J Autism Dev Disord (2007) 37:1823–1832
DOI 10.1007/s10803-006-0316-6

ORIGINAL PAPER

Empathizing and Systemizing in Adults with and without Autism Spectrum Conditions: Cross-Cultural Stability

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Published online: 16 December 2006

Abstract This study tests the empathizing-systemizing (E-S) theory of sex differences and the extreme male brain (EMB) theory of autism. Three groups of participants took part: $n = 48$ people with autism spectrum, $n = 137$ general population controls, and $n = 1{,}250$ university student controls. Each participant completed the Empathy Quotient (EQ) and the Systemizing Quotient (SQ). Results: The autism spectrum condition (ASC) group scored significantly lower than controls on the EQ, and significantly higher on the SQ. Among both control groups, females scored significantly higher than males on the EQ, whilst males scored significantly higher than females on the SQ. The distribution of 'brain types', based on the difference between EQ and SQ scores, showed distinct profiles for people with ASC, control males and control females.

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Keywords Empathizing · Systemizing · Autism · Asperger syndrome · Autism spectrum conditions · Cognitive style · Sex differences

Introduction

Developmental psychologists have found that two primary domains of cognition emerge in infancy: understanding social-psychological (intentional) agency, and understanding physical (causal) events (Cosmides & Tooby, 1994; Wellman & Inagaki, 1997). These two cognitive abilities are sometimes referred to as folk (or intuitive) psychology, used to deduce the cause of an agent's actions, and folk (or intuitive) physics, used to deduce the cause of a non-agent's movement (Dennett, 1987). They are *core* domains of cognition because they are found universally in typical cognitive development.

Most research into causal cognition has been carried out with children and reveals differences between children with and without autism spectrum condition (ASC). Regarding their understanding of social causality, children with ASC show significant deficits (Baron-Cohen, 1995; Baron-Cohen, Leslie, & Frith, 1985), whilst they show no impairment in their understanding of physical causality, and may even be superior relative to mental-age matched controls (Baron-Cohen, 1997; Baron-Cohen, Leslie, & Frith, 1986; Charman & Baron-Cohen, 1995; Leekam & Perner, 1991; Leslie & Thaiss, 1992). This result also suggests the independence of these two causal domains of cognition, perhaps underpinned by independent neurocognitive processes.

The Empathizing-Systemizing Theory as Fundamental Cognitive Styles

Baron-Cohen (2002) proposed the Empathizing-Systemizing (E-S) theory of sex differences in cognition. These concepts of empathizing and systemizing are derived from the concepts of folk psychology and folk physics but go beyond these, in that folk psychology focuses mostly on belief-desire attribution (or theory of mind) whilst empathy also involves an affective reaction to another's mental states; and folk physics mostly focuses on physical causal systems whilst systemizing also involves understanding the laws or rules governing non-causal systems such as mathematics, libraries as systems, or train-timetables (Baron-Cohen, 2003).

Empathizing is the drive to identify another person's emotions and thoughts, and respond to these with an appropriate emotion (Baron-Cohen, 2003). It provides a way of making sense and predicting another person's behaviour. Systemizing is the drive to analyze, explore and construct a system, and provides a way of understanding and predicting non-agents' behaviour (Baron-Cohen, 2003). Systemizing entails extracting the underlying rules that govern the system, and not only allows us to understand and predict an existing system, but to invent a new one. According to the E-S theory, there are sex differences in the general population, males having a stronger drive to systemize while females having a stronger drive to empathize (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003; Lawson, Baron-Cohen, & Wheelwright, 2004). The related 'Extreme Male Brain' (EMB) theory of autism suggests that, if males differ from females on the E-S dimensions, people with ASC simply show an extreme of the male profile in terms of E and S (Baron-Cohen, 2002), that is, low empathizing and high systemizing.

Sex Differences in Cognition

In the general population, there is evidence of sex differences in cognitive abilities, their females showing a superiority on social tasks, such as some aspects of language (Hyde & Linn, 1988), tests of social judgement (Argyle & Cooke, 1976; Hall, 1978; Halpern, 1992), and measures of empathy and cooperation (Ounsted & Taylor, 1972), while males are superior to females on non-social tasks such as mathematical reasoning (geometry) (Lummis & Stevenson, 1990), the Embedded Figures Test (Witkin, Oltman, Raskin, & Karp, 1971), the Mental Rotation task (Masters & Sanders, 1993), and spatial skill (Linn & Peterson, 1985). These results suggest that, on average, females are superior in the abilities that require a high degree of empathizing and males are superior on tasks that require a high degree of systemizing.

Empathizing and Systemizing in ASC

There have been more than 30 experimental studies of the theory of mind and empathy in ASC, and almost all results revealed profound impairments. The evidence related to impaired empathizing is reviewed elsewhere (Baron-Cohen, 1995; Baron-Cohen, Tager-Flusberg, & Cohen, 1993). Adults as well as children with ASC show their deficits in empathizing on more complex ToM tasks. For example, on the 'Reading the Mind in the Eyes' Test, females score higher than males, but individuals with ASC score even lower than males (Baron-Cohen, Wheelwright, & Hill, 2001). 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 Asperger Syndrome (AS) have lower scores on tests of this than typical males (Baron-Cohen, O'Riordan, Jones, Stone, & Plaisted, 1999).

In contrast, people with ASC are intact or even superior in understanding physical causality. The evidence in relation to superior systemizing in ASC includes the fact that some individuals in ASC 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, Wheelwright, Stone, & Rutherford, 1999). All of these need high systemizing ability.

The Empathy and Systemizing Quotients

Such differences between people with and without ASC, and sex differences in general population, have also been found using questionnaires with adults (Baron-Cohen & Wheelwright, 2004; Baron-Cohen et al., 2003). In these studies, the Empathy Quotient (EQ) and the Systemizing Quotient (SQ) have been used.

The EQ and the SQ were developed in order to investigate two cognitive styles, empathizing and systemizing, in adults with normal intelligence (Baron-Cohen & Wheelwright, 2004; Baron-Cohen et al., 2003). They have a forced-choice format, and are self-administered questionnaires that measure individual

differences in empathizing and systemizing. Earlier studies show that the EQ and SQ distinguishes people with ASC (of normal intelligence) from controls (Baron-Cohen & Wheelwright, 2004; Baron-Cohen et al., 2003), in a direction consistent with both the E-S and the EMB theories.

In the UK study with the EQ and SQ (Baron-Cohen et al., 2003), three groups of subjects were tested: $n = 47$ people with AS/HFA (33 males, 14 females), $n = 174$ students (65 males, 109 females), and $n = 103$ people from the general population (49 males, 54 females). The results showed that the AS/HFA group scored higher than the two control groups, the two control groups did not differ from each other, and control males scored significantly higher than control females on the SQ; the reverse was seen on the EQ.

According to the E-S theory (Baron-Cohen, 2003), individuals can be classified into five major cognitive styles. These styles are termed 'brain types': individuals in whom empathizing is at a higher level than their systemizing are referred to as having a brain of type E (the Empathizing brain type). Individuals in whom systemizing is at a higher level than their empathizing are said to have a brain of type S (the Systemizing brain type). Individuals in whom empathizing and systemizing are equally balanced are said to be a brain of type B (the Balanced brain type). According to the EMB theory, individuals with AS or HFA should show the profile of hyper-systemizing alongside hypo-empathizing. Such a brain type is termed the *extreme* of type S. The final brain type is the mirror image of the latter, namely an extreme of type E (hyper-empathizing alongside hypo-systemizing).

Is the E-S Theory of Cognitive Styles Universal or Culture-Dependent?

The aims of the study reported below are to test if the results of the UK study replicate in a Japanese sample, in order to examine the cross-cultural validity of the five brain types. This enables us to test if the E-S theory is universal, and if the results are independent of culture. A core factor which distinguishes western from eastern cultures is Individualism–Collectivism (Communalism) (Hofstede, 1980, 1991; Hui & Triandis, 1986; Laungani, 2000). Western society has an increasing emphasis on individualism. Although the concept itself has come to acquire several different meanings (Triandis, 1994), individualism is concerned with giving priority to one's personal goals over the goals of one's in-group, whilst collectivism is community-oriented, emphasizing collective responsibility and collective achievement.

Japanese society is known to be collectivist, and continues to be community-oriented, although since World War II Japanese society has become more westernized (Americanized). However, Japanese society is to a large extent still *relationship-centred*. Such a cultural difference between the UK and Japan might affect the results on the EQ/SQ scores and the proportion of the brain types in people with ASC as well as general population.

If the E-S theory, and the EQ/SQ, are culture-specific, results in a Japanese sample should differ from those in a British sample. However, if the E-S theory and the EQ/SQ are universal, the results from both countries should be very similar. Therefore, we tested the following predictions in a Japanese sample: (1) High-functioning adults with ASC would score lower than controls on the EQ, and score higher than controls on the SQ. (2) Within the controls, females would score higher on the EQ and males would score higher on the SQ. (3) Differences would be seen in the distribution of cognitive styles (brain types) among the three groups: people with ASC, control males and control females.

Method

Participants

Three groups were tested: Group 1 comprised $n = 48$ adults with high-functioning ASC (38 males, 10 females). All participants in this group had been diagnosed by two psychiatrists (T.U. and Y.Y.) using established criteria (APA, 1994; WHO, 1992). The participants in this group were recruited via a specialist clinic (Yokohama Psycho-Developmental Clinic) carrying out diagnostic assessments. Their mean age was 28.9 yrs ($SD = 8.92$; range: 16–48 yrs). They were assessed for IQ using the WAIS-R Japanese version (Wechsler, 1981; Shinagawa, Kobayashi, Fujita, & Maekawa, 1990), (*mean* FIQ = 96.8, $SD = 17.97$, *mean* VIQ = 99.7, $SD = 16.65$, *mean* PIQ = 93.8, $SD = 21.19$), and all participants had an IQ of 70 or higher. The cases of high-functioning autism (HFA: $n = 31$) and Asperger Syndrome (AS: $n = 17$) were grouped together as the ASC, rather than attempting to separate them into subgroups, as was done in the earlier study in the UK. None of the participants were genetically related to each other. The two psychiatrists who diagnosed participants in Group 1 were trained in the diagnosis of ASC under Dr. Lorna Wing, and were qualified to use the Diagnostic Interview for Social and Communication Disorders (DISCO) (Leekam, Libby,

Wing, Gould, & Taylor, 2002; Wing, Leekam, Libby, Gould, & Larcombe, 2002).

Group 2 comprised $n = 137$ adults selected at random (71 males, 66 females) from a general population. They were recruited through several companies. These companies consisted of several types of business. The EQ and SQ were sent to 400 employees randomly and the completed questionnaires were sent back to the research team, resulting in a response rate of 34.3%. Their mean age was 29.6 yrs ($SD = 4.46$; range: 23–46 yrs).

Group 3 comprised $n = 1{,}250$ university students (616 males and 634 females) randomly selected from eight universities in Japan. They were recruited from several study/degree areas. Their mean age was 19.4-yrs old ($SD = 1.35$, range: 18–26 yrs). This student sample was collected to standardize the EQ and SQ Japanese version.

The IQ of participants in Group 2 and Group 3 were not measured, but they were assumed to have an IQ in the normal range because all of participants in these groups had completed senior-high school and some of Group 2 had completed a university degree.

The Empathy and Systemizing Quotients

Each of the EQ and SQ comprise 60 questions, 40 assessing empathizing or systemizing respectively, and 20 filler items. Half the items are worded to produce an ''agree'' response, and half a ''disagree'' response, and items are randomized to avoid a response bias. An individual scores 2 points if they display a systemizing/empathizing response strongly and 1 point if they display a systemizing/empathizing response slightly (Baron-Cohen & Wheelwright, 2004; Baron-Cohen et al., 2003).

Item Translation

The item translation process was as follows. First, the Japanese authors translated the EQ and SQ items from English into Japanese. Then the Japanese items were checked by an English-Japanese bilingual psychologist for whether they corresponded with the original English items. Finally, the Japanese items were back-translated into English by English-native speakers who could understand Japanese, and they were checked for whether they corresponded with the original English items. The final versions of the Japanese EQ and SQ are similar to the original English versions.

Brain Types

The brain type of each participant was determined using following method based on the E-S theory (Baron-Cohen, 2002; Goldenfeld, Baron-Cohen, & Wheelwright, 2006; Wheelwright et al., 2006). We transformed the raw EQ and SQ scores from each participant into standard (T) scores. Then, we subtracted the standard EQ (T) score from the standard SQ (T) score for each participant. We call this difference a D score. A high D score can be attained either by a high SQ score with a low EQ score, or vice versa. A low D score means the difference between EQ and SQ is small. The greater the D score in a positive direction, the stronger one's systemizing relative to one's empathizing, and the greater the D score in a negative direction, the stronger one's empathizing relative to one's systemizing. D is therefore an index of discrepancy between E and S.

According to the E–S theory (Baron-Cohen et al., 2003), a D score falling below +/–10 (i.e., difference within +/–1 SD) defines the Balanced brain type (*type B*), from 10 to below 20 ($1SD < D < 2SD$) defines the Systemizing brain type (*type S*), and 20 and over ($D > 2SD$) defines the extreme Systemizing brain type (*extreme type S*). A D score falling from –10 to above –20 ($-1SD > D > -2SD$) defines the Empathizing brain type (*type E*), and –20 and below ($D < -2SD$) defines the extreme Empathizing brain type (*extreme type E*).

Procedure

All of the participants in Group 1 were sent the EQ and SQ by a psychiatrist or clinical psychologist in the specialist clinic. All of the participants in Group 2 were sent the EQ and SQ by post. They were instructed to complete it as quickly as possible (to avoid thinking about responses too long). Participants in Group 3 filled out the EQ and SQ in group settings, mainly during introductory classes on psychology. The EQ and SQ were combined together into one questionnaire, in which all items appeared in random order. Scoring was identical to original version in the UK study.

Results

The Empathizing Quotient

Mean total EQ scores for each group, broken down by sex, are shown in Table 1. First, the distribution of EQ scores in each group was examined. The skewnesses were 0.46 in ASC, 0.28 in general population, and 0.35 in students. The kurtoses were –0.71, –0.32 and 0.03 respectively. The internal consistency of the EQ, calculated by using all control participants, was Cronbach's α coefficient = 0.86.

Table 1 Means and SDs of the EQ and SQ scores in three groups

Group	N	EQ	SQ
ASCs	48	24.9 (8.33)	32.4 (13.31)
Males	38	24.6 (8.53)	31.3 (12.99)
Females	10	26.0 (7.83)	36.7 (14.35)
Controls	137	33.9 (11.02)	23.6 (12.18)
Males	71	31.1 (10.70)	29.5 (10.35)
Females	66	36.9 (10.73)	17.3 (10.89)
Students	1250	33.4 (10.72)	22.7 (11.59)
Males	616	30.6 (9.92)	27.8 (11.83)
Females	634	36.1 (10.44)	17.7 (9.01)

In order to compare groups using an ANOVA of total EQ score by Group and Sex, 50 samples (25 males and 25 females) were extracted from Group 2 and Group 3 each randomly. The mean total scores of the EQ for these sample groups (*mean* = 33.7, *SD* = 11.25 in Group 2; *mean* = 33.8, *SD* = 10.66 in Group 3) were identical with those in total samples. *T*-tests between mean scores of sample groups and those in all participants showed statistically no differences ($t(49) = 0.113$, $p = 0.910$ in Group 2; $t(49) = 0.239$, $p = 0.812$ in Group 3).

The results of ANOVA showed that there was a main effect of Group ($F(2, 144) = 14.163$, $p < 0.001$). Post hoc Bonferroni's multiple comparison tests revealed that the ASC group scored significantly lower than the control groups ($p < 0.001$), and two control groups did not differ from one another ($p = 0.984$). Power calculations were also administered on the mean EQ scores between the groups. The results showed that the ASC group scored higher than general population (power was 0.98, $p < 0.01$) and students (power was 0.99, $p < 0.01$).

The main effect of Sex was also significant ($F(1, 144) = 23.789$, $p < 0.001$), females scoring higher than males. *T*-tests using all samples confirmed that there was a significant sex difference in the two control groups, females scoring significantly higher than males (general population: $t(135) = 3.156$, $p < 0.01$; students: $t(1,247) = 8.663$, $p < 0.01$). There were no significant sex differences in the clinical group ($t(46) = 0.467$, $p = 0.321$). There was no interaction of Group by Sex. Figure 1 displays the Group and sex differences graphically.

The Systemizing Quotient

Mean total SQ scores for each group, broken down by sex, are also shown in Table 1. First, the distribution of SQ scores in each group was examined. The skewnesses were 0.38 in ASC, 0.04 in general group, and 0.73 in students. The kurtoses were –0.70, –0.86 and 0.37 respectively. The internal consistency of the SQ, calculated by using all control participants, was Cronbach's α coefficients = 0.88.

Similar to the analysis of the EQ, comparing groups using an ANOVA of total SQ score by Group and Sex in participants with ASC and randomly selected two control groups (50 samples respectively). The mean total scores of the SQ for these sample groups (*mean* = 23.1, *SD* = 11.86 in Group 2; *mean* = 22.6, *SD* = 12.20 in Group 3) were identical with those in total samples. *T*-tests between mean scores of sample groups and those in all participants showed statistically no differences ($t(49) = 0.286$, $p = 0.776$ in Group 2; $t(49) = 0.035$, $p = 0.972$ in Group 3).

There was a main effect of Group ($F(2, 144) = 11.247$, $p < 0.001$). Post hoc Bonferroni's multiple comparison revealed that ASC group scored significantly higher than two control groups ($ps < 0.001$), while two control groups did not differ from each other

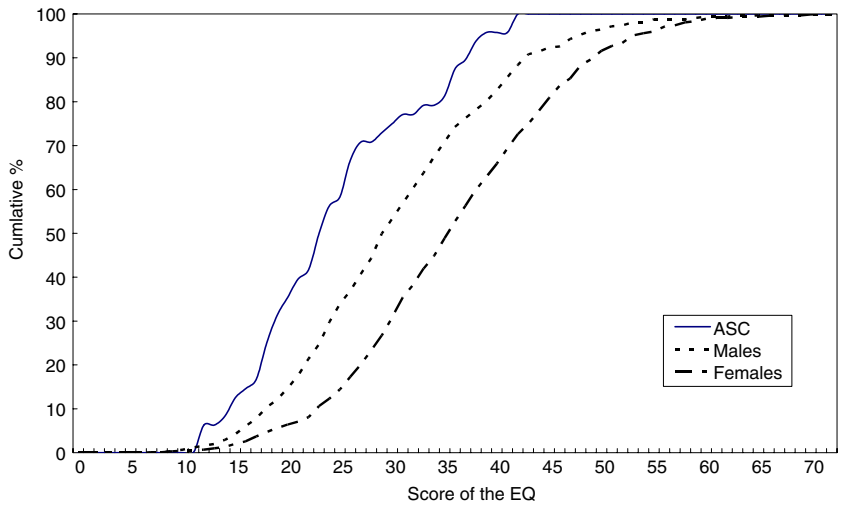

Fig. 1 Cumulative distributions of the EQ score in ASC, males and females

($p = 0.85$). Power calculations were also administered on the mean SQ scores between the groups. The results showed that the ASC group scored higher than general population (power was 0.90, $p < 0.01$) and students (power was 0.92, $p < 0.01$).

The main effect of Sex was also significant ($F(1, 144) = 25.250$, $p < 0.001$), males scoring higher than females. *T*-tests using all samples confirmed that there were significant sex differences in both of the two control groups, males scoring significantly higher than females (general population: $t(135) = 6.742$, $p < 0.01$: University students: $t(1,247) = 14.415$, $p < 0.01$). There were no significant sex differences in the clinical group ($t(46) = 1.142$, $p = 0.259$). There was no interaction of Group by Sex. Figure 2 displays the Group and sex differences graphically.

Pearson's product moment correlation between the scores of the EQ and SQ was calculated using all participants in controls (general population and students), and $r = 0.06$.

An Analysis of the Distribution of Brain Types

Finally, we examined the differences among the groups in terms of the numbers showing each 'brain type'. The percentages of participants fitting each brain type, by group, are shown in Table 2. The proportion of *extreme type S* and *type S* was greater in the ASC group than in control groups, whilst the proportion of *type E* was smaller in the ASC group than in controls. There was no *extreme type E* in the ASC group, as expected. In the two control groups, the proportion of *extreme type S* and *type S* was greater in males, whilst the proportion of *extreme type E* and *type E* was greater in females. These differences in the distributions of brain types between groups were statistically significant for the E type brains (*type E* + *extreme type E*) ($x^2 = 23.860$, $p < 0.001$ between ASC and adult controls; $x^2 = 21.355$, $p < 0.001$ between ASC and students). That is, the proportion of *types E* in the ASC group was smaller than those in control groups. Differences in the distribution of the brain types between groups were also statistically significant for the S type brains (*type S* + *extreme type S*) ($x^2 = 34.407$, $p < 0.001$ between ASC and adult controls; $x^2 = 46.753$, $p < 0.001$ between ASC and students). That is, the proportion of *types S* in the ASC group was greater than those in control groups. The distribution of brain types also differed between males and females in the control groups (in *types E*: $x^2 = 30.058$, $p < 0.001$ in adult controls; $x^2 = 22.733$, $p < 0.001$ in students; in *types S*: $x^2 = 19.187$, $p < 0.001$ in adult controls; $x^2 = 18.516$, $p < 0.001$ in students). That is, the proportion of *types E* was greater in females than males, while the proportion of *types S* was greater in males than females. These results are consistent with the E–S

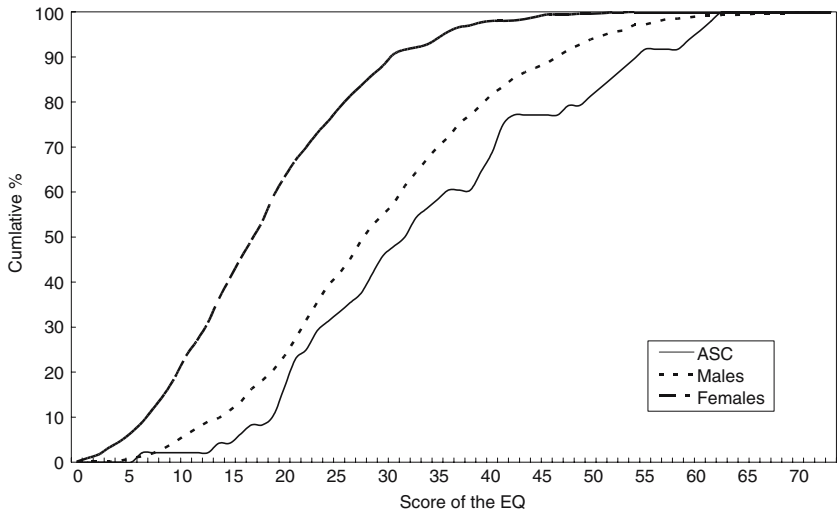

Fig. 2 Cumulative distributions of the SQ score in ASC, males and females

Table 2 The proportion of brain types in each group (%)

Group	Extreme E	E type	B type	S type	Extreme S
ASC	0.0	2.6	28.9	36.8	31.6
Controls (Male)	0.0	11.3	49.3	22.5	16.9
Controls (Female)	16.7	28.8	42.4	9.1	3.0
Students (Male)	2.1	7.9	56.2	20.2	13.5
Students (Female)	12.2	26.7	52.4	7.5	1.2

and EMB theories, and suggest a significant association between group, cognitive style, and sex.

Discussion

This study reports results from two scales, the EQ and the SQ, which measure two fundamental cognitive styles in people with and without ASC in Japan. These were administered to test two linked theories: the Empathizing-Systemizing (E–S) theory of sex differences (Baron-Cohen, 2002) and the EMB theory of autism (Baron-Cohen & Hammer, 1997; Baron-Cohen, 2000). The results obtained in the Japanese samples reported here broadly replicated the UK study, and are consistent with these two theories. Nevertheless there might be certain cultural differences between the UK and Japan.

First, the results showed that the EQ and SQ are reliable as measures of individual differences in a general population and people with ASC in Japan. The scores on both scales showed relatively normal distribution (skewness and kurtosis fell within +/– 1.0) in all groups, although the scores in ASC showed slightly low kurtosis (*platykurtic*, that is the distribution showed certain sharpness of peak) on both scales as expected. Each scale showed high internal consistency (both were close to 0.90 in α coefficient). Additionally, the correlation between scores of two scales was close to zero, which means the scores of the EQ were independent of the scores of the SQ. This result is consistent with the fundamental hypothesis that empathizing and systemizing are independent of each other.

As expected from the UK study, people with ASC scored significantly lower on the EQ, and significantly higher on the SQ, compared with age-matched control groups. The former result replicates the UK study using the EQ (Baron-Cohen & Wheelwright, 2004) and the latter result replicates the UK study using the SQ (Baron-Cohen et al., 2003).

The EQ result with people with ASC is consistent with the view of ASC as an empathy disorder (Gillberg, 1992) (though we prefer to avoid using the term 'disorder' since these instruments reflect a range of different cognitive styles). Most the EQ items involve theory of mind, which many studies have found to be impaired in autism (Baron-Cohen, 1995; Baron-Cohen, Leslie, & Frith, 1985; Perner, Frith, Leslie, & Leekam, 1989). The SQ result with people with ASC provides some support for the view of ASC as involving a talent at systemizing, confirming earlier studies showing an above average understanding of mechanics (Baron-Cohen, Leslie, & Frith, 1986; Leekam & Perner, 1991; Leslie & Thaiss, 1992; Lawson, Baron-Cohen, & Wheelwright, 2004). The hyper-systemizing found alongside the hypo-empathizing in people with ASC support the EMB theory of autism in which individuals with autism are differentiated on the dimensions by two cognitive styles, empathizing and systemizing.

A question might be raised as to whether ASC could impair the ability to respond accurately to items in the EQ, because of subtle mind-reading problems that are found even in high-functioning adults (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Happé, 1994). However, if such impairments had occurred, these would in all likelihood have led the person to score higher on the EQ, rating their own behaviour as more empathic than it might really be. Therefore, any inaccuracies of this kind would if anything have caused an elevated estimate of the person's true EQ score and served to reduce the difference found between groups. On the SQ, most items ask about the person's preferences and about what they find easy or difficult. Previous research using the Autism Spectrum Quotient (AQ) suggests that people with high-functioning ASC are able to report their own preferences and what they find easy or difficult (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001).

Within the control groups, sex differences were found in both empathizing and systemizing, females scored significantly higher on the EQ and males scored significantly higher on the SQ. These results also replicate the UK studies (Baron-Cohen & Wheelwright, 2004; Baron-Cohen et al., 2003). The EQ result confirms several studies reporting a female superiority sex difference on questionnaire measures of empathy (Davis, 1980; Davis & Franzoi, 1991; Hall, 1978; Hoffman, 1977), and is consistent with the results from empathy-related performance tasks (Baron-Cohen, Wheelwright, & Hill, 2001; Buck, Savin, Miller, & Caul, 1972; Happé, 1994). The SQ result is consistent with the result from the Physical Prediction Questionnaire (PPQ) (Lawson et al., 2004), and with the male superiority in mathematics, physics, and engineering (Geary, 1995, 1996; Benbow & Stanley, 1983; Beneditt, 1994; Brush, 1991), which all require high systemizing abilities.

The comparison of people with ASC, control males, and control females on the EQ and SQ showed certain patterns. On the EQ (Fig. 1), females scored high, whilst the ASC group scored low, and males fell in between. On the SQ (Fig. 2), the ASC group scored high, females scored low, and males fell in between. These results support the E-S and EMB theories.

These results were confirmed in the comparison of brain types, which are based on the *difference* between

the standardized scores on the EQ and SQ. The distribution, summarized in Table 2, shows that a strong bias towards systemizing exists in the ASC group and that both sexes in the control groups show a bias either towards empathizing or systemizing. That is, *type E* or *extreme type E* was only found in small numbers of the ASC group, compared to rates of those in males and females in two control groups. On the other hand, *type S* or *extreme type S* was found in large number of the ASC group, compared to a rate of those in control groups. The pattern of female > male > ASC in *type E or extreme type E*, and ASC > male > female in *type S or extreme type S*, fit the EMB theory clearly. The absolute percentages of individuals in each group showing each brain type are somewhat different between the Japanese and UK studies. For example, Goldenfeld et al. (2005) found a smaller percentage of each group showing the extreme brain types than was found in the Japanese data, and this might reflect cultural factors. Nevertheless, looking at the trends by combining type S with extreme type S, or combining type E with extreme type E, replicates the UK patterns very closely, and suggests the E-S and EMB theories apply universally.

It might be questioned that the sex ratio in ASC (males : females, 4:1 here) could have produced the results. However, it is difficult to collect female samples similar to the number of males in people with ASC, and one aim of this study was if to replicate the UK study (Baron-Cohen et al., 2003) in Japanese sample, using similar methodology. It is of interest that where females with ASC have been compared to males with ASC, no differences have been found. In the present study, the mean scores on both the EQ and SQ in people with ASC differed from control males and females. If the ASC group only represented males with ASC, the results would have shown differences between males with ASC and control males only. However, the mean score on the EQ in females with ASC did not differ from that of males with ASC statistically. A similar but reverse pattern was shown on the SQ, where the mean score of SQ in females was even higher than that of males in ASC group. Therefore, imbalanced sex ratio in ASC is unlikely to have affected the results.

Another question might be raised as to whether participants in Group 2 could have been more empathic than average and therefore more likely to respond 'agree' to items in the EQ. However, the mean score of the EQ in this group was almost identical with that in the Group 3 (randomly selected students group). The result of the SQ in Group 2 did not show any difference from those in Group 3 either, which would suggest that people in Group 2 did not differ from average but were representative of the general population.

The other question is that the IQ of the participants in two control groups was not measured, and their IQ might be above average. If so, there is a possibility that a part of the differences on empathizing and systemizing between ASC group and controls resulted from an IQ difference. It is unclear whether the IQs were different between groups, and whether IQ (at least in normal range or above) affects scores on the EQ and SQ. However, if the IQ of the control groups was higher than that of the group with ASC, it cannot explain why people with ASC scored higher than controls on the SQ, although if it could explain a lower EQ score in ASC than controls. These results would suggest that any IQ differences between ASC and controls does not affect scores on the EQ and SQ in the same direction.

Several questions emerge from the studies of the E-S and EMB theories. First, is a superior systemizing cognitive style found in any other non-autistic group or it is specific to ASC? Second, would the same results be apparent if different instruments, such as performance tasks, were used? Regarding the latter question, some studies using performance tasks revealed similar results to those obtained in this study, in children with AS/HFA (Baron-Cohen, Wheelwright, Spong, Scahill, & Lawson, 2001) and in the general population in children and adults (Wakabayashi, Baron-Cohen, Sasaki, Ogawa, & Wheelwright, submitted). Third, the questionnaires used here are suitable for adults with at least average intelligence, because they require self-report. But it would be useful to adapt them for parental report in order to investigate the EQ and SQ in children, as has been done for the Autism Spectrum Quotient (AQ) (Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright, in press). Child versions of the EQ and SQ are under evaluation in our lab.

It is unclear what the underlying neurocognitive mechanisms are that drive empathizing and systemizing. In particular, it will be important to confirm if these two cognitive styles depend on independent mechanisms, or are opposite ends of a single underlying mechanism. In this respect, the correlation between the scores of the EQ and SQ was $r = 0.06$ among the controls in this study, and was $r = -0.16$ in the UK study (Baron-Cohen et al., 2003). These correlation coefficients suggest that the relationship between empathizing and systemizing can be considered to be almost independent. Therefore, we suspect that two independent mechanisms underpin empathizing and systemizing. However, there seems to be a trend

towards a trade-off between the two domains, at least in ASC. The nature of this special relationship remains to be specified.

We conclude that the E–S and the EMB theories provide useful ways to understand two fundamental cognitive styles in people with ASC and typical sex differences. The striking similarity in the results of group differences on the EQ and SQ and the proportion of the brain types from Japan and the UK, despite their clear cultural differences and some differences of the scores themselves on the EQ and SQ between peoples in two countries, suggests that the psychological patterns in two cognitive styles revealed reflect neural universals.

Acknowledgments AW was supported by a grant (The Grant-in Aid for Scientific Research No.16530418) from the Japan Society for the promotion of Science. SBC and SW were supported by the MRC UK and the Nancy Lurie Marks Family Foundation during the period of this work.

References

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

Argyle, M., & Cooke, M. (1976). *Gaze and mutual gaze*. Cambridge: Cambridge University Press.

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

Baron-Cohen, S. (1997). Are children with autism superior at folk physics? In H. Wellman, & K. Inagaki (Eds.), *Children's theories. New direction for child development series*. Jossey-Bass Inc.

Baron-Cohen, S. (2000). Theory of mind and autism: a fifteen year review. In S. Baron-Cohen, H. Tager-Flusberg, & D. Cohen (Eds.), *Understanding other minds* (pp. 3–20) 2nd edition. Oxford: Oxford University Press.

Baron-Cohen, S. (2002). The extreme male brain theory of autism. *Trends in Cognitive Sciences*, *6*, 248–254.

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

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

Baron-Cohen, S., & Hammer, J. (1997). Is autism an extreme form of the male brain? *Advances in Infancy Research*, *11*, 193–217.

Baron-Cohen, S., & Wheelwright, S. (2004). The Empathizing Quotient (EQ): an investigation of adults with Asperger Syndrome and high-functioning autism, and normal sex differences. *Journal of Autism and Developmental Disorders*, *34*, 163–175.

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., Leslie, A. M., & Frith, U. (1986). Mechanical, behavioural and intentional understanding of picture stories in autistic children. *British Journal of Developmental Psychology*, *4*, 113–125.

Baron-Cohen, S., Tager-Flusberg, H., & Cohen, D. J. (eds.), (1993). *Understanding other minds: Perspectives from autism*. Oxford: Oxford University Press.

Baron-Cohen, S., Wheelwright, S., & Hill, J. (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*, 241–252.

Baron-Cohen, S., Hoekstra, R., Knickmeyer, R., & Wheelwright, S. (in press). The Autism-Spectrum Quotient (AQ)—Children's version. *Journal of Autism and Developmental Disorders*.

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. *Journal of Child Psychology and Psychiatry*, *38*, 813–822.

Baron-Cohen, S., Wheelwright, S., Stone, V., & Rutherford, M. (1999). 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., O'Riordan, M., Jones, R., Stone, V., & Plaisted, K. (1999). A new test of social sensitivity: Detection of faux pas in normal children and children with Asperger syndrome. *Journal of Autism and Developmental Disorders*, *29*, 407–418.

Baron-Cohen, S., Richler, J., Bisarya, D., Gurunathan, N., & Wheelwright, S. (2003). The systemizing quotient: an investigation of adults with Asperger Syndrome or high functioning autism, and normal sex differences. In U. Frith, & E. Hill (Eds.), *Autism: mind and brain* (pp. 161–186). Oxford: Oxford University Press.

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. *Journal of Autism and Developmental Disorders*, *31*, 5–17.

Baron-Cohen, S., Wheelwright, S., Spong, A., Scahill, V., & Lawson, J. (2001). Are intuitive physics and intuitive psychology independent? *Journal of Development and Learning Disorders*, *5*, 47–78.

Benbow, C. P., & Stanley, J. (1983). Sex differences in mathematical reasoning ability: More facts. *Science*, *222*, 1029–1031.

Beneditt, J. (1994). Women in science '94. Comparisons across cultures. *Science*, *263*, 1391–1396.

Brush, S. G. (1991). Women in science and engineering. *American Scientist*, *79*, 404–419.

Buck, R. W., Savin, V. J., Miller, R. E., & Caul, W. F. (1972). Communication of affect through facial expression in humans. *Journal of Personality and Social Psychology*, *23*, 362–371.

Charman, T., & Baron-Cohen, S. (1995). Understanding models, photos, and beliefs: A test of the modularity thesis of metarepresentation. *Cognitive Development*, *10*, 287–298.

Cosmides, L., & Tooby, J. (1994). Origins of domain specificity: the evolution of functional organization. In L. A. Hirschfeld, & S. A Gelman (Eds.), *Mapping the mind: domain specificity in cognition and culture* (pp. 85–116). Cambridge: Cambridge University Press.

Davis, M. H. (1980). A multidimensional approach to individual differences in empathy. *JSAS Catalog of Selected Documents in Psychology*, *10*, 85.

Davis, M. H., & Franzoi, S. L. (1991). Stability and change in adolescent self-consciousness and empathy. *Journal of Research in Personality*, *25*, 70–87.

Dennett, D. (1987). *The intentional stance*. Cambridge, Massachusetts: The MIT Press/Bradford Books.

Geary, D. (1995). Sexual selection and sex differences in spatial cognition. *Learning and Individual Differences*, *7*, 289–301.

Gillberg, C. (1992). The Emmanuel Miller Lecture, 1991: Autism and autistic-like conditions: Subclasses among disorders of empathy. *Journal of Child Psychology and Psychiatry*, *33*, 813–842.

Goldenfeld N., Baron-Cohen, S., & Wheelwright, S. (2005). Empathizing and systemizing in males, females, and autism. *Clinical Neuropsychiatry*, *2*, 338–345.

Hall, J. A. (1978). Gender effects in decoding nonverbal cues. *Psychological Bulletin*, *85*, 845–858.

Halpern, D. (1992). *Sex differences in cognitive ability*. Hillsdale, NJ: Laurence Erlbaum Association.

Happé, F. (1994). An advanced test of theory of mind: Understanding story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of Autism and Developmental Disorders*, *24*, 129–154.

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. *Psychological Bulletin*, *84*, 712–722.

Hofstede, G. (1980). *Culture's consequences: International differences in Work-Related Values*. Beverly Hills, CA: Sage.

Hofstede, G. (1991). *Cultures and Organizations: Software of the mind*. London: McGraw-Hill.

Hui, C. H., & Triandis, H. C. (1986). Individualism-Collectivism: A study of cross-cultural researchers. *Journal of Cross-Cultural Psychology*, *17*, 222–248.

Hyde, J., & Linn, M. (1988). Gender differences in verbal ability: A meta-analysis. *Psychological Bulletin*, *104*, 53–69.

Laungani, P. (2000). Culture influences on the development of identity: India and England. In J. Mohan (Eds.), *Personality across cultures*. Oxford: Oxford University Press.

Lawson, J., Baron-Cohen, S., & Wheelwright, S. (2004). Empathizing and systemizing in adults with and without Asperger Syndrome. *Journal of Autism and Developmental Disorders*, *34*, 301–310.

Leekam, S., & Perner, J. (1991). Does the autistic child have a metarepresentational deficit? *Cognition*, *40*, 203–218.

Leekam, S. R., Libby, S. J., Wing, L., Gould, J., & Taylor, C. (2002). The diagnostic interview for social and communication disorders: Algorithms for ICD–10 childhood autism and Wing and Gould autistic spectrum disorder. *Journal of Child Psychology and Psychiatry*, *43*, 327–342.

Leslie, A. M., & Thaiss, L. (1992). Domain specificity in conceptual development: Evidence from autism. *Cognition*, *43*, 225–251.

Linn, M., & Petersen, A. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. *Child Development*, *56*, 1479–1498.

Lummis, M., & Stevenson, H. (1990). Gender differences in beliefs and achievement: A cross-cultural study. *Developmental Psychology*, *26*, 254–263.

Masters, M. S., & Sanders, B. (1993). Is the gender difference in mental rotation disappearing? *Behavior Genetics*, *23*, 337–341.

Ounsted, C. & Taylor, D. (Eds.), (1972). *Gender differences: Their ontogeny and significance*. Churchill, Livingstone.

Perner, J., Frith, U., Leslie, A. M., & Leekam, S. (1989). Exploration of the autistic child's theory of mind: Knowledge, belief, and communication. *Child Development*, *60*, 689–700.

Triandis, H. C. (1994). *Culture and social behavior*. New York: McGraw-Hill.

Wakabayashi, A., Baron-Cohen, S., Sasaki, J., Ogawa, Y., & Wheelwright, S. (submitted). Are intuitive psychology and intuitive physics independent?: A study from the viewpoint of the Empathizing-Systemizing theory.

Wechsler, D. (1981). *Wechsler Adult Intelligence Scale* Revised edition. New York; The Psychological Corporation. (Japanese version: Shinagawa, F., Kobayashi, S.,Fujita, K., & Maekawa, H. (1990) Wechsler Adult Intelligence Scale Revised version. Tokyo: Nihon Bunka Kagakusha.).

Wellman, H. M. & Inagaki, K. (1997). The emergence of core domains of thought: Children's reasoning about physical, psychological, and biological phenomena. Jossey-Bass Inc.

Wheelwright, S., Baron-Cohen, S., Goldenfeld, N., Delaney, J., Fine, D., Smith, R., Weil, L., & Wakabayashi, A. (2006). Predicting Autism Spectrum Quotient (AQ) from the Systemizing Quotient—Revised (SQ-R) and Empathy Quotient (EQ). *Brain Research*, *1079*, 47–56.

Wing, L., Leekam, S. R., Libby, S. J., Gould, J., & Larcombe, M. (2002). The diagnostic interview for social and communication disorders: Background, inter-rater reliability and clinical use. *Journal of Child Psychology and Psychiatry*, *43*, 307–325.

Witkin, H., Oltman, P., Raskin, E., & Karp, S. (1971). *A manual for the Embedded Figures Test*. Consulting psychologists Press.

World Health Organization (1992). *International classification of diseases* (10th ed.). Geneva: World Health Organization.