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Sex and discipline differences in empathising, systemising and autistic symptomatology: Evidence from a student population

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Abstract

Baron-Cohen's (2002) theory of autism suggests that deficits in theory of mind and weak central coherence in autism can be explained as features of an 'extreme male brain' in which empathising is weak and systemising is strong. The two studies presented investigate this theory by examining the relationships between theory of mind, central coherence, empathising, systemising and autistic-like symptomatology in a sample of undergraduates. Study 1 used 48 undergraduates in four equal groups of male and female science and humanities students. Consistent with the theory, there were sex differences in the expected directions on all tasks in the first study. Differences according to discipline were found only on the Block Design task. Individuals with the 'male brain' profile also tended to show higher levels of autistic symptomatology. There was no evidence of a link between empathising and social skills on one hand and systemising and central coherence on the other. In the second study, performance on the Mechanical Reasoning and the Social Skills Inventory tasks was compared with performance on the Baron-Cohen Empathising and Systemising Quotients in a sub-sample of 20 students from Study 1. Moderately significant correlations were found between the Systemising Quotient and the Mechanical Reasoning task and between the Empathising Quotient and the Social Skills Inventory. Findings are largely consistent with the distinction between empathising and systemising but raise some questions concerning the tasks used to measure these abilities.

Sex and discipline differences in empathising, systemising and autistic symptomatology: Evidence from a student population

For many years, there have been two major theoretical explanations for the cognitive deficits shown in autism. The Theory of Mind explanation suggests that individuals with autism have reduced understanding of the mental states of others, leading to delayed use of language, social withdrawal and a lack of pretence in play (Baron-Cohen, Leslie, & Frith, 1985; Frith, 2003). In contrast, the Weak Central Coherence theory suggests that individuals have a cognitive bias towards processing information in a piecemeal, rather than a global manner (Frith & Happe, 1994). This would lead to strengths on tasks in which the 'gestalt' of a picture has to be ignored, as in the block design task used in many intelligence tests. More recently, (Baron-Cohen, 2002, 2003) has suggested that deficits in both of these areas could be explained as an extreme variation of the sex differences shown in processing in the general population. This is known as the Extreme Male Brain theory of autism. This theory is an extension of Baron-Cohen's empathising-systemising model. According to this model females are, on average, more likely to show high social awareness or empathising, and low understanding of 'systems' or systemising, while males are more likely to show the reverse pattern. According to Baron-Cohen (2003), these differences can largely be attributed to biological processes such as pre-natal testosterone levels.

Extreme Male Brain theory extends this idea by arguing that individuals with autism show an extreme example of these sex differences. In the Extreme Male Brain theory, therefore, weak central coherence is regarded as an element of strong systemising, or working out of logical processes, while poor theory of mind would be associated with poor empathising, or a lack of understanding of and appropriate responses to the mental states of others. Individuals with autism could be considered to be at the extremes of the normal distribution in two respects, showing unusually good systemising and unusually weak empathising. If Extreme Male Brain theory was found to be correct, it would be a parsimonious explanation for the range of deficits found in autism: alone, neither theory of mind nor weak central coherence can provide an explanation for all of the behaviours typically associated with autism. For instance, it is not immediately clear why a child who lacks a theory of mind would show repetitive and stereotyped play patterns, or why a child with weak central coherence would show such highly impaired communication.

There are three major claims to Baron-Cohen's Extreme Male Brain theory. Evidence for each of these three claims is assessed below. First, that there are reliable sex differences both in tasks measuring empathising and systemising and in tasks that separate autistic individuals from the general population, namely theory of mind and central coherence tasks. Second, that strengths and weaknesses that characterise autistic individuals map onto the two major areas of sex differences that he describes: empathising and systemising. Third, as Jarrold, Butler, Cottingham and Jimenez, (2000) suggest, these two areas of skill should be negatively correlated, so

that individuals with high systemising abilities would tend to show low levels of empathising, and vice versa. It is not clear, however, that Baron-Cohen assumes that empathising and systemising would be correlated in the general population. In an early review he refers to systemising and empathising as being on '*a* continuum' (p. 210, (Baron-Cohen & Hammer, 1997, italics added). In addition, he suggests that a single biological factor (pre-natal testosterone secretion) could cause both increased systemising and decreased empathising. If this were the case, one would expect the two factors to be highly associated. On the other hand, more recent work by Baron-Cohen and colleagues suggests the opposite; in Lawson, Baron-Cohen and Wheelwright (2004) the empathising and systemising measures used show no significant correlation and are presented as two independent areas of functioning. However, if the two areas are independent, it is difficult to see how linking the empathising – systemising theory to the deficits found in autism increases explanatory power in comparison to previous theories.

There is a growing body of evidence showing that sex differences in empathising and systemising are real. For instance, Voyer, Voyer and Bryden (1995) conducted a meta-analysis examining sex differences on spatial tasks. While the magnitude of the difference varied according to the task presented, there was a consistent male advantage across tests. With regard to empathising, Hoffman (1977) found that females showed higher levels of empathy across a range of studies.

There is also evidence suggesting that there are sex differences in tasks characteristically used to identify autistic individuals. Baron-Cohen, Wheelwright,

Hill, Raste and Plumb (2001) asked 15 men and 15 women to complete the 'Mind in the Eyes' test (assumed to be a measure of theory of mind ability) and the Embedded Figures Test (EFT; Witkin, Oltman, Raskin, & Karp, 1971). The men in the group showed worse scores on the Mind in the Eyes test and better scores on the EFT than the women, suggesting that men do indeed show a mild version of the strengths and weaknesses shown in autism, though sex differences on a revised version of the Mind in the Eyes test were only marginally significant (Baron-Cohen, Wheelwright, Hill et al., 2001).

Jarrold et al. (2000) conducted a detailed investigation of the claims of the Extreme Male Brain theory of autism. They investigated performance on standard theory of mind and embedded figures tasks in typically developing children and adults, as well as a group of children with autism. They did not find clear evidence for sex differences in these two tasks, showing no difference between groups of male and female students on the unrevised Mind in the Eyes test and a marginally significant difference on the EFT. They did, however, find a moderately significant correlation between performances on the two tasks, such that individuals with lower scores on the eye-reading task showed shorter completion times on the embedded figures task. These findings were replicated in the two other groups: a group of typically developing 5-year-old children and a group of children with autism, though the associations only became significant once verbal mental age was controlled.

Other researchers have not shown such clear correlations between these two diagnostic features of autism. Lawson et al (2004) investigated performance on two

tasks aiming to measure empathising and systemising abilities, the Social Stories Questionnaire and the Physical Prediction Questionnaire. Their sample contained adult males and females together with a group of adult males with Asperger's Syndrome (AS). They found that there were differences between all groups on the Social Stories Questionnaire, with females scoring most highly, non-AS males in the middle and AS males having the most difficulty. On the Physical Prediction Questionnaire, results were more equivocal, with AS and non-AS males scoring at the same level, while the females did less well. As described above, there were no significant correlations between scores on the two tasks in any group.

Briskman, Happe, & Frith (2001) gave questionnaires examining the presence of social and non-social autistic characteristics in autistic children and their parents. Significant correlations between scores on the social and non-social elements of the questionnaire were shown for parents of autistic children but not for parents of dyslexic or control group children, suggesting that any link between the two areas is not generally present in the population.

Recent research indicates that social and non-social autistic characteristics may be independent in preschool children on the autistic spectrum (Morgan, Maybery, & Durkin, 2003). While the children showed deficits in joint attention and language and weak central coherence compared to controls, deficits in each of these areas contributed independent variance when predicting the autistic diagnosis.

An alternative way of examining the theory of links between empathising and systemising and autistic symptomatology is to consider whether students who have

chosen to study a subject that requires high levels of systemising show correspondingly high levels of autistic symptomatology. Baron-Cohen, Wheelwright, Stott, Bolton and Goodyer, (1997) found that engineers were twice as common in the families of autistic children as in the families of control children. Conversely, Baron-Cohen et al., (1998) found that the incidence of autism was significantly increased in families of science students in comparison to humanities students. The present study extends this research by assessing the presence of autistic-like symptomatology within students themselves.

A further theoretical issue concerns the validity of the Systemising Quotient questionnaire normally used by Baron-Cohen that assesses the interests and preferences by asking participants to rate how closely statements such as 'I am fascinated by how machines work' apply to them. It could be argued that assessing preferences is very different from assessing abilities: a person may be interested in how machines work, but show no particular aptitude for building or even understanding how they work. This question is addressed in Study 2, in which a subgroup of participants completed both a practical measure of Mechanical Reasoning and the Systemising Quotient questionnaire, as well as the Empathising Quotient, to assess the relationships between the different tasks.

Study 1

The present study aims to build on the work carried out by Jarrold et al. (2000) and Lawson et al. (2004) by assessing the relationships among measures of

empathising, systematising, theory of mind, central coherence and autistic-like symptomatology in a single study. Male and female science and humanities students were asked to complete this battery of tests. It was predicted that there would be good correlations between the tasks purported to measure similar underlying skills, so that empathising would be correlated with theory of mind and systemising would be correlated with weak central coherence. It was also anticipated that there would be sex and discipline differences in all of the measures, with females and humanities students showing better theory of mind and empathising and lower scores on the Block Design and EFT. Females should also show fewer autistic-like symptoms. Finally, we anticipated correlations between the two sets of measures, such that high empathising and theory of mind would be associated with slow and inaccurate performance on the systemising and central coherence tasks.

Method

Participants

The 48 participants were students of the University of York (41 undergraduates and 7 postgraduates). There were 4 equal groups of 12 participants. Group M-S comprised male students (N = 12; mean age 21.1 years) studying science. Group M-H comprised male students (N = 12; mean age 20.6 years) studying humanities. Group F-S comprised female students (N = 12; mean age 21.6 years) studying science. Group F-H comprised female students (N = 12; mean age 20.9 years) studying humanities. All participants were British natives with English as

their first language. There were no significant differences between the groups in age (sex: $F(1, 44) = 1.20$, $p = ns$, $\eta^2 = .03$; discipline: $F(1, 44) = 2.38$, $p = ns$, $\eta^2 = .05$) or verbal IQ (sex: $F(1, 44) = 2.02$, $p = ns$, $\eta^2 = .04$; discipline: $F(1, 44) = 3.16$, $p = .08$, $\eta^2 = .07$). There were no significant interactions.

Materials

Verbal IQ: Participants' verbal IQ was assessed with Wechsler Abbreviated Scale of Intelligence Vocabulary subtest (WASI; Wechsler, 1999). The test requires participants to provide definitions for words. The task is discontinued after five consecutive scores of zero.

Autism-Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001): AQ measures the degree to which any adult of normal IQ possesses traits related to the autistic-spectrum by means of a 50-item self-report questionnaire. The questionnaire comprises 5 subscales of 10 items each, measuring social skill, attention switching, attention to detail, communication, and imagination.

Advanced Theory of Mind test: The revised 'Mind in the Eyes' test was used (Baron-Cohen, Wheelwright, Hill et al., 2001). This paper-and-pencil test included 36 photographs of the eye-region of the face of different actors and actresses. In addition to determining the sex of the face as a control task, participants were required to choose which of the four words best described the mental state of the person in the photograph. The test aims to measure individual's ability to put themselves into the mind of another. There are 36 possible marks for each scale. All participants scored at least 32 out of 36 on the sex recognition control task.

Central Coherence: Central Coherence Bias was assessed with both the *WASI* Block Design subtest (Wechsler, 1999) and the EFT (Witkin et al., 1971). The Block Design subtest involves arranging a specific number of blocks to replicate two-coloured designs, either modelled or printed two-dimensional geometric patterns, within a specified time limit. The EFT consisted of 12 trials. In each trial, the participant was first shown a card presenting a complex figure for 15 seconds. Next the participant was shown a card showing the target shape for 10 seconds. The time taken to identify the target shape within the previous complex figure was measured. In contrast to the procedure detailed in the scoring manual, trials on which the participant did not find the figure were excluded from the total. No participant made more than three errors and 38 of the 48 participants made one or no errors.

Systemizing: Systemizing was assessed with the last 20 items of the Mechanical Reasoning subtest of the Differential Aptitude Test (Bennett, Seashore, & Wesman, 1974). The multiple-choice test consisted of items assessing mechanical/technical systems. This involved problems such as reasoning about the relative movements of different wheels and pulleys in a diagram. It is similar in form to the Physical Prediction Questionnaire used by Lawson et al (2004). This type of measure differs from the Systemising Quotient used by Baron-Cohen (2003) in that there is a concentration on understanding and abilities rather than preferences. There was a total time allocation of 10 minutes. Each correct item earned a score of 1 point, which added up for a total of 20 possible points for the task.

Empathizing: Social Skills Inventory (Riggio, 1989) is a 90-item self-report questionnaire assessing basic social communication skills. The questionnaire consisted of

six subscales: Emotional Expressivity, Emotional Sensitivity, Emotional Control, Social Expressivity, Social Sensitivity, and Social Control. Every subscale consisted of 15 items measured on 5-point Likert scales, with '5' representing 'Exactly like me' while '1' representing 'Not at all like me'. There were 75 possible points for every subscale, and 450 points in total.

Procedure

The experiment involved a 55-minute one-to-one session that required the participant to complete five cognitive tasks; the WASI Vocabulary subtest, WASI Block Design subtest, the Mind in the Eyes task, the modified Mechanical Reasoning test, and the EFT in that order. Participants completed the Social Skills Inventory and AQ in their own time, and returned the questionnaires to the experimenter.

Results and Discussion

Sex and Discipline Differences

Table 1 provides the summary descriptive statistics for all of the measures. A MANOVA was carried out on the six measures of interest. Two independent factors of two levels each were investigated: sex (male or female), and discipline (science or humanities). Overall, there was a significant effect of sex ($F(6, 39) = 6.47$, $p < .001$, $\eta^2 = .50$), but not of discipline ($F(6, 39) = 1.75$, $p = ns$, $\eta^2 = .21$), and these effects were modified by a significant interaction ($F(6, 39) = 2.43$, $p < .05$, $\eta^2 = .27$).

Results on individual measures were then examined. For AQ scores, statistical analysis revealed a main effect of sex (F (1, 44) = 5.93, $p < .05$, $\eta^2 = .12$) but not of discipline (F(1, 44) <1). The Sex x Discipline interaction was not significant (F (1, 44) = 3.31, $p = .08$, $\eta^2 = .07$). Men had significantly higher AQ scores than did the women participants (mean 19.08 (SD 5.96) vs. 15.13 (SD 5.5)), whereas AQ scores did not differ between science students and humanities students (mean 17.08 (SD 4.7) vs. 17.13 (SD 7.16)). On examination of the individual scores, it was found that the three students with the highest scores on the AQ were all male humanities students, which may account for the marginally significant interaction between sex and discipline.

Mind in the Eyes performance yielded a main effect of sex (F (1, 44) = 6.74, $p < .05$, $\eta^2 = .13$) and a marginally significant effect of discipline (F (1, 44) = 3.51, $p < .07$, $\eta^2 = .07$). Men scored significantly lower than females on the Mind in the Eyes test (mean 24.8 (SD 4.6) vs. 27.8 (SD 3.6)), whereas science students were slightly poorer than humanities students (mean 25.2 (SD 4.23) vs. 27.4 (SD 4.2)). There was no significant Sex x Discipline interaction (F(1, 44) <1).

Main effects of sex and discipline on the Block Design subtest were both significant (sex, F (1, 44) = 9.17, $p < .05$, $\eta^2 = .17$; discipline, F (1, 44) = 5.68, $p < .05$, $\eta^2 = .11$). On average, men scored higher than women (mean 64.0 (SD 6.7) vs. mean 58.9 (SD 5.4)), while science students scored higher than humanities students (mean 63.5 (SD 6.3) vs. mean 59.5 (SD 6.2)). The Sex x Discipline interaction was not significant (F (1, 44) <1).

Mean completion time on the EFT showed a significant main effect of sex ($F(1, 44) = 4.62$, $p < .05$, $\eta^2 = .10$) but not of discipline, $F(1, 44) = 3.13$, $p = .08$, $\eta^2 = .07$). There was also a significant interaction, $F(1, 44) = 8.86$, $p < .01$, $\eta^2 = .17$). Female humanities students showed higher mean completion times than the other three groups (24.0s vs. 15.8s, 13.3s and 14.1s respectively).

As predicted in Baron-Cohen's (2002) Empathising-Systemising theory, independent analysis of Social Skills and Mechanical Reasoning scores revealed strong main effects of sex (Social Skills Inventory: $F(1, 44) = 9.75$, $p < .01$, $\eta^2 = .18$; Mechanical Reasoning: $F(1, 44) = 17.02$, $p < .01$, $\eta^2 = .28$). Men were significantly lower on the Social Skills Inventory than women (mean 275.6 (22.6) vs. 294.8 (19.6)), while superior on the modified Mechanical Reasoning test (mean 13.04 (SD 2.9) vs. 9.8 (2.5)). There were no significant main effects of Discipline or Sex x Discipline interaction for either Social Skills Inventory or Mechanical Reasoning ($F(1,44)<1$ in all cases).

Relationships among measures of theory of mind, central coherence, empathising, systemising and autistic symptomatology.

Correlations between the different measures are shown in Table 2. Correlational analysis largely confirmed the findings of the factor analysis that measures of empathising and theory of mind tasks correlate with one another, as do measures of systemising and central coherence. Scores on the AQ were significantly associated with empathising and theory of mind, but not with Mechanical Reasoning or either of the two measures of central coherence.

A link between theory of mind and central coherence was not supported. Mind in the Eyes performance did not correlate with Block Design test scores (r (48) = -.15, p = ns) or mean completion time on the EFT (r (48) = .05, p = ns). The correlation between Social Skills and Mechanical Reasoning scores did not reach significance (r (48) = -.28, p = .06). Partial correlations controlling for chronological age and verbal IQ did not affect the relationship (r (44) = -.28, p = .06).

Male Brain Profile and the Broader Autism Phenotype.

A further prediction of the experiment was that Baron-Cohen's (2002) male brain profile would be associated with the autism-spectrum manifestation, as measured on the AQ. To assess the tendency for participants to show the male brain profile, Empathising and Systemising scores were first converted into z-scores. The participant's Brain Type was then identified by calculating for the discrepancy between the two sets of z-scores: "Systemising $_{\text{z-score}}$ – Empathising $_{\text{z-score}}$". A solution greater than 1.0 from the equation represented the 'male' brain profile, while a solution less than -1.0 represented the 'female' brain profile. A score between 1.0 and -1.0 represented a 'balanced' brain profile.

Table 3 shows the distribution of participants in each group along the three brain types. First inspection suggests that men were distributed towards the male brain profile, while women were more distributed towards the female brain profile. Chi-square tests were used to assess the association between brain type and sex and discipline. There was a significant association between Sex and Brain Type ($\chi^2(2) = 19.80$, $p < .001$), but not between Discipline and Brain Type ($\chi^2(2) = .38$, p = ns). Thus, consistent with the Empathising-Systemising

theory, men were more likely to have the male brain profile, whereas women were likely to have the female brain profile. Science students were not any more likely to be classified as having either the male or female brain profile than humanities students.

Group differences between with reference to Baron-Cohen's (2002) brain types were investigated using one-way between subjects ANOVA with Mind in the Eyes performance and AQ scores as the dependent variables. The groups differed significantly on Mind in the Eyes performance ($F(2,45) = 3.84$, $p < .05$, $\eta^2 = .15$). Post-hoc Tukey's analyses showed a significant difference between those with male and female brains ($p<.05$), but no other significant differences. There was no significant group difference in AQ scores (F (2, 45) = 2.24, p = ns, $\eta^2 = .09$). However, once a single outlier (a male humanities student) with an unusually high AQ score was excluded, the difference between the groups became significant ($F(2,44) = 4.95$, $p<.05$, $\eta^2 = .18$). Post-hoc Tukey's HSD tests confirmed that those with female type brains had significantly lower AQ scores than those with male type brains ($p < .05$) and marginally lower than those with balanced brains ($p = .06$). Individuals with male brains and balanced brains did not differ significantly.

Study 2

At the time of testing, Baron-Cohen's Empathising and Systemising Quotient questionnaires had recently been published and have not, to our knowledge, previously been directly compared to standard tests within the literature. This study describes a pilot project in which different measures of Empathising and Systemising were compared. The Systemising Quotient is concerned with the likes and interests

of the participants, rather than their knowledge and abilities, containing items such as "I do not enjoy games that involve a high degree of strategy". Scores on this test were analysed in relation to the Mechanical Reasoning test included in Study 1, in which participants had to determine the correct answer to a mechanical problem. It was anticipated that scores in these two areas would be correlated, but may be separable.

A closer relationship might be predicted between the two measures of Empathising. The Empathising Quotient includes a few questions assessing basic social skills ("I can sense if I am intruding, even if the other person doesn't tell me"), but centres on assessment of a respondent's empathy in different situations ("I usually stay emotionally detached when watching a film"). Scores on this questionnaire were compared to scores on the Social Skills Inventory (Riggio, 1989), which measures basic social skills that underlie social competence. It contains six subscales which measure, respectively, emotional and social expressivity, sensitivity and control.

Twenty students from Study 1 were asked to complete the Systemising and Empathising Quotient questionnaires and their scores on these tasks were compared to those on the tasks included in Study 1. A delay of approximately two months existed between completion of the first set of tasks and the completion of the Empathising and Systemising Quotient questionnaires.

Method

Participants

A subgroup of twenty students was created which included 5 male humanities students (group M-H), 5 female humanities students (group F-H), 5 male science students (group M-S) and 5 female science students (group F-S). Each of these students had taken part in Study 1. The mean ages and verbal IQs of the participants were as follows; group M-H mean age: 21.1 years, verbal IQ: 140.40; group F-H mean age: 21.41 years, verbal IQ: 140.40, group M-S mean age: 21.40 years, verbal IQ: 132.40; group F-S mean age: 22.27 years, verbal IQ: 136.00.

Additional Materials

In addition to the tasks described in Study 1 the students were asked to complete the following two tasks.

Empathising and Systemising Quotients: Participants were asked to complete two questionnaires: the Systemising Quotient and the Empathising Quotient, as described by Baron-Cohen (2003). These consist of a set of 60 items which participants rate on a four point scale as 'strongly agree', 'slightly agree', 'slightly disagree', 'strongly disagree'. Forty items go forward to make the final score, while the other items are fillers. Scores on each item are added together to make a total maximum score of forty.

Results and Discussion

Group differences on the Empathising Quotient and Systemising Quotient were examined. On the Empathising Quotient, there was a significant main effect of sex ($F(1,16) = 6.39$, $p < .05$, $\eta^2 = .29$), no significant effect of discipline ($F(1,16) = 1.54$, p = ns, $\eta^2 = .09$), and a marginally significant interaction ($F(1,16) = 3.88$, $p = .07$, $\eta^2 = .20$). This was due to the fact that male humanities students showed lower scores than the other three groups (28.00 vs. 43.00, 45.60 and 49.00 respectively). On the Systemising Quotient there was a significant main effect of sex ($F(1,16) = 22.53$, $p < .01$, $\eta^2 = .59$), with males outperforming females and a significant main effect of discipline ($F(1,16) = 7.86$, $p < .05$, $\eta^2 = .33$), with science students outperforming humanities students, but no significant interaction. This effect of discipline was not mirrored in performance on the Mechanical Reasoning task in Study 1, perhaps suggesting that preferences in systemising are more closely related to choice of university degree course than skills are, at least in this sample.

Correlations between scores on the Empathising and Systemising Quotient and the other measures carried out in Study 1 are presented in Table 4. These must be interpreted with caution given the small sample size. Significant correlations were found between Systemising, Block Design and EFT. The association between Mechanical Reasoning and Systemising was moderate, but not significant. The correlations were not substantially altered by controlling for age and verbal ability.

Empathising was significantly associated with the AQ and with the Social Skills Inventory, as predicted. It also showed a moderate, but nonsignificant, correlation with the Mind in the Eyes measure. There was no significant correlation between empathising and systemising either before ($r(20) = -.214$, p = ns) or after controlling for age and verbal ability ($r(16) = -.187$, p = ns).

A 'brain type' score was determined for the Empathising and Systemising Quotients in the same manner as it was for the Social Skills and Mechanical Reasoning measures in Study 1. Both scores were standardised and the standard score for Empathising was subtracted from the standard score for Systemising. This gave a second 'brain type' score, referred to as BCBT (Baron-Cohen Brain Type). This measure was used to form groups of male and female brain profiles in the same way as for the first brain type measure. As with the first brain type measure, BCBT was significant associated with sex (Fishers Exact Test = 9.77, $p < .001$), but not with discipline (Fishers Exact Test = 3.43, p = ns). There was no significant difference between the three brain profiles on the Mind in the Eyes measure ($F(2,17) = 1.54$, p = ns, $\eta^2 = .15$) and a marginally significant difference between the groups on the AQ measure ($F(2,17) = 3.16$, $p = .07$, $\eta^2 = .27$). The effect sizes suggest that these differences might become significant with a larger group.

The brain type group classification system used in Study 1 was not significantly associated with BCBT (Fisher's Exact test = 7.09, $p = .11$). Table 5 shows the association between the two classification systems. 11 of the 20 students were in the same group over the two measures. 3 moved from the balanced group on the first

measure to one of other two groups on the BCBT, and 5 moved from one of the unbalanced groups on our measure to the balanced group on the BCBT measure. One student was considered to have a female brain on our criteria and a male brain on the BCBT. This participant, A, is potentially interesting as he has the highest score in the sample on the AQ, a score that would normally indicate someone with Asperger's type difficulties. His score on the Mechanical Reasoning task was well below average, while his score on the Systemising Quotient was above average. This indicates that perhaps A prefers to work with systems rather than people or animals, but that he shows no particular skills in reasoning through mechanical systems. This is in line with the findings of Lawson et al (2004) that individuals with Asperger's Syndrome do not show a better understanding of physical systems than typical adult males.

General Discussion

The work presented above replicates previous results suggesting sex differences in tasks measuring social skills, central coherence, empathising and systemising (Baron-Cohen & Hammer, 1997; Hoffman, 1977; Voyer et al., 1995). Further, on both classification systems male participants were more likely to have 'male brains' and females were more likely to have 'female brains'. Discipline differences were less consistent, occurring in only the Block Design, EFT and Systemising tasks. Overall, the tasks purported to measure empathising and social skills were associated with one another, and the tasks purporting to measure

systemising and spatial awareness clustered together. In contrast to the findings of Jarrold et al. (2000), there was not a clear association between the two sets of skills.

The brain type measure showed some utility: females were more likely to have 'female type' brains than males, and the groups formed on the basis of the 'brain type' measure also differed with respect to their AQ scores, suggesting that students with female brains tended to show lower levels of autistic-like symptomatology than those with male or balanced brains. However, there was no significant difference in AQ score between those with male brains and those with balanced brains, and a similar result was found with respect to the Mind in the Eyes measure. These findings weaken the argument that high levels of autistic symptoms are associated with an 'extreme male brain' profile.

Brain Types: Empathising-Systemising theory

The findings were consistent across a range of tasks in each area. Overall, Baron-Cohen's (2002) central claim concerning empathising and systemising was supported. Men were more likely to have more developed systemising than empathising, and vice versa for women. As predicted, empathising was associated with theory of mind ability, as measured by the 'Mind in the Eyes' test, while systemising was associated with weak central coherence.

Results were similar using the two different sets of empathising and systemising measures. However, it is important to note that the two sets of measures were not highly correlated.

Extreme Male Brain Theory of Autism

There was some evidence that individuals with male brain profiles showed higher levels of autistic symptomatology than individuals with female brain profiles once a single outlier was excluded. However, the effect was carried by the female group showing lower scores on the AQ than the other two groups. There was no evidence that those with male brain profiles had higher levels of autistic symptomatology than those with balanced brain profiles. These findings therefore provide only limited support for the Extreme Male Brain theory of autism.

There was also no clear evidence of a link between the two sets of abilities. The results are in line with the findings of Lawson et al. (2004), Briskman et al. (2001) and Morgan et al. (2003) that these two areas are not closely related, and cast doubt upon the explanatory value of the Extreme Male Brain theory as an explanation for the symptoms found in autistic individuals.

As described in the introduction, Baron-Cohen does not assume a correlation between empathising and systemising, or between theory of mind and central coherence. However, if one is to assume that autism can be explained in terms of extreme scores in two unrelated areas in which variation is normally distributed, then statistically one would expect to find many more individuals who show weak theory of mind in the absence of weak central coherence, and vice versa. More research is needed to establish whether this is in fact the case, but at present it seems

more likely that autism forms the basis of a 'clustering' of symptoms, rather than being the co-occurrence of two independent extremes of processing.

Findings in the present study are somewhat limited by the sample used, which consisted of university students with verbal abilities in the above average range. Using this sample may have restricted the range of empathising and systemising abilities present in the sample, and therefore reduced the potential for correlation between the two skills. In general, individuals with autistic difficulties tend to have weak verbal abilities, and it is possible that the results would be altered if this study was carried out in this kind of sample, though Lawson et al. (2004) find similar results in a group of individuals with Asperger's syndrome. Further research is needed to assess the relationships between the skills in individuals with more low functioning forms of autism. However, results at present imply that individuals with autism spectrum difficulties will typically show deficits in theory of mind and empathising compared to typically developing individuals, but that high levels of good systemising abilities are not specifically associated with autistic symptomatology.

This somewhat surprising result can be illustrated with an example from our sample. Student A, who achieved the highest score in the sample on the AQ, showed difficulties with Mechanical Reasoning but achieved a high score on the Systemising Quotient. This illustrates the conceptual difference between preferences and interests, on the one hand, and abilities on the other hand. While an individual may enjoy working with machines and systems, this does not entail that they have an

aptitude for this way of reasoning. Hence, it may be that individuals with low social skills would rather interact with logical systems than with people as they are more predictable and less stressful to these individuals. This does not imply that these individuals will have a strength in working with machines, merely that they have a preference for this type of pastime.

Overall, evidence from the experiment supports Baron-Cohen's (2002) Empathising-Systemising theory. Theory of mind, social skills and empathising are associated and spatial awareness, mechanical reasoning and systemising are also associated with one another. However, the evidence in favour of the Extreme Male Brain theory is more equivocal. The two areas of processing were not closely related to one another, and those with male brain profiles did not show increased levels of autistic symptomatology compared to those with balanced brains. Finally, it was shown that an aptitude for and interest in systems are separable, though associated, fields.

References:

Baron-Cohen, S. (2002). The extreme male brain theory of autism. *Trends in Cognitive Sciences, 6*, 248-255.

Baron-Cohen, S. (2003). *The essential difference: Men, women and the extreme male brain*. London: Penguin Books Ltd.

Baron-Cohen, S., Bolton, P., Wheelwright, S., Scahill, V., Short, L., Mead, G., et al. (1998). Does autism occur more often in the families of physicists, engineers, and mathematicians? *Autism, 2*, 296-301.

Baron-Cohen, S., & Hammer, J. (1997). Is autism an extreme form of the "male brain"? *Advances in Infancy Research, 11*, 196-217.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a theory of mind? *Cognition, 21*, 37-46.

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The "reading the mind in the eyes" test revised version: A study with normal adults and adults with asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry, 42*(2), 241-251.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J. G., & Clubley, E. (2001). The Autism-Spectrum Quotient: Evidence from Asperger syndrome/ high functioning autism, males, females, scientists and mathematicians. *Journal of Autism and Developmental Disorders, 31*, 5-17.

Baron-Cohen, S., Wheelwright, S., Stott, C., Bolton, P., & Goodyer, I. (1997). Is there a link between engineering and autism? *Autism, 1*(1), 101-109.

Bennett, G. K., Seashore, H. G., & Wesman, A. G. (1974). *Differential Aptitude Tests* (5th ed.). New York: Psychological Corporation.

Briskman, J., Happe, F., & Frith, U. (2001). Exploring the cognitive phenotype of autism: Weak "central coherence" in parents and siblings of children with

autism II: Real-life skills and preferences. *Journal of Child Psychology and Psychiatry, 42*(3), 309-316.

Frith, U. (2003). *Autism: Explaining the enigma*. Oxford, UK: Blackwell.

Frith, U., & Happe, F. (1994). Autism: "beyond theory of mind". *Cognition, 50*, 115-132.

Hoffman, M. L. (1977). Sex differences in empathy and related behaviours. *Psychological Bulletin, 84*(4), 712-722.

Jarrold, C., Butler, D. W., Cottingham, E. M., & Jimenez, F. (2000). Linking theory of mind and central coherence in autism and in the general population. *Developmental Psychology, 36*(1), 126-138.

Lawson, J., Baron-Cohen, S., & Wheelwright, S. (2004). Empathising and systemising in adults with and without Asperber syndrome. *Journal of Autism and Developmental Disorders, 34*, 301-310.

Morgan, B., Maybery, M., & Durkin, K. (2003). Weak central coherence, poor joint attention and low verbal ability: Independent deficits in early autism. *Developmental Psychology, 39*(4), 646-656.

Riggio, R. E. (1989). Social Skills Inventory. In. USA: Consulting Psychologists Press.

Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin, 117*, 250-270.

Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence*. San Antonio, USA: Psychological Corporation.

Witkin, H. A., Oltman, P. K., Raskin, E., & Karp, S. A. (1971). *A manual for the embedded figures test*. Palo Alto, CA: Consulting Psychologists Press.

Tables and Figures

Table 1. Mean scores on the AQ, Mind in the Eyes, Central Coherence, Social Skills and Mechanical Reasoning Tasks for the Four Subgroups.

	Male		Female	
	Science	Humanities	Science	Humanities
	n = 12	n = 12	n = 12	n = 12
AQ[1]	17.58 (4.36)	20.58 (7.09)	16.58 (5.18)	13.67 (5.55)
Mind in the Eyes test [2]	24.00 (4.92)	25.58 (4.21)	26.42 (3.18)	29.17 (3.49)
WASI Block Design[3]	129.17	124.83	123.83	116.67
	(8.76)	(8.76)	(7.06)	(6.68)
EFT[4]	15.78 (9.89)	13.26 (5.87)	14.05 (3.85)	23.96 (7.87)
Mechanical Reasoning[5]	12.75 (2.93)	13.33 (2.90)	10.17 (2.86)	9.42 (2.15)
Social Skills Inventory[6]	277.00	274.25	289.17	300.33
	(18.25)	(27.04)	(22.93)	(14.54)

Note. Standard deviations in parentheses. AQ = Autism-Spectrum Quotient; EFT = Embedded Figures Test;

[1] Maximum score = 50; [2] Maximum score = 36; [3] Standard scores; [4] Mean reaction time; [5] Maximum score = 20; [6] Maximum score = 450.

Table 2. Correlations between AQ, Mind in the Eyes, Central Coherence, Social Skills and Mechanical Reasoning tasks

Measure (N = 48)	Vocab	AQ	ME	BD	EFT	Mech. Reasoning	SSI
Age	.084	-.232	.018	.057	-.115	-.068	.250
Vocab	-	.150	.092	-.111	-.046	.127	.101
AQ	-	-	-.382**	.128	-.095	.141	-.433**
ME	-	-.413**	-	-.153	.054	.018	.375**
BD	-	.169	-.145	-	-.563**	.429**	-.195
EFT	-	-.019	-.071	-.547**	-	-.348**	.027
Mech. Reasoning	-	.108	.007	.457**	-.437**	-	-.277
SSI	-	-.421**	.378	-.209	.135	-.284	-

Note. Partial correlations controlling for age and verbal ability are shown below the diagonal. Vocab = WASI Vocabulary subtest; AQ = Autism-Spectrum Quotient; ME = Mind in the Eyes test; BD = Block Design; EFT = Embedded Figures Test; Mech. Reasoning = Mechanical Reasoning Test; SSI = Social Skills Inventory.

** Significant at $p < .01$

Table 3: Distribution of participants in the three Brain profiles

Group (N = 48)	Male Brain Profile (E < S)	Balanced Brain (E = S)	Female Brain Profile (E > S)
Male – sciences (n = 12)	5	7	-
Male – humanities (n = 12)	6	5	1
Female-sciences (n = 12)	2	3	7
Female-humanities (n = 12)	-	4	8
TOTAL	13	19	16

Table 4: Correlations between Empathising and Systemising and other measures.

N = 20	Bivariate Correlations		Partial Correlations (age and verbal IQ controlled)	
	Empathising	Systemising	Empathising	Systemising
AQ	-.609**	.373	-.686**	.341
ME	.364	-.199	.406	-.207
EFT	.089	-.499*	.146	-.507*
Block Design	-.113	.579**	-.140	.615**
Mech. Reasoning	-.031	.354	-.021	.337
Social Skills	.459*	-.029	.462	-.010

Note. AQ = Autism-Spectrum Quotient; ME = Mind in the Eyes test; EFT = Embedded Figures Test; Mech. Reasoning = Mechanical Reasoning Test.

** Significant at $p<.01$; * Significant at $p<.05$.

Table 5: The association between the two brain type measures.

		Baron-Cohen Brain Type		
	N = 20	Male profile	Balanced	Female profile
Carroll & Chiew	Male profile	2	4	
Brain type	Balanced	2	5	1
	Female profile	1	1	4