The extreme male brain theory of autism

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The key mental domains in which sex differences have traditionally been studied are verbal and spatial abilities. In this article I suggest that two neglected dimensions for understanding human sex differences are 'empathising' and 'systemising'. The male brain is a defined psychometrically as those individuals in whom systemising is significantly better than empathising, and the female brain is defined as the opposite cognitive profile. Using these definitions, autism can be considered as an extreme of the normal male profile. There is increasing psychological evidence for the extreme male brain theory of autism.

'Empathising' is the drive to identify another person's emotions and thoughts, and to respond to these with an appropriate emotion. Empathising allows you to predict a person's behaviour, and to care about how others feel. In this article, I review evidence that on average, females spontaneously empathise to a greater degree than do males. 'Systemising' is the drive to analyse the variables in a system, to derive the underlying rules that govern the behaviour of a system. Systemising also refers to the drive to construct systems. Systemising allows you to predict the behaviour of a *system*, and to control it. I review evidence that, on average, males spontaneously systemise to a greater degree than do females [1].

Empathising is close enough to the usual English meaning of 'empathise' to need little introduction (although I will come back to it shortly). But systemising is a new concept, and needs a little more definition. By a 'system', I mean anything that takes inputs and deliver outputs. When you systemise, you use 'if–then' (correlation) rules. The brain focuses in on a detail or parameter of the system, and observes how this varies. That is, it treats a feature as a variable. Or a person actively manipulates this variable (hence the English word, systematically). They note the effect(s) of this one input elsewhere
in the system (i.e. the output). 'If I do *x*, then *y* happens'. Systemising therefore needs an exact eye for detail.

There are at least six kinds of system that the human brain can analyse or construct:

(1) Technical systems: a computer, a musical instrument, a hammer, etc.

(2) Natural systems: a tide, a weather front, a plant, etc.

(3) Abstract systems: mathematics, a computer program, syntax, etc.

(4) Social systems: a political election, a legal system, a business, etc.

(5) Organisable systems: a taxonomy, a collection, a library, etc.

(6) Motoric systems: a sports technique, a performance, a technique for playing a musical instrument, etc.

Systemising is an inductive process. You watch what happens each time, gathering data about an event from repeated sampling, often quantifying differences in some variables within the event and their correlation with variation in outcome. After confirming a reliable pattern of association – generating predictable results – you form a rule about how this aspect of the system works. When an exception occurs, the rule is refined or revised; otherwise, the rule is retained.

Systemising works for phenomena that are indeed ultimately lawful, finite and deterministic. The explanation is exact and its truth-value is defeasible. (e.g. '*The light went on because switch A was in the down position*'). Systemising is of almost no use, however, when it comes to predicting moment-by-moment changes in a person's behaviour. To predict human behaviour, empathising is required. Systemising and empathising are entirely different kinds of processes.

Empathising involves the attribution of mental states to others, and an appropriate affective response to the other's affective state. It covers not only what is sometimes called 'theory of mind' or mentalising [2] but also what is implied by the English words 'empathy' and 'sympathy'. Although systemising and empathising are in one way similar – they are both processes that allow us to make sense of events and make reliable predictions – they are in other respects almost the opposite of each other. Empathising involves an imaginative leap in the dark, in the absence of much data (thoughts like '*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 might never be provable. Systemising is our most powerful way of understanding and predicting the law-governed inanimate universe. Empathising is our most powerful way of understanding and predicting the social world. And ultimately, empathising and systemising are likely to depend on independent regions in the human brain.

The main brain types

I will be arguing that systemising and empathising are two key dimensions in defining the male and female brain. We all have both systemising and empathising skills. One can immediately envisage five broad brain types (see also Fig. 1):

(1) Individuals in whom empathising is more developed than systemising. For shorthand, E > S (or Type E). This is what we will call the 'female brain'.

(2) Individuals in whom systemising is more developed than empathising. For shorthand, S > E (or Type S). This is what we will call the 'male brain'.

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(3) Individuals in whom systemising and empathising are both equally developed. For shorthand, S = E. This is what we will call the 'balanced brain' (or Type B).

(4) Individuals with the extreme of the male brain, for shorthand, S ≫ E. In their case, systemising is hyper-developed whereas empathising is hypo-developed. That is, they might be talented systemisers but at the same time they can be 'mind-blind' [3]. In this article, we look at individuals on the autistic spectrum to see if they fit the profile of being an extreme of the male brain.

(5) Finally, we postulate the existence of the extreme of the female brain. For shorthand, E ≫ S. These people would have hyper-developed empathising skills, but their systemising would be hypo-developed: they are 'system-blind'.

The evidence reviewed below suggests that not all men have the male brain type, and not all women have the female brain type. Expressed differently, some women have the male brain type, and some men have the female brain type, or aspects of it. The central claim of this article is only that *more* males than females have a brain of Type S, and *more* females than males have a brain of Type E. Box 1 highlights the role of culture and biology in these sex differences.

The female brain: empathising

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

(1) *Sharing and turn-taking*. On average, girls show more concern for fairness, whereas boys share less. In one study, boys showed fifty times more competition, whilst girls showed twenty times more turn-taking [4].

(2) *Rough and tumble play or 'rough housing'*. Boys show more 'rough housing' (wrestling, mock fighting, etc) than girls do. Although there is a playful component, it can hurt or be intrusive, so it needs lower empathising to carry it out [5].

(3) *Responding empathically to the distress of other people.* Girls from 1 year old show greater concern through more sad looks, sympathetic vocalizations and comforting. More women than men also report frequently sharing the emotional distress of their friends. Women also show more comforting, even of strangers, than men do [6].

(4) *Using a 'theory of mind'*. By 3 years of age, little girls are already ahead of boys in their ability to infer what people might be thinking or intending [7].

(5) *Sensitivity to facial expressions*. 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 [8].

(6) *Questionnaires measuring empathy*. Many of these find that women score higher than men [9].
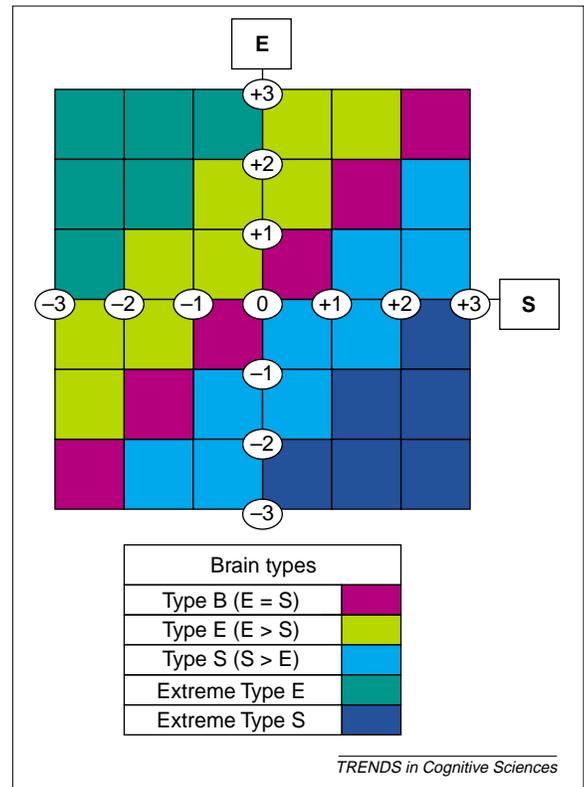
Fig. 1. The main brain types illustrated on axes of empathising (E) and systemising (S) dimensions (numbers are standard deviations from the mean). Balanced brain (Type B, purple zone); female brain (Type E, light green zone), male brain (Type S, light blue zone); the extreme Types E and S lie at the outer borders. According to the 'extreme male brain' theory of autism, people with autism or AS should always fall in the dark blue zone. Modified from Baron-Cohen *et al.* (Ref. [1]).

(7) *Values in relationships*. More women value the development of altruistic, reciprocal relationships, which by definition require empathising. In contrast, more men value power, politics, and competition [10]. 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. Boys are more likely than girls to endorse competitive items and to rate social status as more important than intimacy [11].

(8) *Disorders of empathy*. Disorders such as psychopathic personality disorder and conduct disorder are far more common among males [12,13].

(9) *Aggression*. Even expressed at normal levels, aggression can only occur with reduced empathising. Here again, there is a clear sex difference. Males tend to show far more 'direct' aggression (pushing, hitting, punching, etc.) whereas females tend to show more 'indirect' (or 'relational', covert) aggression (gossip, exclusion, bitchy remarks, etc.). Direct aggression might require an even lower level of empathy than indirect aggression. And indirect aggression needs better mindreading skills than does direct aggression, because its impact is strategic [14].

(10) *Murder*. This is the ultimate example of lack of empathy. Daly and Wilson analysed homicide records dating back over 700 years, from a range of different

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Box 1. Culture and biology

At one year old, boys show a stronger preference to watch a video of cars going past (predictable mechanical systems), than to watch a film showing a human face. Little girls showed the opposite preference. Little girls also show more eye contact that boys do by one year of age [a]. Some argue that even by this age, socialization might have caused these sex differences. Although there is evidence for differential socialization contributing to sex differences, this is unlikely to be a sufficient explanation, as it has been shown that, even among one-day-old babies, boys look longer at a mechanical mobile (a system with predictable laws of motion) than at a person's face (an object that is next to impossible to systemise), whereas girls show the opposite profile [b]. These sex differences are therefore present very early in life. This raises the possibility that, whereas culture and socialisation might partly determine if you develop a male brain (stronger interest in systems) or female brain (stronger interest in empathy), biology might also partly determine this. There is ample evidence for both cultural determinism and biological determinism [c,d]. For example, the amount of eye contact children make at 1-yr old is inversely related to their level of *prenatal* testosterone [e].

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societies [15]. They found that 'male-on-male' homicide was 30–40 times more frequent than 'female-on-female' homicide.

(11) *Establishing a 'dominance hierarchy'.* Males are quicker to establish hierachies of dominance. This partly reflects their lower empathising skills, because often a hierarchy is established by one person pushing others around, to become the leader [16].

(12) *Language style.* Girls' speech is more cooperative, reciprocal and collaborative. In concrete terms, this is also reflected in girls being able to keep a conversational exchange with a partner going for longer. 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' (the speaker presents their own perspective alone). The female speech style is more 'double voiced discourse' (girls spend more time negotiating with the other person, trying to take the other person's wishes into account) [17].

(13) *Talk about emotions.* Women's conversation involves much more talk about feelings, whereas men's conversation with each other tends to be more object- or activity-focused [18].

(14) *Parenting style.* Fathers are less likely than mothers to hold their infant in a face-to-face position. Mothers are more likely to follow through the child's choice of topic in play, whereas fathers are more likely to impose their own topic. And mothers fine-tune their speech more often to match what the child can understand [19].

(15) *Face preference and eye contact.* From birth, females look longer at faces, and particularly at people's eyes, and males are more likely to look at inanimate objects [20].

(16) Females have also been shown to have better language ability in general than males. It seems likely that good empathising would promote language development [21] and vice versa, so these might not be independent.

The male brain: systemising

The relevant domains in which to look for evidence include any that are in principle rule-governed. Thus, chess and football are good examples of systems; faces and conversations are not. Systemising involves monitoring three things in order: input–operation–output. The operation is what you did to the input, or what happened to the input, to produce the output.

(1) *Toy preferences.* Boys are more interested than girls in toy vehicles, weapons, building blocks and mechanical toys, all of which are open to being 'systemised' [22].

(2) *Adult occupational choices.* Some occupations are almost entirely male. These include metalworking, weapon making, manufacturing of musical instruments, or the construction industries, such as boat building. The focus of these occupations is on constructing systems [23].

(3) *Maths, physics, and engineering.* These all require high systemising, and are largely male-dominated disciplines. The Scholastic Aptitude Math Test (SAT-M) is 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 [24]. Taking only those people scoring above 700, the sex ratio is 13:1 (men to women) [25].

(4) *Constructional abilities.* If you ask people to put together a 3-D mechanical apparatus in an assembly task, on average men score higher. Boys are also better at constructing block buildings from 2-D blueprints. Lego bricks can be combined and recombined into an infinite number of systems. Boys show more interest in playing with Lego. Boys as young as 3 yrs are also faster at copying 3-D models of outsized Lego pieces, and older boys, from the age of 9, are better at imagining what a 3-D object will look like if it is laid out flat. They are also better at constructing a 3-D structure from just an aerial and frontal view in a picture [26].

(5) *The Water-Level task.* Originally devised by Swiss child psychologist Jean Piaget, this task is to show someone an empty bottle, tipped at an angle, and then ask them to show the water level when it is, say, half full. Women more often draw the water level aligned with the tilt of the bottle, and not horizontal, as it should be [27].

(6) *The Rod and Frame test.* If a person's judgement of vertical is influenced by the tilt of the frame, they are said to be 'field dependent': 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 show that females are more field dependent – that is, women are relatively more distracted by contextual cues, rather than considering each variable within the system separately. They are more likely than men to say (erroneously) that the rod is upright if it is aligned with its frame [28].

(7) *Good attention to relevant detail.* This is a general feature of systemizing. It is not the only factor, but it is a necessary part of it. Attention to relevant detail is superior in males. A measure of this is the Embedded Figures Task: on average, males are quicker and more accurate in locating the target embedded within the larger, complex pattern [29]. Males, on average, are also better at detecting a particular feature (static or moving) [30].

(8) *The Mental Rotation test.* Here again, males are quicker and more accurate. This test involves systemising because you have to treat each feature in a display as a variable that can be transformed (e.g. rotated) and predict how it will appear (the 'output') [31].

(9) *Map reading.* Reading maps is another everyday test of systemising, because it is necessary to take features from 3-D input and predict how they will appear when represented in 2-D. Boys perform at a higher level than girls. Men can also learn a route in fewer trials, just from looking at a map, correctly recalling more details about direction and distance. This suggests they are treating features in the map as variables that can be transformed into 3-D. If you ask school children to make a map of an area that they have visited only once, boys' maps have a more accurate layout of the features in the environment than girls' maps. More of the girls' maps make serious errors in the location of important landmarks. The boys tend to emphasise routes or roads, whereas the girls tend to emphasise specific landmarks (the corner shop, etc.). These two strategies – using directional cues versus landmark cues – have been widely studied (for example, [32]). The directional strategy is an instance of taking understanding space as a geometric system and the focus on roads or routes is an instance of considering space in terms of another system, in this case a transport system.

(10) *Motoric systems.* If you ask people to throw or catch moving objects (target directed tasks) such as playing darts or intercepting balls flung from a launcher, males tend to be better. Equally, if you ask men to judge which of two moving objects is travelling faster, men are on average more accurate [33].

(11) *Organisable systems.* People in the Aguaruna tribe (northern Peru) were asked to classify a hundred or more examples of local specimens together into related species [34]. Men's classification systems had more sub-categories (i.e. they introduced greater differentiation) and more consistency between each other than those of the women. 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 [34]. Classification and organisation involves systemising because categories are predictive. The more fine-grained the categories, the better the system of prediction will be.

(12) *The Systemising Quotient.* This questionnaire has been tested among adults in the general population. It has 40 items asking about the 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 (S. Baron-Cohen and J. Reichler, unpublished data).

(13) *Mechanics.* The Physical Prediction Questionnaire (PPQ) is based on an established method for selecting applicants for engineering. The task involves predicting which direction levers will move when an internal mechanism (of cog wheels and pulleys) of one type or another is involved. Men score significantly higher on this test than women (J. Lawson *et al.*, unpublished data).

Autism: an extreme form of the male brain

Autism is diagnosed when a person shows abnormalities in social development, communication, and displays unusually strong obsessional interests, from an early age [35]. Asperger Syndrome (AS) has been proposed as a variant of autism, in children with normal or high IQ, who develop speech on time. Today, approximately 1 in 200 children have one of the 'autistic spectrum conditions', which include AS [36]. Autism spectrum conditions affect males far more often than females. In people with high-functioning autism or AS, the sex ratio is at least 10 males to every female. These conditions are also strongly heritable [37] and neurodevelopmental. There is evidence of structural and functional differences in regions of the brain (such as the amygdala being abnormal in size, and this structure not responding to cues of emotional expression) [38].

The extreme male brain theory of autism was first informally suggested by Hans Asperger in 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' [39] (Uta Frith's translation). In 1997 this controversial hypothesis was re-examined [40]. We can test the extreme male brain theory empirically, now that we have definitions of the brain types.

Evidence for the extreme male brain theory

Initial tests of this theory are proving positive [41,42]. Some of the convergent lines of evidence are summarised here.

Impaired empathising

Mindreading. Girls are better than boys on standard 'theory of mind' tests, and children with autism or AS are even worse than normal boys [7]. They have specific delays and difficulties in the development of 'mindreading' (i.e. in making sense of and predicting another's feelings, thoughts and behaviour). Autism has been referred to as a condition of 'mindblindness' [3].

The Empathy Quotient (EQ). On this questionnaire, females score higher than males, and people with AS or high-functioning autism score even lower than males (S. Baron-Cohen and S. Wheelwright, unpublished data).

The 'Reading the Mind in the Eyes' test. In this test of discriminating emotions from expressions in the eyes, females score higher than males, but people with AS score even lower than males [43].

The Complex Facial Expressions test. Females score higher than males, but people with AS score even lower than males [44].

Eye contact. Females make more eye contact than do males, and people with autism or AS make less eye contact than males [45,46].

Language development. Girls develop vocabulary faster than boys, and children with autism are even slower than males to develop vocabulary [47].

Pragmatics. Females tend to be superior to males in terms of chatting and the pragmatics of conversation, and it is precisely this aspect of language which people with AS find most difficult [48].

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 do [49].

The Friendship Questionnaire (FQ). This assesses empathic styles of relationships. Women score higher on the FQ than males, and adults with AS score even lower than normal males (S. Baron-Cohen and S. Wheelwright, unpublished data).

Superior systemising

Islets of ability. Some people with autism spectrum disorders have 'islets of ability', or special abilities to a high degree, in mathematical calculation, calendrical calculation, syntax acquisition, music, or memory for railway timetable information [50]. In the high-functioning cases this can lead to considerable achievement in mathematics, chess, mechanical knowledge, and other factual, scientific, technical or rule-based subjects. All of these are highly systemisable domains. Most of them are also domains where males in the general population have a greater natural interest.

Attention to detail. Autism also leads to extra fine attention to detail. For example, on the Embedded Figures Task (EFT) males score higher than females, and people with AS or high-functioning autism score even higher than males. The EFT is not a systemising test *per se*, but it is a measure of detailed local perception, which is a prerequisite for systemising [51]. On visual search tasks, males have better attention to detail than do females, and people with autism or AS have even faster, more accurate visual search [52].

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.

Tests of intuitive physics. Males score higher than females on such tests, and people with AS score higher than males [53].

Toy preference. Boys like constructional and vehicle toys more than girls do, and clinical reports suggest that children with autism or AS have this as a very strong toy preference.

Collecting. Boys engage in more collecting or organising of items than girls do, and the diagnosis of autism identifies this to an even greater extent.

Obsessions with closed systems. Most individuals with autism are naturally drawn to predictable things, such as computers. Unlike people, computers follow strict laws, and are closed systems – all the variables are well-defined within the system, are knowable, predictable and, in principle, controllable. Other individuals with autism might not make computers their target of understanding, but latch on to different, equally closed, systems such as bird-migration or train spotting [54].

The Systemising Quotient. Males score higher on this questionnaire, and people with autism and AS score even higher than normal males (S. Baron-Cohen and J. Reichler, unpublished data).

Biological and familial evidence

The Autism Spectrum Quotient (AQ). Males in the general population score higher on the AQ than do females, and people with AS or high-functioning autism score highest of all [55].

Sexually dimorphic somatic markers. On measures of finger-length ratio, males tend to have a longer ring finger than their second finger, and people with autism or AS show this trait in a magnified form [56].

Early puberty. Males with autism have been reported to show precocious puberty, correlating with increased levels of testosterone [57].

Familiality of talent. Fathers and grandfathers (on both sides of the family) of autistic individuals are over-represented in occupations such as engineering, which require good systemising but in which a mild impairment in empathising (as has also been documented) would not necessarily be an impediment to success [58]. There is a higher rate of autism in the families of those talented in fields such as maths, physics and engineering, as compared with those talented in the humanities [59]. These two findings suggest that the extreme male cognitive style is in part inherited.

A key symptom explained

Phenomena that are unpredictable and less controllable (like people) leave individuals with autism either anxious or disinterested. Phenomena that are more predictable are highly attractive to them. When they are confronted with the unpredictable social world, they react by trying to impose predictability and 'sameness', trying to control people through tantrums and insistence on repetition. People with autism and AS have their greatest difficulties in the playground, in friendship, in intimate relationships, and at work, where the situation is unstructured, unpredictable, and where social sensitivity is needed. The more able individuals report that they struggle to work out a huge set of rules of how to behave in each and every situation, attempting to develop a mental 'manual' for social interaction of 'if–then' rules. It is as though they are trying to systemise social behaviour when the natural approach to socialising should be via empathising [60].

Central coherence versus systemising

A rival theory of the non-social cognitive anomalies observed in autism is that individuals with autism suffer from 'weak central coherence' [61]. The systemising account suggests a different view: that people with autism or AS start their cognitive processing by focussing in on the most local details, as an attempted search for whether these might be 'variables' in a systemisable domain. This focus on local processing might appear to arise from a deficit in global processing, but from the perspective of systemising, local detail is simply the best (possibly the only) place to start.

Moreover, if one is ever to 'crack' a system, it is best to over-attend to a small part of the system, and isolate and understand the laws governing a small number of relevant variables, before moving onto the next part of the system. This might appear as a narrow, obsessive preoccupation with the details of a highly specific phenomenon (e.g. spinning the wheels on a toy car). The weak central coherence hypothesis argues that the autistic failure to use linguistic context is evidence for the theory. However, linguistic context is like human speech – full of meaning that depends on recognizing the author's intentions (which requires empathising), rather than deriving from a set of predictable rules. The autistic 'failure' to use linguistic context might instead result from a narrow focus on local details, as the person with autism automatically tries to systemise.

How might these two theories be tested against each other? First, weak central coherence theory would predict that people with autism or AS would never come to understand a whole system. A whole system is made up not only of local, proximate rules ('A causes B', where A and B are adjacent components) but also of distant rules ('B causes Z', where Z is distal). Furthermore, a system is made up not only of local elements (e.g. musical notes) but also of relationships between those elements (such as intervals between notes). Studies of autistic 'savants' show that there is often a good implicit understanding of the rules of the system (be it maths, music, drawing, syntax, calendars) and of *relational* patterns within the system [62].

This is exactly what systemising theory predicts, but is not predicted by weak central coherence theory. Among the topics of fascination or even obsession in people with Asperger Syndrome, for example, are woodwork, where the design of the product is understood both at a global level (as a 'system') and in terms of the mechanics of local details in the system. Weak central coherence would not predict such competence in understanding the system as a whole. Similarly, the fact that many people with AS become fascinated with code-breaking is an example that would be predicted by the systemising theory, but not necessarily by the weak central coherence theory.

Conclusions and future research

The evidence presented in this article suggests that the male brain is characterised by Type S (where $S > E$), the female brain by Type E (where $E > S$), and that the autistic brain is an extreme of the male brain ($S \gg E$). Referring back to Fig. 1, development of an autism spectrum condition means their brain type has shifted towards the lower right-hand quadrant. For males, it is a small shift, from Type S to extreme Type S. For females, the shift is bigger, from Type E to extreme Type S. What causes this shift remains unclear, but candidate factors include both genetic differences and prenatal testosterone [37,47].

All we know about the extreme female brain is that, from the model in Fig. 1, it is predicted to arise. What would such people look like? They are defined as falling in the upper left-hand quadrant of the graph. Their empathising would be significantly better than other people in the general population, but their systemising would be impaired. These would be people who have difficulty understanding maths or physics or machines or chemistry as systems, but who are extremely good at tuning in to others' feelings and thoughts. Would such a profile carry with it any necessary disability? The person with the extreme female brain would be 'system-blind'. In our society, there is considerable tolerance for such individuals. It is hoped that people who are 'mind-blind' through the facts of their biology will also enjoy the same tolerance by society.

We know something about the neural circuitry of empathising [63], but at present we know very little about the neural circuitry of systemising. It is hoped that research will soon begin to reveal the key brain regions involved in this aspect of cognition.

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