classifications of brain type based upon median positions of the sub-populations control males, females and AS/HFA (data from figure 2a), and upon percentiles of the entire sample (data from figure 1a). Both classifications give similar results. Noteworthy are that more females have a brain of Type E, more males have a brain of Type S, and more individuals with AS/HFA have brain of Extreme Type S.

Brain Type	Extreme E	E	B	S	Extreme S
Brain Sex	Extreme female	Female	Balanced	Male	Extreme male
Defining Characteristic	S << E	S < E	S ≈ E	S > E	S >> E
Brain types based on median positions of the three sub-populations male, females, AS/HFA					
Brain Boundary (median)	D < -0.16	-0.16 < D < 0.035	-0.035 < D < 0.052	0.052 < D < 0.21	D > 0.21
Female %	7	47	32	14	0
Male %	0	17	31	46	6
AS/HFA %	0	0	13	40	47
Brain types based on percentiles of male and female controls					
Brain Boundary (percentile)	D < -0.16	-0.16 < D < -0.048	-0.048 < D < 0.027	0.027 < D < 0.21	D > 0.21
percentile (per)	per < 2.5	2.5 ≤ per < 35	35 ≤ per < 65	65 ≤ per < 97.5	per ≥ 97.5
Female %	4.3	44.2	35.0	16.5	0
Male %	0	16.7	23.7	53.5	6.1
AS/HFA %	0	0	12.8	40.4	46.8

Fig 1a: SQ scores versus EQ scores for all participants. Note that the origin of the graph is at the controls' mean SQ and EQ scores. Visual inspection of the data show that scores are not randomly scattered in all 4 quadrants of EQ and SQ space, but cluster significantly. Shown in black, it is unclear if these clusters are linked to sex, or diagnosis, but such associations are revealed Figure 1b shows (in colour).

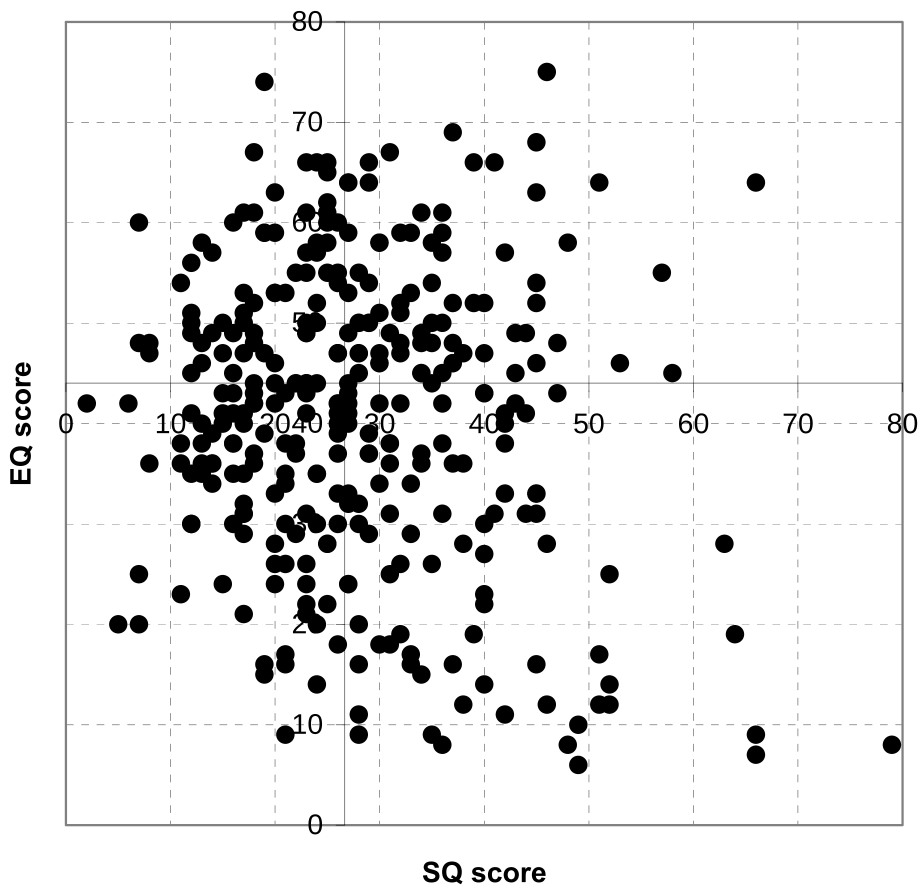


Fig 1b: SQ scores versus EQ scores for all participants, separated into the 3 groups. Note that the origin of the graph is at the controls' mean SQ and EQ scores. Also shown are the C axis (the combined EQ and SQ scores) and the D axis (the difference between the SQ and EQ scores). Whilst Fig 1a was blind to sex and diagnosis (all participants are shown in a single colour), in Fig 1b it becomes immediately apparent that the more females are clustering towards the upper left quadrant, more males are clustering towards the lower left quadrant, and that more people with AS/HFA are clustering deep into the lower left quadrant.

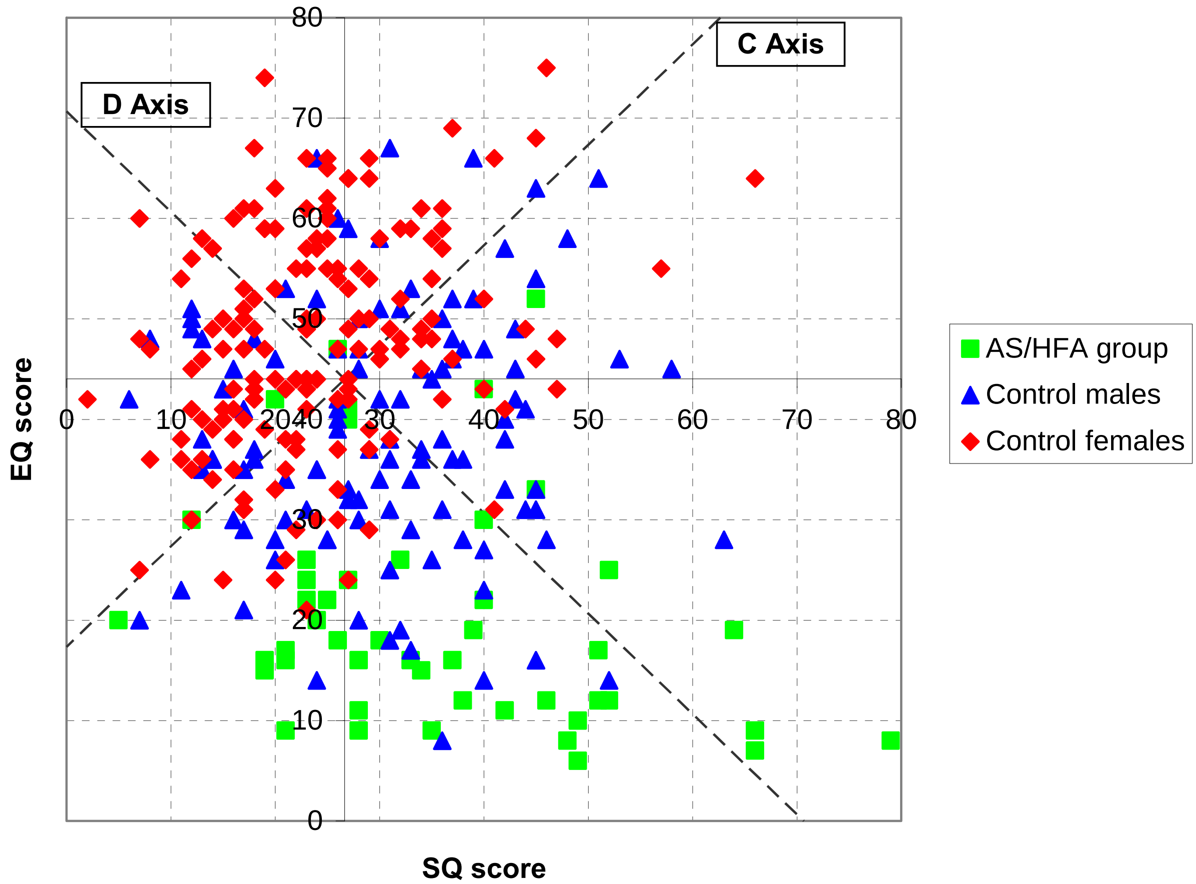


Fig 2a: Cumulative distribution function (Σ_D) of D. This graph dramatically reveals that the *difference* scores (D) between EQ and SQ significantly differentiate the three populations (males, females, and individuals with a diagnosis of AS/HFA).

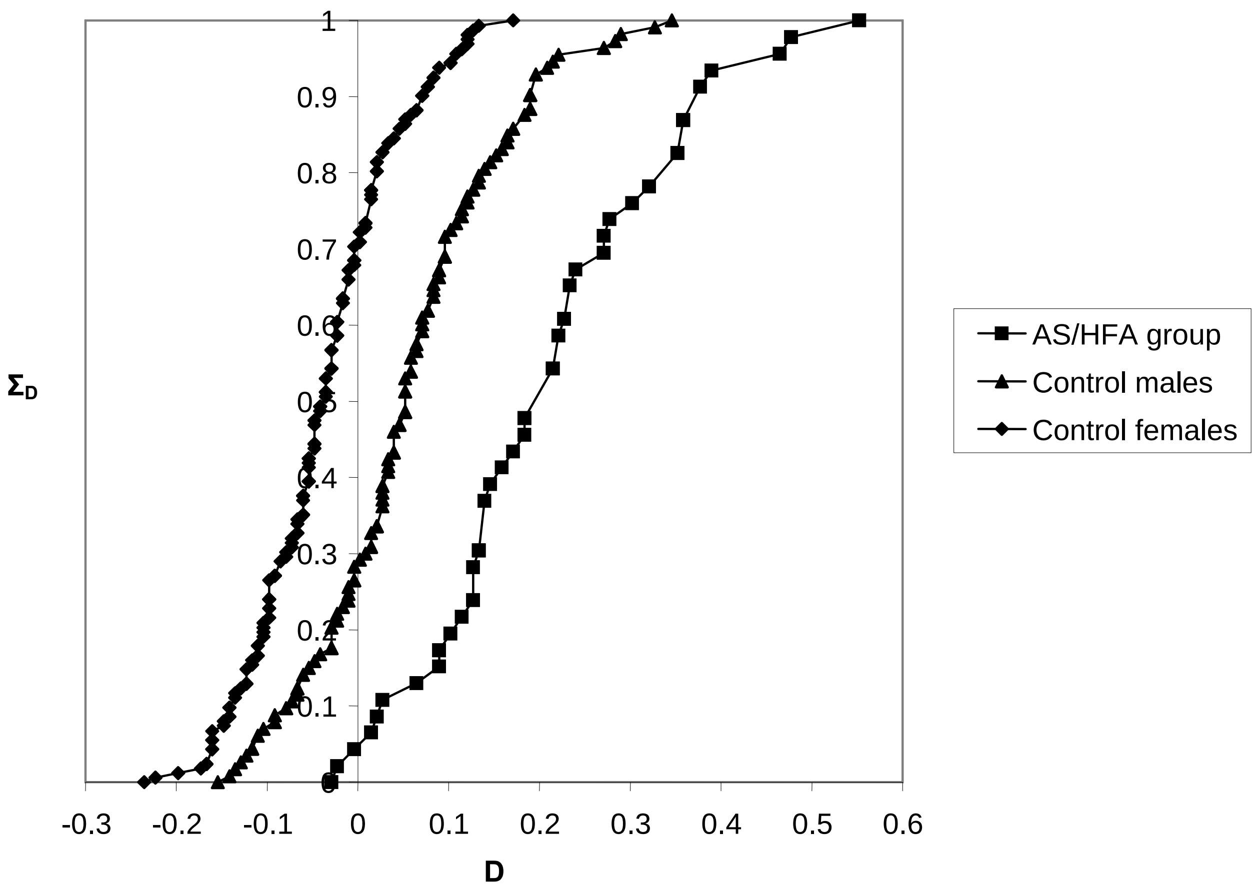


Fig 2b: Cumulative distribution function (Σ_C) of C. This graph reveals that when EQ and SQ scores are *summed*, the resulting C scores do not differ between males and females. This means that overall, neither sex is superior, and that there is neural compensation: the more EQ one has, the less SQ, and vice-versa. Such a relationship does not hold for individuals with AS/HFA, who remain with a lower overall C score, evidence of their empathy deficit.

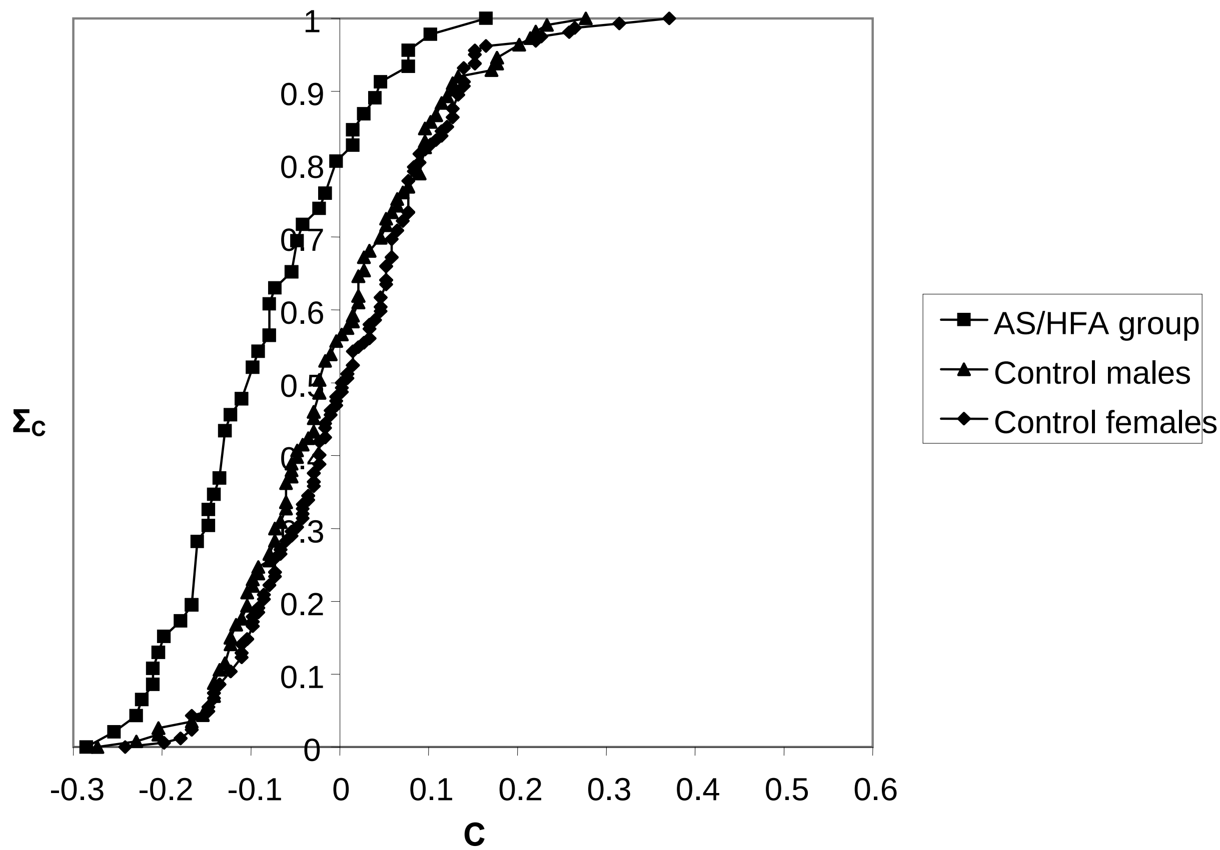
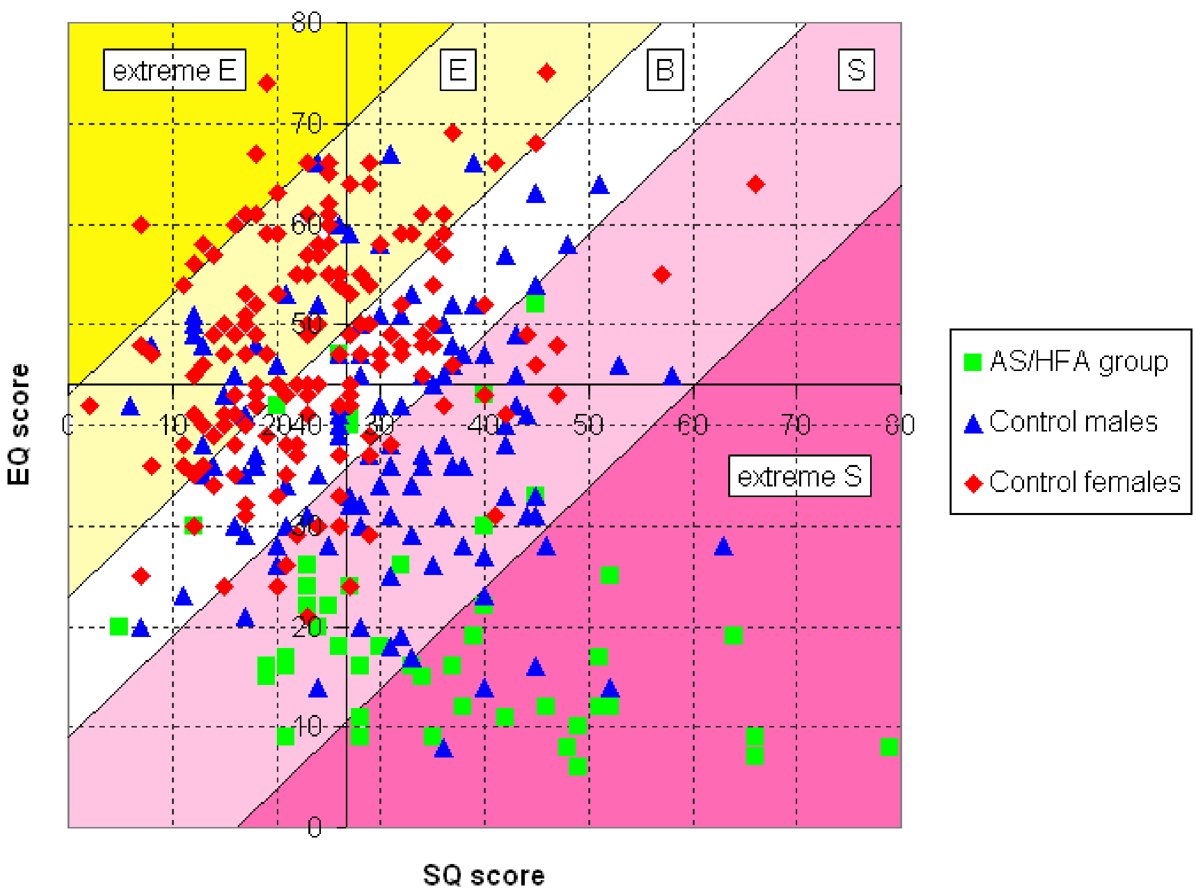


Fig 3: SQ scores versus EQ scores for all participants with the proposed boundaries for the different brain types. 5 clear bands or brain types are justified: (1) more males fall in the lilac zone (Type S, where S >E); (2) more females fall in the light yellow zone (Type E, where E>S); (3) many individuals show a Type B (Balanced profile, where E=S), in the white zone; (4) more individuals with AS/HFA fall in the purple zone (Extreme Type S, where S>>E); and (5) some females (but no males) fall in dark yellow zone (Extreme Type E, where E>>S).



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