4 *Does biology play any role in sex differences in the mind?*

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THERE ARE INTERESTING DIFFERENCES between the *average* male and female mind. Recognizing these could lead to mutual respect of difference. In using the word 'average' I am from the outset recognizing that such differences may have little to say about individuals. In addition, the differences are subtle, and are to do with the relative proportions of different drives in the typical male and female mind. The field of sex differences in psychology in the 1960s and '70s was so conflict ridden as to make an open-minded debate about any possible role of biology contributing to psychological sex differences impossible. Those who explored the role of biology – even whilst acknowledging the importance of culture – found themselves accused of defending an essentialism that perpetuated inequalities between the sexes, and of oppression. Not a climate in which scientists can ask questions about mechanisms in nature. Today, the pendulum has settled sensibly in the middle of the nature–nurture debate, and scientists who care deeply about ending inequality and oppression can at the same time also talk freely about biological differences between the male and female brain and mind.

My own view is that the field of sex differences in mind needs to proceed in a fashion that is sensitive to this history of conflict by cautiously looking at the evidence and being careful not to overstate what can be concluded. Once again, the evidence says nothing about individuals. As we will see, the data actually require us to look at each individual on his or her own merits, as individuals may or may not be typical for their sex. In this chapter I will first look at the evidence from scientific studies of sex differences in the mind. At the end of the chapter, in keeping with the theme of this edited collection, I then consider the relevance of such work for our concepts of 'gender'.

Systemizing and empathizing

'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. In this chapter, I review the evidence that, in general, females spontaneously empathize to a greater degree than do males. 'Systemizing' is the drive to analyse the variables in a system in order to derive the underlying rules that govern its behaviour. Systemizing also refers to the drive to construct systems. Systemizing allows one to *predict* the behaviour of a system and to control it. I review the evidence that, on average, males spontaneously systemize to a greater degree than do females (Baron-Cohen et al. 2002).

Empathizing is close enough to the standard English definition to need little introduction, and I will come back to it shortly. But systemizing is a new concept and needs a little more definition. By a 'system' I mean something that takes inputs and deliver outputs. To systemize, one uses 'if–then' (correlation) rules. The brain zooms in on a detail or parameter of the system and observes how this varies. That is, it treats a feature of a particular object or event as a variable. Alternately, a person actively, or systematically, manipulates a given variable. One notes the effect(s) of operating on one single input in terms of its effects elsewhere in the system (the output). The key data structure used in systemizing is [input–operation–output]. If I do x, a changes to b. If z occurs, p changes to q. Systemizing therefore requires an exact eye for detail.

There are at least six kinds of systems that the human brain can analyse or construct, as shown in Table 4.1. Systemizing is an inductive process. One watches what happens each time, gathering data about an event from repeated sampling, often quantifying differences in some variables within the event and observing their correlation with variation in outcome. After confirming a reliable pattern of association – that is, generating predictable results – one forms a rule about how a particular aspect of the system works. When an exception occurs, the rule is refined or revised. Otherwise, the rule is retained. Systemizing works for phenomena that are ultimately lawful, finite and deterministic. The explanation is exact, and its truth-value is testable. ('The light went on because the switch was in the down position.') Systemizing is of almost no use for predicting

Table 4.1 Main types of analysable systems

- **Technical** systems (e.g. a computer, a musical instrument, a hammer)
- **Natural** systems (e.g. a tide, a weather front, a plant)
- **Abstract** systems (e.g. mathematics, a computer program, syntax)
- **Social** systems (e.g. a political election, a legal system, a business)
- **Organizable** systems (e.g. a taxonomy, a collection, a library)
- **Motoric** systems (e.g. a sports technique, a performance, a musical technique)

moment-to-moment changes in a person's behaviour. To predict human behaviour, empathizing is required. Systemizing and empathizing are wholly different kinds of processes.

Empathizing involves the attribution of mental states to others and involves an appropriate affective response to the other's affective state. It not only includes what is sometimes called 'theory of mind', or mentalizing, (Morton, Leslie and Frith 1995) but also encompasses the common English words 'empathy' and 'sympathy'. Although systemizing and empathizing are in one way similar because they are processes that allow us to make sense of events and make reliable predictions, they are in another way almost the opposite of each other. Empathizing involves an imaginative leap in the dark in the absence of complete data. ('Maybe she didn't phone me because she was feeling hurt by my comment.') The causal explanation is at best a 'maybe', and its truth may never be provable. Systemizing is our most powerful way of understanding and predicting the law-governed inanimate universe. Empathizing is our most powerful way to understand and predict the social world. Ultimately, empathizing and systemizing depend on separate, independent regions in the human brain.

The main brain types

In this chapter I will argue that systemizing and empathizing are two key dimensions that define the male and female brain. We all have both systemizing and empathizing skills. One can envisage five broad types of brain, as Table 4.2 shows. This chapter concerns itself primarily with those on the extreme male brain end of the spectrum. Individuals who have this psychological profile may be talented

Table 4.2 The main brain types

Profile	*Shorthand equation*	*Type of brain*
Individuals in whom empathizing is more developed than systemizing	E>S	'female' (or Type E)
Individuals in whom systemizing is more developed than empathizing	S>E	'male' (or Type S)
Individuals in whom systemizing and empathizing are both equally developed	S=E	'balanced' (or Type B)
Individuals in whom systemizing is hyperdeveloped while empathizing is hypodeveloped (the autistic end of the spectrum). They may be talented systemizers, but at the same time, they may be 'mind-blind'	S>>E	extreme male brain
Individuals who have hyperdeveloped empathizing skills, while their systemizing is hypodeveloped. They may be 'system-blind'	E>>S	extreme female brain (postulated)

systemizers, but they are often, at the same time, 'mind-blind'. (Baron-Cohen 1995). The evidence reviewed here suggests that not all men have the male brain and not all women have the female brain. Expressed differently, some women have the male brain, and some men have the female brain. My central claim here is only that *more* males than females have a brain of type S, and *more* females than males have a brain of type E. I will review the evidence supporting these profiles. In the final section of this chapter, I will highlight the role of culture and biology in these sex differences.

The female brain: empathizing

What is the evidence for female superiority in empathizing? In the studies summarized here, sex differences of a small but statistically significant magnitude have been found.

- *Sharing and turn taking*. On average, girls show more concern for fairness, while boys share less. In one study, boys showed fifty

times greater competition, as compared to girls, while girls showed twenty times greater turn taking, as compared to boys (Charlesworth and Dzur 1987).

- *Rough and tumble play or 'rough housing'* (wrestling, mock fighting, etc.). Boys show more of this than do girls. Although such activity is often playful, it can hurt or be intrusive. Lower empathizing levels are necessary to engage in rough and tumble play (Maccoby 1998).
- *Responding empathically to the distress of other people*. Girls from the age of 1 year show greater concern for others through sad looks, sympathetic vocalizations and comforting as compared to boys. Also, more women than men report frequently sharing the emotional distress of their friends. Women also show more comforting, even to strangers, than men do (Hoffman 1977).
- *Using a 'theory of mind'*. As early as 3 years of age, little girls are ahead of boys in their ability to infer what people might be thinking or intending (Happe 1995).
- *Sensitivity to facial expressions*. Women are better at decoding nonverbal communication, picking up subtle nuances from tone of voice or facial expression, or judging a person's character (Hall 1978).
- *Empathy*. Women score higher than men on questionnaires designed to measure empathic response (Davis 1994).
- *Values in relationships*. More women than men value the development of altruistic, reciprocal relationships, which by definition require empathizing. In contrast, more men value power, politics and competition (Ahlgren and Johnson 1979). Girls are more likely to endorse cooperative items on a questionnaire and to rate the establishment of intimacy as more important than the establishment of dominance. In contrast, boys are more likely than girls to endorse competitive items and to rate social status as more important than intimacy (Knight and Chao 1989).
- *Disorders of empathy*. Disorders such as psychopathic personality disorder or conduct disorder are far more common among males (Dodge 1980; Blair 1995).
- *Aggression*. Even in normal quantities, this can only occur with reduced empathizing. Here again, there is a clear sex difference. Males tend to show far more 'direct' aggression (pushing, hitting, punching, etc.), while females tend to show more 'indirect'

(relational, covert) aggression (gossip, exclusion, cutting remarks, etc.). Direct aggression may require an even lower level of empathy than indirect aggression. Indirect aggression needs better mind-reading skills than does direct aggression because its impact is strategic (Crick and Grotpeter 1995).

- *Murder*. This is the ultimate example of a lack of empathy. Daly and Wilson analysed homicide records dating back over 700 years, from a range of different societies. They found that 'male-on-male' homicide was thirty to forty times more frequent than 'female-on-female' homicide (Daly and Wilson 1988).
- *Establishing a* '*dominance hierarchy*'. Males are quicker to establish such hierarchies. This in part reflects their lower empathizing skills because often a hierarchy is established by one person pushing others around to become the leader (Strayer 1980).
- *Language style*. Girls' speech is more co-operative, reciprocal and collaborative. In concrete terms, this is also reflected in girls being able to continue a conversational exchange with a partner for a longer period. When girls disagree, they are more likely to express their different opinion sensitively, in the form of a question rather than an assertion. Boys' talk is more 'single-voiced discourse'; that is, the speaker presents only his own perspective. The female speech style is more 'double-voiced discourse'; girls spend more time negotiating with their partner, trying to take the other person's wishes into account (Smith 1985).
- *Talk about emotions*. Women's conversations involve much more talk about feelings, while men's conversations tend to be more object- or activity-focused (Tannen 1990).
- *Parenting style*. Fathers are less likely than mothers to hold their infants in a face-to-face position. Mothers are more likely to follow through the child's choice of topic in play, while fathers are more likely to impose their own topic. Also, mothers fine-tune their speech more often to match their children's understanding (Power 1985).
- *Face preference and eye contact*. From birth, females look longer at faces, particularly at people's eyes, whereas males are more likely to look at inanimate objects (Connellan et al. 2000).

Females have also been shown to have better language ability than males. It seems likely that good empathizing would promote language

development (Baron-Cohen, Baldwin and Crowson 1997) and vice versa, so these factors may not be independent.

The male brain: systemizing

The relevant domains to explore for evidence of systemizing include any fields that are in principle rule-governed. Thus, chess and football are good examples of systems, but faces and conversations are not. As noted previously, systemizing involves monitoring three elements: input, operation and output. The operation is what was done or what happened to the input in order to produce the output. What is the evidence for a stronger drive to systemize in males?

- *Toy preferences*. Boys are more interested than girls in toy vehicles, weapons, building blocks and mechanical toys, all of which are open to being 'systemized' (Jennings 1977).
- *Adult occupational choices*. Some occupations are almost entirely male. These include metalworking, weapon making, manufacture of musical instruments, and the construction industries, such as boat building. The focus of these occupations is on creating systems (Geary 1998).
- *Maths, physics and engineering*. These disciplines all require high systemizing and are largely male-dominated. The Scholastic Aptitude Math Test (SAT-M) is the mathematics part of the test administered nationally to college applicants in the United States. Males on average score 50 points higher than females on this test (Benbow 1988). Considering only individuals who score above 700, the sex ratio is 13:1 (men to women) (Geary 1996).
- *Constructional abilities*. On average men score higher than women in an assembly task in which people are asked to put together a three-dimensional (3-D) mechanical apparatus. Boys are also better at constructing block buildings from two-dimensional blueprints. Lego bricks can be combined and recombined into an infinite number of systems. Boys show more interest than girls in playing with Lego. Boys as young as 3 years of age are also faster at copying 3-D models of outsized Lego pieces. Older boys, from the age of 9 years, are better than girls at imagining what a 3-D object will look like if it is laid out flat. Boys are also better at constructing a 3-D structure from just an aerial and frontal view in a picture (Kimura 1999).

- *The Water Level Task*. Originally devised by the Swiss child psychologist Jean Piaget, the water level task involves a bottle that is tipped at an angle. Individuals are asked to predict the water level. Women more often draw the water level aligned with the tilt of the bottle and not horizontal, as is correct (Wittig and Allen 1984).
- *The Rod and Frame Test*. If a person's judgement of vertical is influenced by the tilt of the frame, he or she is said to be 'field dependent'; that is, their judgement is easily swayed by extraneous input in the surrounding context. If they are not influenced by the tilt of the frame, they are said to be 'field independent'. Most studies indicate that females are more field dependent; that is, women are relatively more distracted by contextual cues, and they tend not to consider each variable within a system separately. They are more likely than men to state erroneously that a rod is upright if it is aligned with its frame (Witkin et al. 1954).
- *Good attention to relevant detail*. This is a general feature of systemizing and is clearly a necessary part of it. Attention to relevant detail is superior in males. One measure of this is the Embedded Figures Test. On average, males are quicker and more accurate in locating a target object from a larger, complex pattern (Elliot 1961). Males, on average, are also better at detecting a particular feature (static or moving) than are women (Voyer, Voyer and Bryden 1995).
- *The Mental Rotation Test*. This test provides another example in which males are quicker and more accurate. This test involves systemizing because it is necessary to treat each feature in a display as a variable that can be transformed (e.g., rotated) and then predict the output, or how it will appear after transformation (Collins and Kimura 1997).
- *Reading maps*. This is another everyday test of systemizing, because features from 3-D input must be transformed to a two-dimensional representation. In general, boys perform at a higher level than girls in map reading. Men can also learn a route by looking at a map in fewer trials than women, and they are more successful at correctly recalling greater detail about direction and distance. This observation suggests that men treat features in the map as variables that can be transformed into three dimensions. When children are asked to make a map of an area that they have only visited once, boys' maps

have a more accurate layout of the features in the environment. More of the girls' maps make serious errors in the location of important landmarks. Boys tend to emphasize routes or roads, whereas girls tend to emphasize specific landmarks (the corner shop, the park, etc.). These strategies of using directional cues versus using landmark cues have been widely studied. The directional strategy represents an approach to understanding space as a geometric system. Similarly, the focus on roads or routes is an example of considering space in terms of another system, in this case a transportation system (Galea and Kimura 1993).

- *Motoric systems*. When people are asked to throw or catch moving objects (target directed tasks), such as playing darts or intercepting balls flung from a launcher, males tend to perform better than females. In addition, on average men are more accurate than women in their ability to judge which of two moving objects is travelling faster (Schiff and Oldak 1990).
- *Organizable systems*. People in the Aguaruna tribe of northern Peru were asked to classify a hundred or more examples of local specimens into related species. Men's classification systems included more sub-categories (i.e., they introduced greater differentiation) and were more consistent among individuals. Interestingly, the criteria that the Aguaruna men used to decide which animals belonged together more closely resembled the taxonomic criteria used by western (mostly male) biologists (Atran 1994). Classification and organization involves systemizing because categories are predictive. With more fine-grained categories, a system will provide more accurate predictions.
- *The Systemizing Quotient*. This is a questionnaire that has been tested among adults in the general population. It includes forty items that ask about a subject's level of interest in a range of different systems that exist in the environment, including technical, abstract and natural systems. Males score higher than females on this measure (Baron-Cohen et al. 2003).
- *Mechanics*. The Physical Prediction Questionnaire (PPQ) is based on an established method for selecting applicants to study engineering. The task involves predicting which direction levers will move when an internal mechanism of cog wheels and pulleys is engaged. Men score significantly higher on this test, compared with women.

Culture and biology

At age 1 year, boys strongly prefer to watch a video of cars going past, an example of predictable mechanical systems, than to watch a film showing a human face. Little girls show the opposite preference. Young girls also demonstrate more eye contact than do boys at age 1 year (Lutchmaya and Baron-Cohen 2002). Some investigators argue that, even by this age, socialization may have caused these sex differences. Although evidence exists for differential socialization contributing to sex differences, this is unlikely to be a sufficient explanation. Connellan and colleagues showed that among *1-day-old* babies, boys look longer at a mechanical mobile, which is a system with predictable laws of motion, than at a person's face, an object that is next to impossible to systemize. One-day-old girls show the opposite profile (Connellan et al. 2000). These sex differences are therefore present very early in life. This raises the possibility that, while culture and socialization may partly determine the development of a male brain with a stronger interest in systems or a female brain with a stronger interest in empathy, biology may also partly determine this. There is ample evidence to support both cultural determinism and biological determinism (Eagly 1987; Gouchie and Kimura 1991). For example, the amount of time a 1-year-old child maintains eye contact is inversely related to the prenatal level of testosterone (Lutchmaya, Baron-Cohen and Raggatt 2002b). The evidence for the biological basis of sex differences in the mind is reviewed elsewhere (Baron-Cohen 2003).

Autism: an extreme form of the male brain

Autism is diagnosed when a person shows abnormalities in social development and communication and displays unusually strong obsessional interests from an early age (Task Force on DSM-IV 1994). Asperger Syndrome (AS) has been proposed as a variant of autism. It is seen in children who have normal or high IQ scores and who develop speech at the normal developmental age. Today, approximately 1 in 200 children have one of the 'autistic spectrum conditions', which include AS (Frith 1991). Autism spectrum conditions are far more common in males than females. Among individuals with high-functioning autism (HFA) or AS, at least ten males are affected for

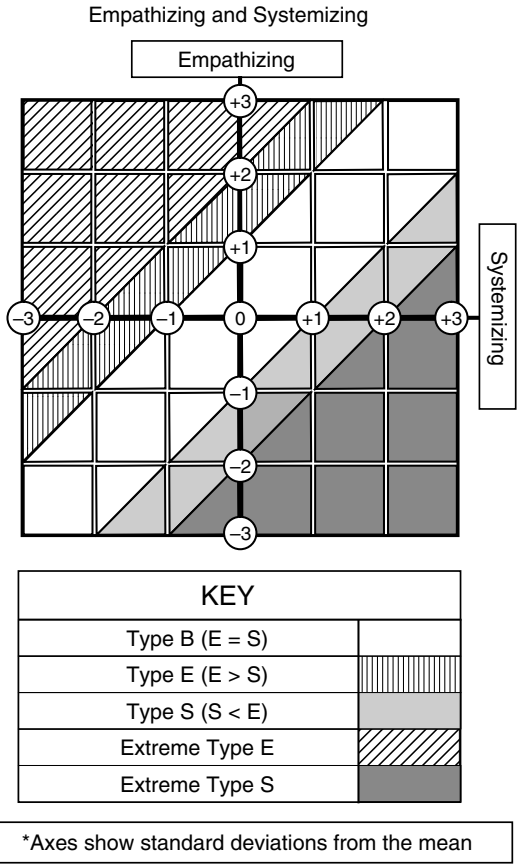

Figure 4.1. A model of the different brain types

every one female. These conditions are also strongly heritable (Bailey, Bolton and Rutter 1998) and neurodevelopmental in origin. Considerable evidence supports structural and functional differences in certain regions of the brain. For example, the amygdala is abnormal in size in many individuals with austistic spectrum disorders, and it may not respond in the usual fashion to cues of emotional expression (Baron-Cohen et al. 2000).

The extreme male brain (EMB) theory of autism was first informally suggested by Hans Asperger in 1944. According to the 1991 translation by Uta Frith, 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). In 1997 this controversial hypothesis was re-examined (Baron-Cohen and Hammer 1997). We can now test the EMB theory empirically, as the female brain (E > S), the male brain (S > E), and the balanced brain (E = S) have been defined. According to the EMB theory, people with autism or AS should always fall in the dark grey zone as illustrated in Figure 4.1.

Evidence for the extreme male brain theory

Initial tests are beginning to provide positive proof of this theory (Baron-Cohen et al. 1999b; Baron-Cohen 2000). A number of studies utilizing different approaches and standard instruments indicate that people with autism show markedly impaired empathizing. Some of the convergent lines of evidence are summarized here.

- *Mind reading*. Girls score better than boys on standard 'theory of mind' tests, and children with autism or AS tend to perform even worse than do normal boys (Happe 1995). Children with autism have specific delays and difficulties in the development of 'mind reading', and they are unable to make sense of or predict another's feelings, thoughts and behaviour. Autism has been referred to as a condition of 'mind-blindness' (Baron-Cohen 1995).
- *The Empathy Quotient*. On this questionnaire, females score higher than males, and people with AS or HFA score even lower than males (Baron-Cohen et al. 2003).
- *The 'Reading the Mind in the Eyes' Test*. Females score higher on this test than males, but people with AS do not even score as well as males (Baron-Cohen et al. 1997a).
- *The Complex Facial Expressions Test*. Similar to the other tests mentioned, females score higher than males, and people with AS score even lower than do males (Baron-Cohen, Wheelwright and Jolliffe 1997).
- *Eye contact*. Females make eye contact more often and maintain it for longer periods of time than do males. People with autism or AS make less eye contact than males (Lutchmaya et al. 2002b; Swettenham, Baron-Cohen and Charman et al. 1998).

- *Language development*. Girls develop vocabulary faster than boys, and children with autism are even slower than males to develop vocabulary (Lutchmaya, Baron-Cohen and Raggatt 2002a).
- *Pragmatics*. Females tend to be superior to males at chatting with others and at understanding the pragmatics of conversation. It is precisely this aspect of language which people with AS find most difficult (Baron-Cohen 1988).
- *The Faux Pas Test*. Females are better than males at judging what would be socially insensitive or potentially hurtful or offensive. People with autism or AS have even lower scores on tests of this than do males (Baron-Cohen et al. 1999a).
- *The Friendship Questionnaire (FQ)*. This instrument assesses empathic styles of relationships. Females score higher than males on this questionnaire, and adults with AS score even lower than do normal males on the FQ (Baron-Cohen and Wheelwright 2003).

There also exists a growing body of evidence that supports the superior systemizing abilities of individuals with autism spectrum disorders.

- *Islets of ability*. Some people with autism spectrum disorders have 'islets of ability' in mathematical calculation, calendrical calculation, syntax acquisition, music, or memory for railway timetable information to a precise degree (Baron-Cohen and Bolton 1993). For high-functioning individuals, this can lead to considerable achievement in mathematics, chess, mechanical knowledge, and other factual, scientific, technical or rule-based subjects. All of these areas are highly systemizable domains, and most are also domains that are more interesting to males than to females in the general population.
- *Attention to detail*. People with autism also tend to pay extra-fine attention to detail. For example, on the Embedded Figures Test (EFT) males score higher than females, and people with AS or HFA score even higher than males. This is not a systemizing test per se, but it is a measure of detailed local perception, which is a prerequisite for successful systemizing (Jolliffe and Baron-Cohen 1997). On visual search tasks, males demonstrate better attention to detail than do females, and people with autism or AS have even faster, more accurate visual search skills (O'Riordan et al. 2001).

- *Preference for rule-based, structured, factual information*. People with autism are strongly drawn to structured, factual and rule-based information. A male bias for this kind of information is also found in the general population.
- *Intuitive physics*. Males score higher than females on tests of intuitive physics. People with AS tend to score higher than males on such tests (Baron-Cohen et al. 2001a).
- *Toy preference*. In general, boys prefer construction-type and vehicle toys more than girls do. Clinical reports suggest that children with autism or AS demonstrate a very strong preference towards these types of toys as well (J. Lawson, S. Baron-Cohen and S. Wheelwright, unpublished data, 2002).
- *Collecting*. Boys engage in more collecting or organizing of items than girls, and people with autism show this characteristic to an even greater extent (Baron-Cohen 2003).
- *Obsessions with closed systems*. Most individuals with autism are naturally drawn to predictable things, such as computers. Unlike people, computers follow strict laws. Computers are closed systems; that is, all the variables are well defined within the system, and they are knowable, predictable and, in principle, controllable. Other individuals with autism may not make computers their target of understanding but may latch on to a different, equally closed system, such as bird migration or trainspotting (Baron-Cohen and Wheelwright 1999).
- *The Systemizing Quotient*. As noted previously in this chapter, males score higher on this test, and people with autism and AS score even higher than normal males on this instrument (Baron-Cohen et al. 2003).

Finally, some evidence rooted in biology and genetics supports the EMB theory of autism.

- *The Autism Spectrum Quotient (the AQ)*. Males in the general population score higher than females, and people with AS or HFA score highest of all on this instrument (Baron-Cohen et al. 2001b).
- *Sexually dimorphic somatic markers*. Finger length ratio is a sexually dimorphic somatic marker. In general, males tend to have a longer ring finger compared to their second finger, which is

different than the ratio in females. People with autism or AS show an even greater difference in the ratio of ring finger to second finger length (Manning et al. 2001).

- *Puberty*. Males with autism are reported to show precocious puberty, which correlates with increased levels of circulating testosterone (Tordjman et al. 1997).
- *Familiality of talent*. Males are over-represented in occupations such as engineering, which require good systemizing but where a mild impairment in empathizing is not necessarily an impediment to success (Baron-Cohen et al. 1997b). There is a higher rate of autism in the families of those talented in fields such as mathematics, physics and engineering, as compared to those who are most talented in the humanities (Baron-Cohen et al. 1998). These findings suggest that the extreme male cognitive style is, in part, inherited.

Conclusions

The above evidence suggests that the male brain is characterized by type S (where S > E), the female brain by type E (where E > S), and the autistic brain is an extreme of the male brain (S >> E). Referring to Figure 4.1, development of an autism spectrum condition indicates that an individual's brain type is shifted towards the lower right quadrant. For males, it is a small degree of shift, from type S to extreme type S. For females, the movement is greater, from type E to extreme type S. The causes of this shift remain unclear, but candidate factors include both genetic differences and prenatal testosterone levels (Bailey et al. 1998).

The model in Figure 4.1 predicts that the extreme female brain (EFB) exists. How would such individuals behave? By definition, their brain type is in the upper left quadrant of Figure 4.1. Their ability to empathize is significantly better than that of other people in the general population, but their systemizing abilities are impaired. This category would include people who have difficulty understanding mathematics, physics, mechanical objects, chemistry, and the like as systems (Baron-Cohen et al. 2002) but who are extremely accurate at tuning in to others' feelings and thoughts. Would such a profile carry with it any disability? A person with EFB would be 'system-blind'. In our

society, there remains considerable tolerance for such individuals. It is hoped that people who are 'mind-blind' will also enjoy the same tolerance by society.

We know something about the neural circuitry of empathizing (Baron-Cohen et al. 1999), but at present we know very little about the neural circuitry of systemizing. Research will hopefully begin to reveal the key brain regions involved in systems processing.

Finally, what are the implications of such research for our concepts of 'gender'? I think there are several. First, it appears that our behaviour and our psychology are a product not just of our experience (important as this is) but also of our biology. John Money, the now infamous paediatrician of the 1960s, ignored biology at his peril, in claiming that a child's gender could be determined purely by experience. The little boy whose parents were encouraged to bring him up as a girl, with a new name, new clothes and even surgical sex reassignment, grew up to feel she never fitted in as a woman, and felt deep down to be male, despite Money's strong insistence that she was female. Tragically, this dishonest sex reassignment recently led to suicide in this particular case. Second, the research suggests we should not expect that the sex ratio in occupations such as maths or physics will ever be 50–50 if we leave the workplace to reflect simply the numbers of applicants of each sex who are drawn to such fields. If we want a particular field to have an equal representation of men and women, which I think may be desirable for reasons other than scientific, we need to put in place social policies that will bring out that outcome. In other fields, it will not be necessary to intervene with policy. Medicine is a good example of a science where female applicants now outnumber male ones, probably because it is a science that favours the Type B brain (good systemizing and good empathy), and Type B is actually more common among females. But maths and physics may have little or no role for empathy, and so favour the Type S brain that is more common in males. Third, and most importantly, the research teaches us that there is no scientific justification for stereotyping, since none of the studies allow one to predict an individual's aptitudes or interests on the basis of sex. This is because – at risk of repetition – they only capture differences between groups on average. Individuals are just that – they may be typical or atypical for their group (their sex). Which means that to prejudge an individual on the basis of sex is, as the word 'prejudge' suggests, mere prejudice.

References

Ahlgren, A. and Johnson, D. W. (1979) 'Sex Differences in Cooperative and Competitive Attitudes from the 2nd through the 12th Grades', *Developmental Psychology* 15: 45–9.

Atran, S. (1994) 'Core Domains versus Scientific Theories: Evidence from Systematics and Itzaj-Maya Folkbiology', in L. A. Hirschfeld and S. A. Gelman (eds.), *Mapping the Mind: Domain Specificity in Cognition and Culture* (Cambridge: Cambridge University Press), 316–40.

Bailey, A., Bolton, P. and Rutter, M. (1998) 'A Full Genome Screen for Autism with Evidence for Linkage to a Region on Chromosome 7q', *Human Molecular Genetics* 7: 571–8.

Baron-Cohen, S. (1988) 'Social and Pragmatic Deficits in Autism: Cognitive or Affective?', *Journal of Autism and Developmental Disorders* 18: 379–402.

(1995) *Mindblindness: An Essay on Autism and Theory of Mind* (Boston, MA: MIT Press).

(2000) 'The Cognitive Neuroscience of Autism: Evolutionary Approaches', in M. S. Gazzaniga (ed.-in-chief), L. Cosmides and J. Tooby (eds.), *The New Cognitive Neurosciences*, 2nd edition (Cambridge, MA: MIT Press), 1249–57.

(2003) *The Essential Difference: Men, Women, and the Extreme Male Brain* (Boston: Basic Books).

Baron-Cohen, S., Baldwin, D. A. and Crowson, M. (1997) 'Do Children with Autism Use the Speaker's Direction of Gaze Strategy to Crack the Code of Language?', *Child Development* 68: 48–57.

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

Baron-Cohen, S., Bolton, P., Wheelwright, S., et al. (1998) 'Does Autism Occur More Often in Families of Physicists, Engineers, and Mathematicians?', *Autism* 2: 296–301.

Baron-Cohen, S. and Hammer, J. (1997) 'Is Autism an Extreme Form of the "Male Brain"?', in C. Rovee-Collier and L. P. Lipsitt (eds.), *Advances in Infancy Research* vol. 11 (Greenwich, CT: Ablex Publishing), 193–217.

Baron-Cohen, S., Jolliffe, T., Mortimore, C. and Robertson, M. (1997a) 'Another Advanced Test of Theory of Mind: Evidence from Very High Functioning Adults with Autism or Asperger Syndrome', *Journal of Child Psychology and Psychiatry and Allied Disciplines* 38: 813–22.

Baron-Cohen, S., O'Riordan, M., Stone, V., Jones, R. and Plaistead, K. (1999a) 'Recognition of Faux Pas by Normally Developing Children and Children with Asperger Syndrome or High-Functioning Autism', *Journal of Autism and Developmental Disorders* 29: 407–18.

Baron-Cohen, S., Richler, J., Bisarya, D., Gurunathan, N. and Wheelwright, S. (2003) 'The Systemising Quotient (SQ): An Investigation of Adults with Asperger Syndrome or High Functioning Autism and Normal Sex Differences', *Philosophical Transactions of the Royal Society, Series B* 358: 361–74.

Baron-Cohen, S., Ring, H. A., Bullmore, E. T., Wheelwright, S., Ashwin, C. and Williams, S. C. (2000) 'The Amygdala Theory of Autism', *Neuroscience and Biobehavioral Reviews* 24: 355–64.

Baron-Cohen, S., Ring, H. A., Wheelwright, S., et al. (1999) 'Social Intelligence in the Normal and Autistic Brain: An fMRI study', *European Journal of Neuroscience* 11: 1891–8.

Baron-Cohen, S. and Wheelwright, S. (1999) ' "Obsessions" in Children with Autism or Asperger Syndrome: A Content Analysis in Terms of Core Domains of Cognition', *British Journal of Psychiatry* 175: 484–90.

(2003) 'The Friendship and Relationship Questionnaire', *Journal of Autism and Developmental Disorders* 33: 509–17.

Baron-Cohen, S., Wheelwright, S. and Jolliffe, T. (1997) 'Is There a "Language of the Eyes"? Evidence from Normal Adults and Adults with Autism or Asperger Syndrome', *Visual Cognition* 4: 311–31.

Baron-Cohen, S., Wheelwright, S., Lawson, J., Griffin, R. and Hill, J. (2002) 'The Exact Mind: Empathising and Systemising in Autism Spectrum Conditions', in U. Goswami (ed.), *Handbook of Cognitive Development* (Oxford: Blackwell Publishers), 491–508.

Baron-Cohen, S., Wheelwright, S., Scahill, V., Spong, A. and Lawson, J. (2001a) 'Are Intuitive Physics and Intuitive Psychology Independent? A Test with Children with Asperger Syndrome', *Journal of Developmental and Learning Disorder* 5: 47–78.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J. and Clubley, E. (2001b) 'The Autism-Spectrum Quotient (AQ): Evidence from Asperger Syndrome/High-Functioning Autism, Males and Females, Scientists and Mathematicians', [published correction appears in *Journal of Autism and Developmental Disorders* 31: 603] *Journal of Autism and Developmental Disorders* 31: 5–17.

Baron-Cohen, S., Wheelwright, S., Stone, V. and Rutherford, M. (1999b) 'A Mathematician, a Physicist, and a Computer Scientist with Asperger Syndrome: Performance on Folk Psychology and Folk Physics Test', *Neurocase* 5: 475–83.

Baron-Cohen, S., Wheelwright, S., Stott, C., Bolton, P. and Goodyer, I. (1997b) 'Is There a Link between Engineering and Autism?', *Autism* 1: 101–8.

Benbow, C. P. (1988) 'Sex Differences in Mathematical Reasoning Ability in Intellectually Talented Preadolescents: Their Nature, Effects, and Possible Causes', *Behavioral and Brain Sciences* 11: 169–232.

Blair, R. J. (1995) 'A Cognitive Developmental Approach to Morality: Investigating the Psychopath', *Cognition* 57: 1–29.

Charlesworth, W. R. and Dzur, C. (1987) 'Gender Comparisons of Preschoolers' Behavior and Resource Utilization in Group Problem Solving', *Child Development* 58: 191–200.

Collins, D. W. and Kimura, D. (1997) 'A Large Sex Difference on a Two-Dimensional Mental Rotation Task', *Behavioral Neuroscience* 111: 845–9.

Connellan, J., Baron-Cohen, S., Wheelwright, S., Batki, A. and Ahluwalia, J. (2000) 'Sex Differences in Human Neonatal Social Perception', *Infant Behavior and Development* 23: 113–18.

Crick, N. R. and Grotpeter, J. K. (1995) 'Relational Aggression, Gender, and Social-Psychological Adjustment', *Child Development* 66: 710–22.

Daly, M. and Wilson, M. (1988) *Homicide* (New York: Aldine de Gruyter).

Davis, M. H. (1994) *Empathy: A Social Psychological Approach*, ed. J. Harvey. Brown and Benchmark Social Psychology Series (Boulder, CO: Westview Press).

Dodge, K. A. (1980) 'Social Cognition and Children's Aggressive Behavior', *Child Development* 51: 162–70.

Eagly, A. H. (1987) *Sex Differences in Social Behavior: A Social-Role Interpretation* (Hillsdale, NJ: Lawrence Erlbaum Associates).

Elliot, R. (1961) 'Interrelationship among Measures of Field Dependence, Ability, and Personality Traits', *Journal of Abnormal and Social Psychology* 63: 27–36.

Frith, U. (ed.) (1991) *Autism and Asperger Syndrome* (Cambridge: Cambridge University Press).

Galea, L. A. M. and Kimura, D. (1993) 'Sex Differences in Route-Learning', *Personality and Individual Differences* 14: 53–65.

Geary, D. C. (1996) 'Sexual Selection and Sex Differences in Mathematical Abilities', *Behavioral and Brain Sciences* 19: 229–84.

(1998) *Male, Female: The Evolution of Human Sex Differences* (Washington, DC: American Psychological Association).

Gouchie, C. and Kimura, D. (1991) 'The Relationship between Testosterone Levels and Cognitive Ability Patterns', *Psychoneuroendocrinology* 16: 323–34.

Hall, J. A. (1978) 'Gender Effects in Decoding Nonverbal Cues', *Psychological Bulletin* 85: 845–58.

Happe, F. G. (1995) 'The Role of Age and Verbal Ability in the Theory of Mind Task Performance of Subjects with Autism', *Child Development* 66: 843–55.

Hoffman, M. L. (1977) 'Sex Differences in Empathy and Related Behaviors', *Psychological Bulletin* 84: 712–22.

Jennings, K. D. (1977) 'People versus Object Orientation in Preschool Children: Do Sex Differences Really Occur?', *Journal of Genetic Psychology* 131: 65–73.

Jolliffe, T. and Baron-Cohen, S. (1997) 'Are People with Autism or Asperger Syndrome Faster than Normal on the Embedded Figures Test?', *Journal of Child Psychology and Psychiatry and Allied Disciplines* 38: 527–34.

Kimura, D. (1999) *Sex and Cognition* (Cambridge, MA: MIT Press).

Knight, G. P. and Chao, C.- C. (1989) 'Gender Differences in the Cooperative, Competitive, and Individualistic Social Values of Children', *Motivation and Emotion* 13: 125–41.

Lutchmaya, S. and Baron-Cohen, S. (2002) 'Human Sex Differences in Social and Nonsocial Looking Preferences at 12 Months of Age', *Infant Behavior and Development* 25: 319–25.

Lutchmaya, S., Baron-Cohen, S. and Raggatt, P. (2002a) 'Foetal Testosterone and Vocabulary Size in 18- and 24-Month-Old Infants', *Infant Behavior and Development* 24: 418–24.

(2002b) 'Foetal Testosterone and Eye Contact in 12 Month-Old Infants', *Infant Behavior and Development* 25: 327–35.

Maccoby, E. E. (1998) *The Two Sexes: Growing Up Apart, Coming Together* (Cambridge, MA: Belknap Press/Harvard University Press).

Manning, J. T., Baron-Cohen, S., Wheelwright, S. and Sanders, G. (2001) 'The 2nd to 4th Digit Ratio and Autism', *Developmental Medicine and Child Neurology* 43: 160–4.

Morton, J., Leslie, A. and Frith, U. (1995) 'The Cognitive Basis of a Biological Disorder: Autism', *New Scientist* 14: 434–8.

O'Riordan, M., Plaisted, K. C., Driver, J. and Baron-Cohen, S. (2001) 'Superior Visual Search in Autism', *Journal of Experimental Psychology: Human Perception and Performance* 27: 719–30.

Power, T. G. (1985) 'Mother– and Father–Infant Play: a Developmental Analysis', *Child Development* 56: 1514–24.

Schiff, W. and Oldak, R. (1990) 'Accuracy of Judging Time to Arrival: Effects of Modality, Trajectory, and Gender', *Journal of Experimental Psychology: Human Perception and Performance* 16: 303–16.

Smith, P. M. (1985) *Language, the Sexes, and Society* (Oxford: Blackwell Publishers).

Strayer, F. F. (1980) 'Child Ethology and the Study of Preschool Social Relations', in H. C. Foot, A. J. Chapman and J. R. Smith (eds.), *Friendship and Social Relations in Children* (Chichester: John Wiley & Sons), 235–65.

Swettenham, J., Baron-Cohen, S., Charman, T., et al. (1998) 'The Frequency and Distribution of Spontaneous Attention Shifts between Social and

Nonsocial Stimuli in Autistic, Typically Developing, and Nonautistic Developmentally Delayed Infants', *Journal of Child Psychology and Psychiatry and Allied Disciplines* 39: 747–53.

Tannen, D. (1990) *You Just Don't Understand: Women and Men in Conversation* (New York: William Morrow & Company).

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

Tordjman, S., Ferrari, P., Sulmont, V., Duyme, M. and Roubertoux, P. (1997) 'Androgenic Activity in Autism', *American Journal of Psychiatry* 154: 1626–7.

Voyer, D., Voyer, S. and Bryden, M. (1995) 'Magnitude of Sex Differences in Spatial Abilities: A Meta-analysis and Consideration of Critical Variables', *Psychological Bulletin* 117: 250–70.

Witkin, H. A., Lewis, H. B., Hertzman, M., Machover, K., Bretnall Meissner, P. and Wapner, S. (1954) *Personality Through Perception* (New York: Harper & Brothers).

Wittig, M. A., Allen, M. J. (1984) 'Measurement of Adult Performance on Piaget's Water Horizontality Task', *Intelligence* 8: 305–13.