THE ROYAL SOCIETY

Published online 17 January 2003

The systemizing quotient: an investigation of adults with Asperger syndrome or high-functioning autism, and normal sex differences

Simon Baron-Cohen*, Jennifer Richler, Dheraj Bisarya, Nhishanth Gurunathan and Sally Wheelwright

Autism Research Centre, Departments of Experimental Psychology and Psychiatry, University of Cambridge, Downing Street, Cambridge CB2 3EB, UK

Systemizing is the drive to analyse systems or construct systems. A recent model of psychological sex differences suggests that this is a major dimension in which the sexes differ, with males being more drawn to systemize than females. Currently, there are no self-report measures to assess this important dimension. A second major dimension of sex differences is empathizing (the drive to identify mental states and respond to these with an appropriate emotion). Previous studies find females score higher on empathy measures. We report a new self-report questionnaire, the Systemizing Quotient (SQ), for use with adults of normal intelligence. It contains 40 systemizing items and 20 control items. On each systemizing item, a person can score 2, 1 or 0, so the SQ has a maximum score of 80 and a minimum of zero. In Study 1, we measured the SQ of $n = 278$ adults (114 males, 164 females) from a general population, to test for predicted sex differences (male superiority) in systemizing. All subjects were also given the Empathy Quotient (EQ) to test if previous reports of female superiority would be replicated. In Study 2 we employed the SQ and the EQ with $n = 47$ adults (33 males, 14 females) with Asperger syndrome (AS) or high-functioning autism (HFA), who are predicted to be either normal or superior at systemizing, but impaired at empathizing. Their scores were compared with $n = 47$ matched adults from the general population in Study 1. In Study 1, as predicted, normal adult males scored significantly higher than females on the SQ and significantly lower on the EQ. In Study 2, again as predicted, adults with AS/HFA scored significantly higher on the SQ than matched controls, and significantly lower on the EQ than matched controls. The SQ reveals both a sex difference in systemizing in the general population and an unusually strong drive to systemize in AS/HFA. These results are discussed in relation to two linked theories: the 'empathizing–systemizing' (E–S) theory of sex differences and the extreme male brain (EMB) theory of autism.

Keywords: Asperger syndrome; sex differences; systemizing; empathizing

1. THE EMPATHIZING–SYSTEMIZING THEORY

A recent model of sex differences in the mind proposes that the major dimensions of relevance are empathizing and systemizing (Baron-Cohen 2002). Systemizing is held to be our most powerful way of understanding and predicting the law-governed inanimate universe. Empathizing is held to be our most powerful way of understanding and predicting the social world.

Empathizing is the drive to identify another person's emotions and thoughts, and to respond to these with an appropriate emotion. Empathizing allows you to *predict* a person's behaviour, and to care about how others feel. A large body of evidence suggests that, on average, females spontaneously empathize to a greater degree than do males. Systemizing is the drive to analyse the variables in a system, to derive the underlying rules that govern the behaviour of a system. Systemizing also refers to the drive to construct systems. Systemizing allows you to *predict* the behaviour of a system, and to control it. A growing body of evidence suggests that, on average, males spontaneously systemize to a greater degree than do females.

A system is defined as something that takes inputs, which can then be operated on in *variable* ways, to deliver *different* outputs in a rule-governed way. There are at least six kinds of system: Technical, Natural, Abstract, Social, Organizable, Motoric, but all share this same underlying process which is monitored closely during systemizing:

INPUT → OPERATION → OUTPUT

Below, an example from each of the six types of system are given:

A. An example of a *technical* system: a sail

INPUT	→ OPERATION	→ OUTPUT
Sail	Angle 10°	Speed slow
Sail	Angle 30°	Speed medium
Sail	Angle 60°	Speed fast

*Author for correspondence (sb205@cam.ac.uk).

One contribution of 14 to a Theme Issue 'Autism: mind and brain'.

B. An example of a *natural* system: a plant

INPUT	→ OPERATION	→ OUTPUT
Rhododendron	Mildly alkaline soil	Light blue petals
Rhododendron	Strongly alkaline soil	Dark blue petals
Rhododendron	Acidic soil	Pink petals

C. An example of an *abstract* system: mathematics

INPUT	→ OPERATION	→ OUTPUT
3	Squared	9
3	Cubed	27
3	Inverse	0.3

D. An example of a *social* system: a constituency boundary

INPUT	→ OPERATION	→ OUTPUT
New York	Inner city	Small number of voters
New York	Whole city	Medium number of voters
New York	Whole state	Large number of voters

E. An example of an *organizable* system: a CD collection

INPUT	→ OPERATION	→ OUTPUT
CD collection	Alphabetical	Order on shelf: A–Z
CD collection	Date of release	Order on shelf: 1980–2000
CD collection	Genre	Order on shelf: classical → pop

F. An example of a *motoric* system: a tennis stroke

INPUT	→ OPERATION	→ OUTPUT
Hit ball	Top spin	Ball bounces left
Hit ball	Back spin	Ball bounces right
Hit ball	No spin	Ball bounces forward

As can be seen in the examples above, the process in systemizing is always the same. One of the three elements (typically the input) is treated as a *fixed* feature (i.e. it is held constant), while another of the three elements (typically the operation) is treated as a *variable* (i.e. it can vary: think of a dimmer on a light switch). Merely observing the consequences of these two elements delivers to you important information: the output changes from Output 1, to Output 2, to Output 3. That is, you learn about the system. Systemizing works for phenomena that are indeed ultimately lawful, finite and deterministic. Note that the other way we systemize is when we are confronted by various outputs, and try to infer *backwards* from the output as to what the operation is that produces this particular output.

Systemizing is practically useless for predicting the moment-by-moment changes in a person's behaviour. To predict human behaviour, empathizing is required. Systemizing and empathizing are very different kinds of process. Empathizing involves attributing mental states to others, and responding with appropriate affect to the other's affective state. Empathizing covers not only what is sometimes called 'theory of mind or 'mentalizing' (Morton *et al.* 1991), but also what is covered by the English words 'empathy' and 'sympathy'.

In order see why you cannot systemize a person's behaviour with much predictive power, consider the next example:

INPUT	→ OPERATION	→ OUTPUT
Jane	Birthday	Relaxes
Jane	Birthday	Withdraws
Jane	Birthday	Laughs
Jane	Birthday	Cries

Why does the same input (Jane) have such different outputs (behaviour) when the same operation (her birthday) is repeated? Someone who relies on systemizing to predict people's behaviour would have to conclude that people are not clearly rule-governed. This is a correct conclusion, but there is nevertheless an alternative way of predicting and making sense of Jane's behaviour: via empathizing. During empathizing, the focus is on the person's *mental state* (including his or her emotion). Furthermore, during empathizing there is an appropriate emotional reaction in the observer to the other person's mental state. Without this extra stage, one could have a very accurate reading of the person's emotion, a very accurate prediction of the other's behaviour, but a psychopathic lack of concern about their mental state.

To complicate matters further, during empathizing, the observer does not expect lawful relationships between the person's mental state and his or her behaviour. The observer only expects that the person's mental state will at least constrain their behaviour.

There are individual differences in both empathizing and systemizing. According to the E–S theory, individuals in whom empathizing is more developed than systemizing are referred to as type E. Individuals in whom systemizing is more developed than empathizing are called type S. Individuals in whom systemizing and empathizing are both equally developed are called type B (to indicate the 'balanced' brain). Individuals whose systemizing is normal or even hyperdeveloped but whose empathizing is hypodeveloped are an extreme of type S. That is, they may be talented systemizers but at the same time, they may be 'mind-blind' (Baron-Cohen 1995). We test if individuals on the autistic spectrum fit the profile of having an extreme of type S. Finally, we postulate the existence of a brain of extreme type E: people who have normal or even hyperdeveloped empathizing skills, whereas their systemizing is hypodeveloped—they may be 'system-blind'.

One final central claim of the E–S theory is that, on average, *more* males than females have a brain of type S, and *more* females than males have a brain of type E. The evidence for female superiority in empathizing is reviewed elsewhere (Baron-Cohen 2002) and includes the finding that women are better at decoding non-verbal communication, picking up subtle nuances from tone of voice or facial expression, or judging a person's character (Hall 1978). The evidence for a male advantage in systemizing is also reviewed elsewhere (Baron-Cohen *et al.* 2002) and includes the findings that maths, physics and engineering (which all require a high degree of systemizing) are largely male in sex ratio. For example, on the Scholastic Aptitude

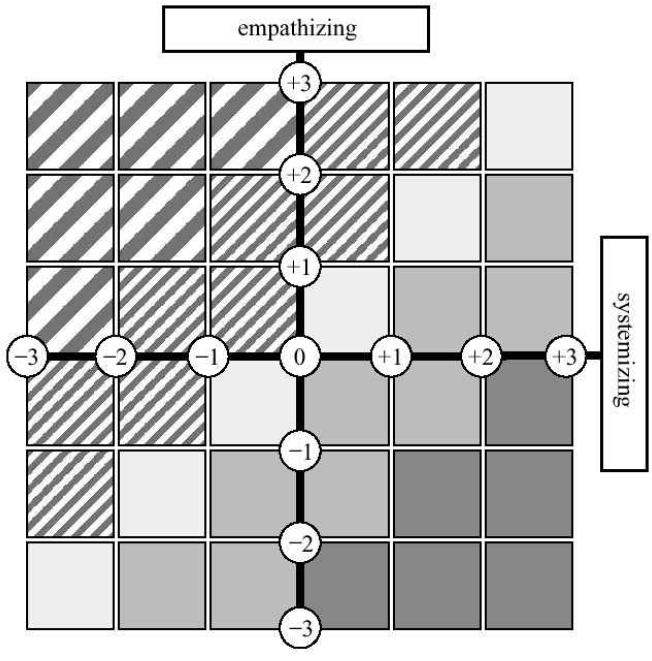

Figure 1. A model of the E–S theory. Type B (E = S): unshaded; type E (E > S): narrow diagonal stripes; type S (E < S): grey shading; extreme type E: wide diagonal stripes; extreme type S: dark grey shading. Axes show s.d. from mean.

Math Test, the maths part of the test administered nationally to college applicants in the USA males, on average, score 50 points higher than females on this test (Benbow 1988). Among those scoring above 700, the sex ratio is 13 : 1 (men : women) (Geary 1996). A candidate biological factor influencing these sex differences is prenatal testosterone and its action on the developing brain (Geschwind & Galaburda 1985; Lutchmaya *et al.* 2002).

2. THE EXTREME MALE BRAIN THEORY OF AUTISM

The EMB theory of autism was first informally suggested by Hans Asperger (1944). He wrote: 'The autistic personality is an extreme variant of male intelligence. Even within the normal variation, we find typical sex differences in intelligence …In the autistic individual, the male pattern is exaggerated to the extreme' (Frith 1991). It took 53 years from the date that this controversial hypothesis was raised casually for it to be formally examined (Baron-Cohen & Hammer 1997). We can test the EMB theory empirically, now that we have definitions of the female brain (type E) (figure 1: narrow diagonal stripes), the male brain (type S) (figure 1: light grey zone), and the balanced brain (figure 1: white zone). According to the EMB theory, people with autism or AS should fall into the dark grey zone: that is, they should have impaired empathizing but intact or superior systemizing, relative to their mental age.

3. EVIDENCE FOR THE EMB THEORY

Initial tests of this theory are providing convergent lines of evidence consistent with the EMB theory of autism. The evidence related to impaired empathizing is reviewed elsewhere (Baron-Cohen *et al.* 2002) and includes the findings from the 'Reading the Mind in the Eyes' Test, that females score higher than males, but people with AS score even lower than males (Baron-Cohen *et al.* 1997). Additionally, on the Faux Pas Test, females are better than males at judging what would be socially insensitive or potentially hurtful and offensive and people with autism or AS have even lower scores on tests of this than males (Baron-Cohen *et al.* 1999*a*).

The evidence in relation to superior systemizing includes the fact that some people with autism spectrum conditions have 'islets of ability' in, for example, mathematical calculation, calendrical calculation, syntax acquisition, music or memory for railway timetable information to a precise degree (Baron-Cohen & Bolton 1993; Hermelin 2002). In high-functioning individuals these abilities can lead to considerable achievement in mathematics, chess, mechanical knowledge and other factual, scientific, technical or rule-based subjects (Baron-Cohen *et al.* 1999*c*). All of these are highly systemizable domains. On the EFT, males score higher than females, and people with AS or HFA score even higher than males. The EFT is a systemizing test, in that each piece of the puzzle (the target shape) is the input, its orientation is the operation, with rules from these that predict if the piece of the puzzle will fit in the target locations (Shah & Frith 1983; Jolliffe & Baron-Cohen 1997). Finally, on the AQ, males in the general population score higher than females, and people with AS or HFA score highest of all (Baron-Cohen *et al.* 2001).

4. THE SYSTEMIZING QUOTIENT

To test both the E–S theory and the EMB theory further, we designed the SQ. This was to fulfil the need to have an instrument that could assess an individual's interest in systems across the range of different classes of system. In the two studies reported here, we first test for a sex difference in systemizing in the general population, and secondly test for the predicted superiority in systemizing in adults with AS or HFA.

The SQ was designed to be short, easy to complete and easy to score. It is shown in Appendix A. The SQ comprises 60 questions, 40 assessing systemizing and 20 filler (control) items. Approximately half the items were worded to produce a 'disagree' and half an 'agree', for the systemizing response. This was to avoid a response bias either way. Following this, items were randomized. An individual scores two points if they strongly display a systemizing response and one point if they slightly display a systemizing response. There are 20 filler items (items 2, 3, 8, 9, 10, 14, 16, 17, 21, 22, 27, 36, 39, 46, 47, 50, 52, 54, 58, 59), randomly interspersed throughout the SQ, to distract the participant from a relentless focus on systemizing. These questions are not scored at all. The final version of the SQ has a forced-choice format, can be self-administered and is straightforward to score, since it does not depend on any interpretation in the scoring.

Initially, we had planned to devise the SQ so that it would tap into each of the domain-specific systems described above. However, this proved to be problematical because individuals who were well rounded but not necessarily good systemizers would end up scoring highly, whereas those who were highly systematic but only

interested in one domain would receive a low score. Thus, we decided, instead, to use examples from everyday life in which systemizing could be used to varying degrees. The assumption is that a strong systemizer would be drawn to use their systemizing skills across the range of examples more often than a poor systemizer, and would consequently score higher on the SQ.

A pilot study was conducted by distributing the SQ to 20 normal adults to check that the questions were understandable and that the range of results indicated both individual differences across the scale, and avoided ceiling or floor effects. These participants were also able to offer feedback about the questionnaire.

5. THE EMPATHIZING QUOTIENT

In the two studies reported below, subjects were not only given the SQ, but also given the EQ (S. Baron-Cohen and S. Wheelwright, unpublished data). This is shown in Appendix B. The EQ has a very similar structure to the SQ, in that it also comprises 60 questions, broken down into two types: 40 questions tapping empathy and 20 filler items (items 2, 3, 5, 7, 9, 13, 16, 17, 20, 23, 24, 30, 31, 33, 40, 45, 47, 51, 53, 56). Each of the empathy items scores one point if the respondent records the empathic behaviour mildly, or two points if strongly (see below for scoring each item). Like the SQ, approximately half the items were worded to produce a 'disagree', and half an 'agree' for the empathic response, to avoid a response bias either way. Also, as with the SQ, the EQ has a forced-choice format, can be self-administered and is straightforward to score.

6. AIMS

In the studies reported below, we had four aims.

(i) To test for a female superiority on the EQ, replicating earlier work (Hall 1978; Hoffman 1977; Davis 1980; Davis & Franzoi 1991; S. Baron-Cohen and S. Wheelwright, unpublished data) (Study 1).
(ii) To test for sex differences in systemizing, given the male superiority in many separate systemizable domains reported earlier (Benbow 1988; Kimura 1999).
(iii) To test if adults with HFA or AS scored lower than normal males on the EQ but higher than normal males on the SQ (Study 2).
(iv) To test if the EQ was inversely correlated with the SQ.

7. HIGH-FUNCTIONING AUTISM AND ASPERGER SYNDROME

Autism is diagnosed when an individual shows abnormalities in social and communication development, in the presence of marked repetitive behaviour and limited imagination (American Psychiatric Association 1994). The term HFA is given when an individual meets the criteria for autism in the presence of normal IQ. AS is defined in terms of the individual meeting the same criteria for autism but with no history of cognitive or language delay (ICD-10 1994). Language delay itself is defined as not using single words by two years of age, and/or phrase speech by three years of age. There is growing evidence that autism and AS are of genetic origin. The evidence is strongest for autism, and comes from twin and behavioural genetic family studies (Folstein & Rutter 1977, 1988; Bolton & Rutter 1990; Bailey *et al.* 1995). Furthermore, family pedigrees of AS implicate heritability (Gillberg 1991). There is also an assumption that autism and AS lie on a continuum, with AS as the 'bridge' between autism and normality (Wing 1981, 1988; Frith 1991; Baron-Cohen 1995).

8. SUBJECTS

(a) *Subjects in Study 1*

Study 1 comprised $n = 278$ normal adults (114 males, 164 females) taken from two sources: $n = 103$ were drawn from the general public in the UK and Canada, and represented a mix of occupations, both professional, clerical and manual workers, and $n = 174$ were drawn from undergraduate students currently studying at Cambridge University or a local 'A' level college in Cambridge. Students from a variety of disciplines were targeted. In Study 1, to check if academic/educational attainment influences either SQ or EQ, these sub-groups were analysed separately. The students had a mean age of $x = 20.5$ yr (s.d. = 6.5) and the non-students had a mean age of $x = 41.3$ yr (s.d. = 12.7).

(b) *Subjects in Study 2*

Two groups of subjects were tested:

Group 1 comprised $n = 47$ adults with AS/HFA (33 males, 14 females). This sex ratio of 2.4 : 1 (m : f) is similar to that found in other samples (Klin *et al.* 1995). All subjects in this group had been diagnosed by psychiatrists using established criteria for autism or AS (American Psychiatric Association 1994). They were recruited from several sources, including the National Autistic Society (UK), specialist clinics carrying out diagnostic assessments, and advertisements in newsletters/web pages for adults with AS/HFA. Their mean age was 38.1 yr (s.d. = 13.3). They had all attended mainstream schooling and were reported to have an IQ in the normal range (see below for a check of this). Their occupations reflected their mixed socio-economic status. Because we could not confirm age of onset of language with any precision (due to the considerable passage of time), these individuals are grouped together, rather than attempting to separate them into AS versus HFA.

Group 2 comprised 47 adults selected from the pool of 278 controls in Study 1 based on being matched with Group 1 for age, sex and handedness. The 278 volunteers are described in Study 1. The 47 comparison subjects, as in Group 1, consisted of 32 males and 15 females. Their mean age was 36.5 years (s.d. = 13.2). Their socio-economic status profile was similar to that of Group 1.

9. METHODS (FOR STUDIES 1 AND 2)

Subjects were sent the SQ and EQ by post. Two versions of the questionnaires were sent out, one in which

the SQ appeared first, followed by the EQ, and the other in the reverse order, so as to guard against order effects. The exception to this were a sub-group of subjects in each group, who had already completed the EQ for another study, so these individuals only received the SQ for this study. Subjects were instructed to complete the two questionnaires on their own, as quickly as possible, and to avoid thinking about their responses too long. Subjects in Group 2 had the option to remain anonymous. To confirm the diagnosis of adults in Group 1 being high-functioning, 15 subjects in each of Groups 1 and 2 were randomly selected and invited into the laboratory for intellectual assessment using four sub-tests of the WAIS-R (Wechsler 1958) The four sub-tests of the WAIS-R were Vocabulary, Similarities, Block Design and Picture Completion. On this basis, all of these had a prorated IQ of at least 85, that is, in the normal range (Group 1, $x = 106.5$, s.d. = 8.0; Group 2, $x = 105.8$, s.d. = 6.3), and these did not differ from each other statistically (t-test, $p > 0.05$).

Subjects in Group 1 were also sent the AQ (Baron-Cohen *et al.* 2001) by post. Their mean AQ score was 36.4 (s.d. = 7.1). This is in the clinical range on this measure, as our previous study using the AQ shows that more than 80% of people with a diagnosis of AS or HFA score equal to or above 32 (maximum: 50).

10. SCORING

(a) *The SQ*

'Strongly agree' responses score two points, and 'slightly agree' responses score one point, on the following items: 1, 4, 5, 7, 13, 15, 19, 20, 25, 29, 30, 33, 34, 37, 41, 44, 48, 49, 53, 55. 'Strongly disagree' responses score two points, and 'slightly disagree' responses score one point on the following items: 6, 11, 12, 18, 23, 24, 26, 28, 31, 32, 35, 38, 40, 42, 43, 45, 51, 56, 57, 60. The filler (control) questions score no points, irrespective of how the individual answers them. Nevertheless, responses on the filler items were analysed for any systematic bias.

(b) *The EQ*

'Strongly agree' responses score two points and 'slightly agree' responses score one point, on the following items: 1, 6, 19, 22, 25, 26, 35, 36, 37, 38, 41, 42, 43, 44, 52, 54, 55, 57, 58, 59, 60. 'Strongly disagree' responses score two points, and 'slightly disagree' responses score one point, on the following items: 4, 8, 10, 11, 12, 14, 15, 18, 21, 27, 28, 29, 32, 34, 39, 46, 48, 49, 50.

11. RESULTS

(a) *Study 1*

The response rate was 60%, which is a good response rate in a postal survey research. Mean SQ scores and subscores for these individuals are shown in table 1. This shows that, within this general population sample, males (mean = 30.3, s.d. = 11.5) scored significantly higher than females (mean = 24.1, s.d. = 9.5) on the SQ. A between-subjects ANOVA was performed to test for the main effects of sex and group. In this case, 'group' was used to separate students from workers. Scores by group are also shown in table 1. There was a main effect of sex ($F(1,270) = 18.1$, $p < 0.0001$), as predicted. There was no significant main effect of group ($F(1,270) = 0.18$, $p = 0.67$) and no sex by group interaction ($F(1,270) = 2.05$, $p = 0.15$). Age was treated as a covariate in all analyses.

Mean EQ scores are also shown in table 1. A between-subjects ANOVA was performed to test for the main effects of sex and group. As before, 'group' was used to separate students from workers. There was a main effect of sex ($F(1,269) = 38.6$, $p < 0.0001$), as predicted. There was no significant main effect of group ($F(1, 264) = 1.24$, $p = 0.27$) and no sex by group interaction ($F(1, 269) = 1.43$, $p = 0.23$). Pearson's correlation shows that, as predicted, there is a significant negative correlation between the EQ and SQ when all subjects' data were analysed ($r = -0.16$, $p < 0.01$).

Finally, a factor analysis was carried out to investigate whether any meaningful factors in the SQ could be elucidated. The factor analysis was necessarily only explorative in nature as the items on the SQ are ordinal rather than continuous. Following the initial principal component analysis, 11 factors had an eigenvalue of greater than one, and were retained. The data were then subjected to a varimax rotation. An examination of the factors generated suggested that these did not correspond to factors with any psychological significance. Thus, total SQ score was the only measure analysed.

(b) *Study 2*

The response rate was 50%, which again is a good response rate in a postal survey research. Mean SQ scores of AS/HFA subjects and controls are shown in table 2. These scores show that HFA/AS individuals scored higher (mean = 35.7, s.d. = 15.3) than matched controls (mean = 29.7, s.d. = 10.2). A t-test was used to examine the significance of the difference between the means of the two samples. This indicated that the AS/HFA group scored significantly higher than controls on the SQ ($t = 2.2$, d.f. = 80, $p < 0.03$).

The two subject groups were then compared on their responses to the filler (control) items. A t-test revealed that there was no significant difference in their responses to these questions ($t = 1.496$, d.f. = 323, $p > 0.14$). This suggests the groups only performed differently in their responses to system-based questions. The mean SQ scores of males and females in the AS/HFA sample are also shown in table 2. This shows that males with AS/HFA (mean = 36.3, s.d. = 15.5) do not score significantly higher than females with AS/HFA (mean = 34.1, s.d. = 15.1). A t-test reveals that there is no significant difference between the two means ($t = -0.46$, d.f. = 45, $p > 0.65$). Figure 2 shows the distribution of scores from the full population in Study 1 (normal males and females) and the distribution of scores from the AS/HFA group in Study 2. Note that the curve from the AS/HFA group is only based on $n = 47$, whereas the curves from the control males and females are based on $n = 278$.

On the EQ, individuals with HFA/AS scored lower than matched controls. A t-test revealed that the difference between means was significant ($t = -8.5$, d.f. = 92, $p < 0.0001$). The mean EQ scores of males and females in the AS/HFA sample are also shown in table 2. A t-test revealed that there was no significant difference between

Table 1. EQ and SQ scores in students versus non-students in Study 1 (maximum score on each: 80).

	males			females		
group	*n*	mean	s.d.	*n*	mean	s.d.
EQ						
students	65	39.4	11.5	109	46.7	10.5
workers	49	38.0	13.6	54	49.6	11.8
combined groups	114	38.8	12.4	164	47.7	11.0
SQ						
students	65	30.0	11.7	109	22.3	8.6
workers	49	30.6	11.2	55	27.7	11.2
combined groups	114	30.3	11.5	164	24.1	9.5

Table 2. Means (and s.d.) of SQ and EQ scores in AS versus matched controls (Study 2) (maximum on each test: 80).

		SQ		EQ	
group	*n*	mean	s.d.	mean	s.d.
AS/HFA	47	35.7	15.3	20.3	11.4
males	33	36.3	15.5	18.9	9.9
females	14	34.1	15.1	23.4	14.1
controls	47	29.7	10.2	42.2	13.6

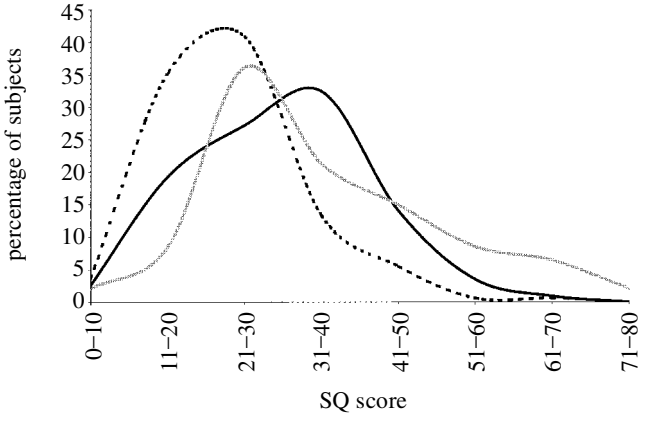

Figure 2. Distribution of scores on the SQ in typical males (solid black line), females (dashed line), and in people with AS (grey line) conditions.

these two means ($t = 1.09$, d.f. = 18.68, $p > 0.22$). It was possible to look at correlations between the EQ, SQ and AQ for the HFA/AS group alone. This showed that whereas the EQ was inversely correlated with the AQ ($r = -0.48$, $p < 0.001$), the SQ was positively correlated with the AQ ($r = 0.46$, $p < 0.002$), as would be expected. Finally, Cronbach's alpha coefficent on the SQ (for all subjects) was 0.79, which is good, and for the HFA/AS subjects alone, was 0.91, which is very high. This suggests the SQ is tapping a single construct. (Cronbach's alpha coefficient for the EQ is reported elsewhere; S. Baron-Cohen and S. Wheelwright (unpublished data) as 0.92, also very high.)

One possibility, suggested by figure 2, is that the *mean* for the AS group on the SQ is actually higher than for males in the general population, whereas the *mode* for males in the general population is higher than it is in the AS group. The mean of the AS group may be being pulled up by a sub-group of people with AS who have particularly high scores on the SQ, as suggested by both the skew of the distribution and by the standard deviation for the AS group, which was larger than for the males in the general population.

12. DISCUSSION

The two studies report results from a new instrument, the SQ. This was needed to test two linked theories: the E–S theory of sex differences in the mind (Baron-Cohen 2002) and the EMB theory of autism (Baron-Cohen & Hammer 1997; Baron-Cohen 2000; Baron-Cohen *et al.* 2002).

As predicted, in Study 1, males scored significantly higher than females on the SQ. Replicating our earlier study and those of others who have studied sex differences in empathy (Davis 1994; S. Baron-Cohen and S. Wheelwright, unpublished data) females scored higher than males on the EQ. Unsurprisingly, the SQ and EQ were inversely correlated, but while this was significant, the correlation was small ($r = -0.16$, $p < 0.01$). The strength of this correlation may reflect the fact that systemizing and empathizing are wholly different kinds of process, and that although there is some trade-off between performance on these two instruments, there is no necessary trade-off. This confirms predictions from the E–S theory and the model shown in figure 1.

Again, as predicted in Study 2, people with AS/HFA scored significantly higher on the SQ, and significantly lower on the EQ, compared with matched controls. The latter result replicates the finding on empathy measures from our earlier study (S. Baron-Cohen and S. Wheel-

wright, unpublished data) and the former is in line with the EMB model of autism. The fact that the group with AS/HFA actually scored higher on the SQ, rather than at an equivalent level to them, is noteworthy, because the EMB predicts either normal or superior performance on systemizing measures. It also replicates good performance from more specific measures of systemizing such as the Physical Prediction Questionnaire (J. Lawson, S. Baron-Cohen and S. Wheelwright, unpublished data). Figure 2 suggests the possibility of a sub-group of people with AS who are particularly high systemizers, which could be tested more thoroughly in future in a larger sample of people with AS.

The results can be interpreted with some confidence, for several reasons. First, if the AS/HFA group were in some way disadvantaged overall, this should have been evident on lower scores on both questionnaires, whereas the pattern of results actually obtained is exactly as predicted by the EMB theory. Second, the analysis of performance on the filler items of both questionnaires shows that the groups did not differ on these, but only on the items of relevance to each questionnaire. Third, the lack of a difference between the students and the non-students in the general population study (Study 1) on either the SQ or EQ suggests that these dimensions are not a function of age or education, but are best predicted on the basis of sex.

It is, of course, important to acknowledge several limitations of the present studies. First, only a proportion of subjects could actually be tested *in vivo*, and it would be beneficial for future studies to validate performance of subjects on these measures with observed test performance on related instruments. Second, it was not possible to include a non-autistic psychiatric control group in Study 2, and this would be of interest to establish if the superior systemizing found in the group with AS/HFA is specific to this clinical condition. Third, the design of the questionnaires makes them mainly suitable for adults of normal intelligence who are capable of completing self-report questionnaires. In the future, it would be valuable to adapt them for parental report of their children. Finally, the AS/HFA group is only $n = 47$, and in future it would be important to increase this sample size.

It is worth emphasizing that the pattern of scores on the SQ and EQ is clearly not one that would be predicted by alternative cognitive theories of autism. The executive dysfunction theory (Ozonoff *et al.* 1994; Russell 1997) would make no clear prediction on the EQ, but might even predict impaired performance on the SQ, as many aspects of systemizing require executive function. Equally, the weak central coherence theory (Frith 1989; Happé 1996) would predict that people with autism should be impaired on both the EQ and the SQ, as both need strong central coherence. In this respect, the E–S theory makes predictions of a highly specific profile (impaired EQ, superior SQ), which were confirmed. It is difficult to maintain that good systemizing is predicted by weak central coherence theory for two reasons: (i) weak central coherence theory was first described in 1989 (Frith 1989) and for the 10 years following this there was no mention by its proponents that good systemizing would be expected; (ii) systemizing requires excellent integration of information using the rule-based structure (input–operation–output), whereas weak central coherence predicts poor integration. Good systemizing in autism was first predicted by the E–S theory (Baron-Cohen 2002), and the data reported here provide good evidence for this. Central coherence theory predicts that integration of information should be impaired in autism, whereas E–S theory predicts that if a domain is systemizable, ability in autism will be in line with mental age, or even superior. Furthermore, central coherence theory predicts 'holistic' processing deficits, whereas E–S theory predicts that both holistic systems (such as astronomy) or particle-based systems (such as particle physics) should be readily grasped, and only non-systemizable domains (such as fiction) will be poorly integrated in autism. These predictions remain to be tested.

An objection to E–S theory might be of circularity, namely, that empathizing deficits and systemizing talents might be expected purely because of how people with autism are diagnosed. Against this criticism, DSM-IV does not gather information about systemizing, and although empathizing deficits might be noted as a diagnostic symptom, neither of these constructs is quantified during diagnostic procedures. The SQ and EQ thus go beyond diagnosis to provide quantitative instruments for measuring individual differences. In addition, some of the behaviours that the E–S theory sees as a result of superior systemizing (such as expertise or detailed perception) are viewed by DSM-IV in rather negative terms (e.g. as restricted or repetitive interests or behaviour, or obsessions). In this way, the E–S theory provides a fresh lens through which to understand these behaviours.

What remains unclear is the nature of the underlying neurocognitive mechanisms that drive empathizing and systemizing. In particular, it is of considerable importance to establish if these reflect independent mechanisms, or one underlying one, such that as one gets better at one, one gets worse at the other. We suspect that two independent mechanisms are involved, simply because of the existence of few individuals who are superior at both empathizing and systemizing. However, there seems to be a trend for some trade-off between these two domains, suggesting that even if two independent mechanisms are involved, there may be a special relationship between them. The nature of this special relationship needs to be understood both at the level of cognition and neuroscience. In terms of the brain basis of empathizing, several important brain regions have now been identified, specifically the orbito- and medial-frontal cortex, superior temporal sulcus and the amygdala (Baron-Cohen & Ring 1994; Frith & Frith 1999; Baron-Cohen *et al.* 1999*b*, 2000). The brain basis of systemizing remains to be studied.

We conclude by suggesting that the E–S theory of sex differences in the mind, and the EMB theory of autism warrant further biomedical research, as a result of this new evidence of intact or superior systemizing in AS, as measured on the SQ.

S.B.-C., J.R. and S.W. were supported by the Medical Research Council and the James S. McDonnell Foundation, during the development of this work. D.B. and N.G. submitted this work as a final year project in part fulfilment of the BSc in Psychology, Cambridge University. The authors are grateful to Johnny Lawson for help in preparing figure 1.

APPENDIX A: THE SYSTEMIZING QUOTIENT

1.	When I listen to a piece of music, I always notice the way it's structured.	strongly agree	slightly agree	slightly disagree	strongly disagree
2.	I adhere to common superstitions.	strongly agree	slightly agree	slightly disagree	strongly disagree
3.	I often make resolutions, but find it hard to stick to them.	strongly agree	slightly agree	slightly disagree	strongly disagree
4.	I prefer to read non-fiction than fiction.	strongly agree	slightly agree	slightly disagree	strongly disagree
5.	If I were buying a car, I would want to obtain specific information about its engine capacity.	strongly agree	slightly agree	slightly disagree	strongly disagree
6.	When I look at a painting, I do not usually think about the technique involved in making it.	strongly agree	slightly agree	slightly disagree	strongly disagree
7.	If there was a problem with the electrical wiring in my home, I'd be able to fix it myself.	strongly agree	slightly agree	slightly disagree	strongly disagree
8.	When I have a dream, I find it difficult to remember precise details about the dream the next day.	strongly agree	slightly agree	slightly disagree	strongly disagree
9.	When I watch a film, I prefer to be with a group of friends, rather than alone.	strongly agree	slightly agree	slightly disagree	strongly disagree
10.	I am interested in learning about different religions.	strongly agree	slightly agree	slightly disagree	strongly disagree
11.	I rarely read articles or web pages about new technology.	strongly agree	slightly agree	slightly disagree	strongly disagree
12.	I do not enjoy games that involve a high degree of strategy.	strongly agree	slightly agree	slightly disagree	strongly disagree
13.	I am fascinated by how machines work.	strongly agree	slightly agree	slightly disagree	strongly disagree
14.	I make it a point of listening to the news each morning.	strongly agree	slightly agree	slightly disagree	strongly disagree
15.	In maths, I am intrigued by the rules and patterns governing numbers.	strongly agree	slightly agree	slightly disagree	strongly disagree
16.	I am bad about keeping in touch with old friends.	strongly agree	slightly agree	slightly disagree	strongly disagree
17.	When I am relating a story, I often leave out details and just give the gist of what happened.	strongly agree	slightly agree	slightly disagree	strongly disagree
18.	I find it difficult to understand instruction manuals for putting appliances together.	strongly agree	slightly agree	slightly disagree	strongly disagree
19.	When I look at an animal, I like to know the precise species it belongs to.	strongly agree	slightly agree	slightly disagree	strongly disagree
20.	If I were buying a computer, I would want to know exact details about its hard drive capacity and processor speed.	strongly agree	slightly agree	slightly disagree	strongly disagree
21.	I enjoy participating in sport.	strongly agree	slightly agree	slightly disagree	strongly disagree
22.	I try to avoid doing household chores if I can.	strongly agree	slightly agree	slightly disagree	strongly disagree
23.	When I cook, I do not think about exactly how different methods and ingredients contribute to the final product.	strongly agree	slightly agree	slightly disagree	strongly disagree

(*Continued.*)

24.	I find it difficult to read and understand maps.	strongly agree	slightly agree	slightly disagree	strongly disagree
25.	If I had a collection (e.g. CDs, coins, stamps), it would be highly organised.	strongly agree	slightly agree	slightly disagree	strongly disagree
26.	When I look at a piece of furniture, I do not notice the details of how it was constructed.	strongly agree	slightly agree	slightly disagree	strongly disagree
27.	The idea of engaging in 'risk-taking' activities appeals to me.	strongly agree	slightly agree	slightly disagree	strongly disagree
28.	When I learn about historical events, I do not focus on exact dates.	strongly agree	slightly agree	slightly disagree	strongly disagree
29.	When I read the newspaper, I am drawn to tables of information, such as football league scores or stock market indices.	strongly agree	slightly agree	slightly disagree	strongly disagree
30.	When I learn a language, I become intrigued by its grammatical rules.	strongly agree	slightly agree	slightly disagree	strongly disagree
31.	I find it difficult to learn my way around a new city.	strongly agree	slightly agree	slightly disagree	strongly disagree
32.	I do not tend to watch science documentaries on television or read articles about science and nature.	strongly agree	slightly agree	slightly disagree	strongly disagree
33.	If I were buying a stereo, I would want to know about its precise technical features.	strongly agree	slightly agree	slightly disagree	strongly disagree
34.	I find it easy to grasp exactly how odds work in betting.	strongly agree	slightly agree	slightly disagree	strongly disagree
35.	I am not very meticulous when I carry out D.I.Y.	strongly agree	slightly agree	slightly disagree	strongly disagree
36.	I find it easy to carry on a conversation with someone I've just met.	strongly agree	slightly agree	slightly disagree	strongly disagree
37.	When I look at a building, I am curious about the precise way it was constructed.	strongly agree	slightly agree	slightly disagree	strongly disagree
38.	When an election is being held, I am not interested in the results for each constituency.	strongly agree	slightly agree	slightly disagree	strongly disagree
39.	When I lend someone money, I expect them to pay me back exactly what they owe me.	strongly agree	slightly agree	slightly disagree	strongly disagree
40.	I find it difficult to understand information the bank sends me on different investment and saving systems.	strongly agree	slightly agree	slightly disagree	strongly disagree
41.	When travelling by train, I often wonder exactly how the rail networks are coordinated.	strongly agree	slightly agree	slightly disagree	strongly disagree
42.	When I buy a new appliance, I do not read the instruction manual very thoroughly.	strongly agree	slightly agree	slightly disagree	strongly disagree
43.	If I were buying a camera, I would not look carefully into the quality of the lens.	strongly agree	slightly agree	slightly disagree	strongly disagree
44.	When I read something, I always notice whether it is grammatically correct.	strongly agree	slightly agree	slightly disagree	strongly disagree

(*Continued*.)

45.	When I hear the weather forecast, I am not very interested in the meteorological patterns.	strongly agree	slightly agree	slightly disagree	strongly disagree
46.	I often wonder what it would be like to be someone else.	strongly agree	slightly agree	slightly disagree	strongly disagree
47.	I find it difficult to do two things at once.	strongly agree	slightly agree	slightly disagree	strongly disagree
48.	When I look at a mountain, I think about how precisely it was formed.	strongly agree	slightly agree	slightly disagree	strongly disagree
49.	I can easily visualise how the motorways in my region link up.	strongly agree	slightly agree	slightly disagree	strongly disagree
50.	When I'm in a restaurant, I often have a hard time deciding what to order.	strongly agree	slightly agree	slightly disagree	strongly disagree
51.	When I'm in a plane, I do not think about the aerodynamics.	strongly agree	slightly agree	slightly disagree	strongly disagree
52.	I often forget the precise details of conversations I've had.	strongly agree	slightly agree	slightly disagree	strongly disagree
53.	When I am walking in the country, I am curious about how the various kinds of trees differ.	strongly agree	slightly agree	slightly disagree	strongly disagree
54.	After meeting someone just once or twice, I find it difficult to remember precisely what they look like.	strongly agree	slightly agree	slightly disagree	strongly disagree
55.	I am interested in knowing the path a river takes from its source to the sea.	strongly agree	slightly agree	slightly disagree	strongly disagree
56.	I do not read legal documents very carefully.	strongly agree	slightly agree	slightly disagree	strongly disagree
57.	I am not interested in understanding how wireless communication works.	strongly agree	slightly agree	slightly disagree	strongly disagree
58.	I am curious about life on other planets.	strongly agree	slightly agree	slightly disagree	strongly disagree
59.	When I travel, I like to learn specific details about the culture of the place I am visiting.	strongly agree	slightly agree	slightly disagree	strongly disagree
60.	I do not care to know the names of the plants I see.	strongly agree	slightly agree	slightly disagree	strongly disagree

APPENDIX B: THE EMPATHIZING QUOTIENT

1.	I can easily tell if someone else wants to enter a conversation.	strongly agree	slightly agree	slightly disagree	strongly disagree
2.	I prefer animals to humans.	strongly agree	slightly agree	slightly disagree	strongly disagree
3.	I try to keep up with the current trends and fashions.	strongly agree	slightly agree	slightly disagree	strongly disagree
4.	I find it difficult to explain to others things that I understand easily, when they don't understand it first time.	strongly agree	slightly agree	slightly disagree	strongly disagree
5.	I dream most nights.	strongly agree	slightly agree	slightly disagree	strongly disagree
6.	I really enjoy caring for other people.	strongly agree	slightly agree	slightly disagree	strongly disagree
7.	I try to solve my own problems rather than discussing them with others.	strongly agree	slightly agree	slightly disagree	strongly disagree

(*Continued*.)

8.	I find it hard to know what to do in a social situation.	strongly agree	slightly agree	slightly disagree	strongly disagree
9.	I am at my best first thing in the morning.	strongly agree	slightly agree	slightly disagree	strongly disagree
10.	People often tell me that I went too far in driving my point home in a discussion.	strongly agree	slightly agree	slightly disagree	strongly disagree
11.	It doesn't bother me too much if I am late meeting a friend.	strongly agree	slightly agree	slightly disagree	strongly disagree
12.	Friendships and relationships are just too difficult, so I tend not to bother with them.	strongly agree	slightly agree	slightly disagree	strongly disagree
13.	I would never break a law, no matter how minor.	strongly agree	slightly agree	slightly disagree	strongly disagree
14.	I often find it difficult to judge if something is rude or polite.	strongly agree	slightly agree	slightly disagree	strongly disagree
15.	In a conversation, I tend to focus on my own thoughts rather than on what my listener might be thinking.	strongly agree	slightly agree	slightly disagree	strongly disagree
16.	I prefer practical jokes to verbal humour.	strongly agree	slightly agree	slightly disagree	strongly disagree
17.	I live life for today rather than the future.	strongly agree	slightly agree	slightly disagree	strongly disagree
18.	When I was a child, I enjoyed cutting up worms to see what would happen.	strongly agree	slightly agree	slightly disagree	strongly disagree
19.	I can pick up quickly if someone says one thing but means another.	strongly agree	slightly agree	slightly disagree	strongly disagree
20.	I tend to have very strong opinions about morality.	strongly agree	slightly agree	slightly disagree	strongly disagree
21.	It is hard for me to see why some things upset people so much.	strongly agree	slightly agree	slightly disagree	strongly disagree
22.	I find it easy to put myself in somebody else's shoes.	strongly agree	slightly agree	slightly disagree	strongly disagree
23.	I think that good manners are the most important thing a parent can teach their child.	strongly agree	slightly agree	slightly disagree	strongly disagree
24.	I like to do things on the spur of the moment.	strongly agree	slightly agree	slightly disagree	strongly disagree
25.	I am good at predicting how someone will feel.	strongly agree	slightly agree	slightly disagree	strongly disagree
26.	I am quick to spot when someone in a group is feeling awkward or uncomfortable.	strongly agree	slightly agree	slightly disagree	strongly disagree
27.	If I say something that someone else is offended by, I think that that's their problem, not mine.	strongly agree	slightly agree	slightly disagree	strongly disagree
28.	If anyone asked me if I liked their haircut, I would reply truthfully, even if I didn't like it.	strongly agree	slightly agree	slightly disagree	strongly disagree
29.	I can't always see why someone should have felt offended by a remark.	strongly agree	slightly agree	slightly disagree	strongly disagree
30.	People often tell me that I am very unpredictable.	strongly agree	slightly agree	slightly disagree	strongly disagree
31.	I enjoy being the centre of attention at any social gathering.	strongly agree	slightly agree	slightly disagree	strongly disagree
32.	Seeing people cry doesn't really upset me.	strongly agree	slightly agree	slightly disagree	strongly disagree

(*Continued*.)

33.	I enjoy having discussions about politics.	strongly agree	slightly agree	slightly disagree	strongly disagree
34.	I am very blunt, which some people take to be rudeness, even though this is unintentional.	strongly agree	slightly agree	slightly disagree	strongly disagree
35.	I don't tend to find social situations confusing.	strongly agree	slightly agree	slightly disagree	strongly disagree
36.	Other people tell me I am good at understanding how they are feeling and what they are thinking.	strongly agree	slightly agree	slightly disagree	strongly disagree
37.	When I talk to people, I tend to talk about their experiences rather than my own.	strongly agree	slightly agree	slightly disagree	strongly disagree
38.	It upsets me to see an animal in pain.	strongly agree	slightly agree	slightly disagree	strongly disagree
39.	I am able to make decisions without being influenced by people's feelings.	strongly agree	slightly agree	slightly disagree	strongly disagree
40.	I can't relax until I have done everything I had planned to do that day.	strongly agree	slightly agree	slightly disagree	strongly disagree
41.	I can easily tell if someone else is interested or bored with what I am saying.	strongly agree	slightly agree	slightly disagree	strongly disagree
42.	I get upset if I see people suffering on news programmes.	strongly agree	slightly agree	slightly disagree	strongly disagree
43.	Friends usually talk to me about their problems as they say that I am very understanding.	strongly agree	slightly agree	slightly disagree	strongly disagree
44.	I can sense if I am intruding, even if the other person doesn't tell me.	strongly agree	slightly agree	slightly disagree	strongly disagree
45.	I often start new hobbies but quickly become bored with them and move on to something else.	strongly agree	slightly agree	slightly disagree	strongly disagree
46.	People sometimes tell me that I have gone too far with teasing.	strongly agree	slightly agree	slightly disagree	strongly disagree
47.	I would be too nervous to go on a big roller-coaster.	strongly agree	slightly agree	slightly disagree	strongly disagree
48.	Other people often say that I am insensitive, though I don't always see why.	strongly agree	slightly agree	slightly disagree	strongly disagree
49.	If I see a stranger in a group, I think that it is up to them to make an effort to join in.	strongly agree	slightly agree	slightly disagree	strongly disagree
50.	I usually stay emotionally detached when watching a film.	strongly agree	slightly agree	slightly disagree	strongly disagree
51.	I like to be very organised in day to day life and often make lists of the chores I have to do.	strongly agree	slightly agree	slightly disagree	strongly disagree
52.	I can tune into how someone else feels rapidly and intuitively.	strongly agree	slightly agree	slightly disagree	strongly disagree
53.	I don't like to take risks.	strongly agree	slightly agree	slightly disagree	strongly disagree
54.	I can easily work out what another person might want to talk about.	strongly agree	slightly agree	slightly disagree	strongly disagree
55.	I can tell if someone is masking their true emotion.	strongly agree	slightly agree	slightly disagree	strongly disagree
56.	Before making a decision I always weigh up the pros and cons.	strongly agree	slightly agree	slightly disagree	strongly disagree
57.	I don't consciously work out the rules of social situations.	strongly agree	slightly agree	slightly disagree	strongly disagree

(*Continued*.)

58.	I am good at predicting what someone will do.	strongly agree	slightly agree	slightly disagree	strongly disagree
59.	I tend to get emotionally involved with a friend's problems.	strongly agree	slightly agree	slightly disagree	strongly disagree
60.	I can usually appreciate the other person's viewpoint, even if I don't agree with it.	strongly agree	slightly agree	slightly disagree	strongly disagree

REFERENCES

American Psychiatric Association 1994 *DSM-IV Diagnostic and Statistical Manual of Mental Disorders*, 4th edn. Washington, DC: American Psychiatric Association.

Asperger, H. 1944 Die 'Autistischen Psychopathen' im Kindesalter. *Arch. Psychiat. Nervenkrank.* **117**, 76–136.

Bailey, T., Le Couteur, A., Gottesman, I., Bolton, P., Simonoff, E., Yuzda, E. & Rutter, M. 1995 Autism as a strongly genetic disorder: evidence from a British twin study. *Psychol. Med.* **25**, 63–77.

Baron-Cohen, S. 1995 *Mindblindness: an essay on autism and theory of mind*. Boston, MA: MIT Press/Bradford Books.

Baron-Cohen, S. 2000 Theory of mind and autism: a fifteen year review. In *Understanding other minds*, vol. 2 (ed. S. Baron-Cohen, H. Tager Flusberg & D. Cohen). Oxford University Press.

Baron-Cohen, S. 2002 The extreme male brain theory of autism. *Trends Cogn. Sci.* **6**, 248–254.

Baron-Cohen, S. & Bolton, P. 1993 *Autism: the facts*. Oxford University Press.

Baron-Cohen, S. & Hammer, J. 1997 Is autism an extreme form of the male brain? *Adv. Infancy Res.* **11**, 193–217.

Baron-Cohen, S. & Ring, H. 1994 A model of the mindreading system: neuropsychological and neurobiological perspectives. In *Origins of an understanding of mind* (ed. P. Mitchell & C. Lewis). Hillsdale, NJ: Lawrence Erlbaum Associates.

Baron-Cohen, S., Jolliffe, T., Mortimore, C. & Robertson, M. 1997 Another advanced test of theory of mind: evidence from very high functioning adults with autism or Asperger Syndrome. *J. Child Psychol. Psychiat.* **38**, 813–822.

Baron-Cohen, S., O'Riordan, M., Jones, R., Stone, V. & Plaisted, K. 1999*a* A new test of social sensitivity: detection of faux pas in normal children and children with Asperger syndrome. *J. Autism Devl Disorders* **29**, 407–418.

Baron-Cohen, S., Ring, H., Wheelwright, S., Bullmore, E., Brammer, M., Simmons, A. & Williams, S. 1999*b* Social intelligence in the normal and autistic brain: an fMRI study. *Eur. J. Neurosci.* **11**, 1891–1898.

Baron-Cohen, S., Wheelwright, S., Stone, V. & Rutherford, M. 1999*c* A mathematician, a physicist, and a computer scientist with Asperger syndrome: performance on folk psychology and folk physics test. *Neurocase* **5**, 475–483.

Baron-Cohen, S., Ring, H., Bullmore, E., Wheelwright, S., Ashwin, C. & Williams, S. 2000 The amygdala theory of autism. *Neurosci. Behav. Rev.* **24**, 355–364.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J. & Clubley, E. 2001 The autism spectrum quotient (AQ): evidence from Asperger syndrome/high functioning autism, males and females, scientists and mathematicians. *J. Autism Devl Disorders* **31**, 5–17.

Baron-Cohen, S., Wheelwright, S., Griffin, R., Lawson, J. & Hill, J. 2002 The exact mind: empathising and systemising in autism spectrum conditions. In *Handbook of cognitive development* (ed. U. Goswami). Oxford: Blackwell.

Benbow, C. P. 1988 Sex differences in mathematical reasoning ability in intellectually talented preadolescents: their nature, effects, and possible causes. *Behav. Brain Sci.* **11**, 169–232.

Bolton, P. & Rutter, M. 1990 Genetic influences in autism. *Int. Rev. Psychiat.* **2**, 67–80.

Davis, M. H. 1980 A multidimensional approach to individual differences in empathy. *JSAS Cat. Select. Docs Psychol.* **10**, 85.

Davis, M. H. 1994 *Empathy: a social psychological approach*. Boulder, CO: Westview Press.

Davis, M. H. & Franzoi, S. L. 1991 Stability and change in adolescent self-consciousness and empathy. *J. Res. Personality* **25**, 70–87.

Folstein, S. & Rutter, M. 1977 Infantile autism: a genetic study of 21 twin pairs. *J. Child Psychol. Psychiat.* **18**, 297–321.

Folstein, S. & Rutter, M. 1988 Autism: familial aggregation and genetic implications. *J. Autism Devl Disorders* **18**, 3–30.

Frith, C. D. & Frith, U. 1999 Interacting minds—a biological basis. *Science* **286**, 1692–1695.

Frith, U. 1989 *Autism: explaining the enigma*. Oxford: Basil Blackwell.

Frith, U. 1991 *Autism and Asperger's syndrome*. Cambridge University Press.

Geary, D. 1996 Sexual selection and sex differences in mathematical abilities. *Behav. Brain Sci.* **19**, 229–284.

Geschwind, N. & Galaburda, A. M. 1985 Cerebral lateralization. biological mechanisms, associations, and pathology: I. A hypothesis and a program for research. *Arch. Neurol.* **42**, 428–459.

Gillberg, C. 1991 Clinical and neurobiological aspects of Asperger syndrome in six family studies. In *Autism and Asperger syndrome* (ed. U. Frith). Cambridge University Press.

Hall, J. A. 1978 Gender effects in decoding nonverbal cues. *Psychol. Bull.* **85**, 845–858.

Happé, F. 1996 Studying weak central coherence at low levels: children with autism do not succumb to visual illusions. A research note. *J. Child Psychol. Psychiat.* **37**, 873–877.

Hermelin, B. 2002 *Bright splinters of the mind: a personal story of research with autistic savants*. London: Jessica Kingsley.

Hoffman, M. L. 1977 Sex differences in empathy and related behaviors. *Psychol. Bull.* **84**, 712–722.

ICD-10 1994 *International Classification of Diseases*, 10th edn. Geneva: World Health Organization.

Jolliffe, T. & Baron-Cohen, S. 1997 Are people with autism or Asperger's syndrome faster than normal on the embedded figures task? *J. Child Psychol. Psychiat.* **38**, 527–534.

Kimura, D. 1999 *Sex and cognition*. Cambridge, MA: MIT Press.

Klin, A., Volkmar, F., Sparrow, S., Cicchetti, D. & Rourke, B. 1995 Validity and neuropsychological characterization of Asperger syndrome: convergence with nonverbal learning disabilities syndrome. *J. Child Psychol. Psychiat.* **36**, 1127–1140.

Lutchmaya, S., Baron-Cohen, S. & Raggett, P. 2002 Foetal testosterone and eye contact in 12 month old infants. *Infant Behav. Dev.* **25**, 327–335.

Morton, J., Frith, U. & Leslie, A. 1991 The cognitive basis of a biological disorder: autism. *Trends Neurosci.* **14**, 434–438.
Ozonoff, S., Strayer, L., McMahon, A. & Filloux, F. 1994 Executive function abilities in autism and Tourette syndrome: an information processing approach. *J. Child Psychol. Psychiat.* **35**, 1015–1032.
Russell, J. 1997 How executive disorders can bring about an inadequate theory of mind. In *Autism as an executive disorder* (ed. J. Russell). Oxford University Press.
Shah, A. & Frith, U. 1983 An islet of ability in autism: a research note. *J. Child Psychol. Psychiat.* **24**, 613–620.
Wechsler, D. 1958 *Sex differences in intelligence: the measurement and appraisal of adult intelligence*. Baltimore, OH: Williams & Wilking.
Wing, L. 1981 Asperger syndrome: a clinical account. *Psychol. Med.* **11**, 115–130.
Wing, L. 1988 The autistic continuum. In *Aspects of autism: biological research* (ed. L. Wing). London: Gaskell/Royal College of Psychiatrists.

GLOSSARY

AQ: autism spectrum quotient
AS: Asperger syndrome
EFT: embedded figures task
EMB: extreme male brain
EQ: empathy quotient
E–S: empathizing–systemizing
HFA: high-functioning autism
SQ: systemizing quotient
WAIS-R: Weschler Adult Intelligence Scale—Revised