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The Empathizing System: a revision of the 1994 model of the Mindreading System.

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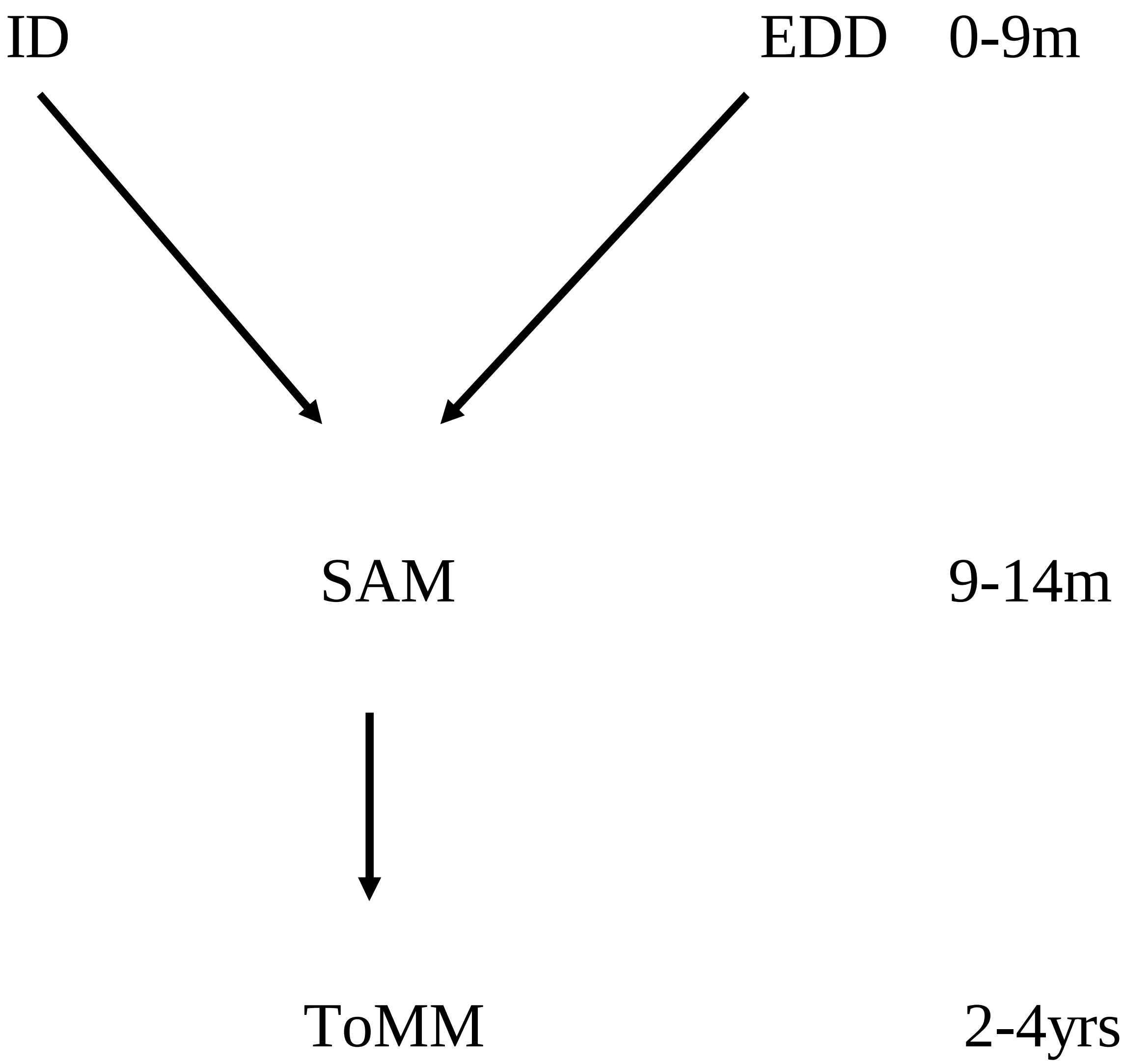
Origins of the Social Mind as a book title is very broad, and in my chapter I focus specifically on ‘empathizing’. This is defined as the drive to identify another person’s emotions and thoughts, and to respond to these with an appropriate emotion. The chapter has three main aims: First, to challenge my own earlier model of development (Baron-Cohen, 1994). Second, to consider the evidence for sex differences in empathizing. And finally, to outline the relevance of these first two aims for our understanding of the neuro-developmental condition of autism.

A neurocognitive developmental model: a ten year revision

The Mindreading System

My 1994 model attempted to specify the neurocognitive mechanisms that comprise the ‘mindreading system’ (Baron-Cohen, 1994, 1995). Mindreading is defined as the ability to interpret one’s own or another agent’s actions as driven by mental states. The model was proposed in order to explain (a) ontogenesis of a theory of mind, and (b) neurocognitive dissociations that are seen in children with or without autism. The model is shown in Figure 1 and contains four components: ID, or the Intentionality Detector. EDD, or the Eye Direction Detector. SAM, or the Shared Attention Mechanism. And finally ToMM, or the Theory of Mind Mechanism. Full details of these are given in the earlier publications, but here I briefly recap of the functions and justifications of these.

Figure 1: Baron-Cohen's (1994) model of mindreading



Key: IDD = Intentionality Detector
EDD = Eye Direction Detector
SAM = Shared Attention Mechanism
ToMM = Theory of Mind Mechanism

ID and EDD build ‘dyadic’ representations of simple mental states. ID automatically interprets or represents an agent’s self-propelled movement as a desire or goal-directed movement, a sign of its agency, or an entity with volition (Premack, 1990). For example, ID interprets an animate-like moving shape as “it wants x”, or “it has goal y”. EDD automatically interprets or represents eye-like stimuli as “looking at me” or “looking at something else”. That is, EDD picks out that an entity with eyes can perceive. Both ID and EDD are developmentally prior to the other two mechanisms, and are active early in infancy.

SAM is developmentally more advanced and comes on line at the end of the first year of life. SAM automatically interprets or represents if the self and another agent are (or are not) perceiving the *same* event. SAM does this by building ‘triadic’ representations. For example, where ID can build the dyadic representation ‘Mother *wants* the cup’ and where EDD can build the dyadic representation ‘Mother *sees* the cup’, SAM can build the triadic representation ‘Mother *sees that I see* the cup’. As is apparent, triadic representations involve embedding or recursion. (A dyadic representation (“I see a cup”) is embedded within another dyadic representation (“Mum sees the cup”) to produce this triadic representation). SAM takes its input from ID and EDD, and triadic representations are made out of dyadic representations. SAM typically functions from 9-14 months of age, and allows ‘joint attention’ behaviours such as protodeclarative pointing and gaze monitoring (Scaife & Bruner, 1975).

ToMM is the jewel in the crown of the 1994 model of the mindreading system. It allows an *epistemic* mental states to be represented (e.g., ‘Mother ***thinks*** this cup contains water’ or ‘Mother ***pretends*** this cup contains water’), and it integrates the full set of mental state concepts (including emotions) into a theory. ToMM develops between 2 and 4 years of age, and allows pretend play (Leslie, 1987), understanding of false belief (Wimmer & Perner, 1983), and understanding of the relationships between mental states (Wellman, 1990). An example of the latter is the seeing-leads-to-knowing principle (Pratt & Bryant, 1990), where the typical 3 year old can infer that if someone has *seen* an event, then they will *know* about it.

The model shows the ontogenesis if a theory of mind in the first four years of life, and justifies the existence of four components on the basis of developmental competence and neuropsychological dissociation. In terms of developmental competence, joint attention does not appear possible until 9-14 months of age, and joint attention appears to be a necessary but not sufficient condition for understanding epistemic mental states (Baron-Cohen, 1991; Baron-Cohen & Swettenham, 1996). There appears to be a developmental lag between acquiring SAM and ToMM, suggesting that these two mechanisms are dissociable. In terms of neuropsychological dissociation, congenitally blind children can ultimately develop joint (auditory or tactile) attention, using the amodal ID rather than the visual EDD route. Children with autism appear able to represent the dyadic mental states of seeing and wanting, but show delays in shared attention (Baron-Cohen, 1989b) and in understanding false belief (Baron-Cohen, 1989a; Baron-Cohen, Leslie, & Frith, 1985) –

that is, in acquiring SAM and ultimately ToMM. It is this specific developmental delay that suggests that SAM is dissociable from EDD.

One reason for evolutionary psychology's interest in the mindreading model is the central role that theory of mind, and social cognition in general, have been proposed to play in human evolution. A number of theorists, beginning with Humphrey (Humphrey, 1976), have proposed that the most potent selection pressure for the rapid evolution of complex cognition and representational thought in the line that lead to *Homo sapiens* was having to cooperate and compete with conspecifics e.g., (Alexander, 1979; Dunbar, 1998; Geary, in press); see Bjorklund & Rosenberg, this volume. Social cognition in all modern human groups has its basis in understanding that one's actions and the actions of others are based on what one knows, or believes, and what one wants, or desires, what (Wellman & Woolley, 1990) referred to as *belief-desire reasoning*. Even apparently more advanced forms of social cognition, such as detecting cheaters or negotiating contracts, have as their basis the folk psychology reflected in belief-desire reasoning.

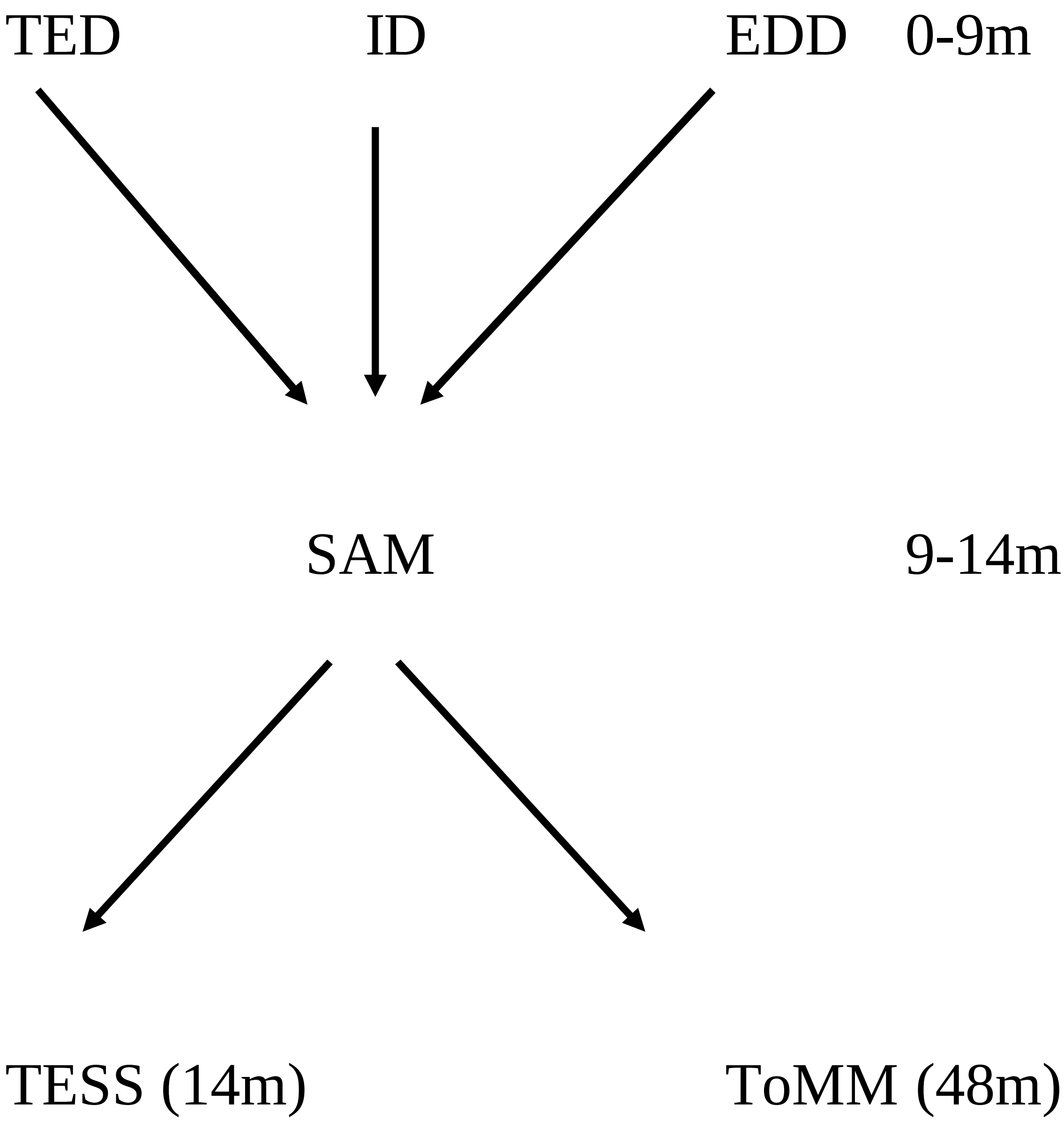
The 1994 mind-reading model provided specific mechanisms for the development of such belief-desire reasoning, and also provided a model for how theory of mind may have evolved. Consistent with the perspective of evolutionary psychology (Tooby & Cosmides, 1992), the 1994 model postulated domain-specific modules, the product of natural selection that deal with specific problems faced by our ancestors. Some of these modules (ID and EDD for example) are likely to be shared by many species of animal with brains, whereas others are likely to be unique to humans (SAM and TOMM, for instance).

Importantly, hypotheses about the evolution of these modular abilities can be evaluated empirically by assessing the skills associated with these different mechanisms in extant species. Although findings from the primate literature are often controversial (Povinelli & Bering, 2002; Suddendorf & Whiten, 2001), there is little evidence that human's closest living relative, chimpanzees (*Pan troglodytes*), can pass false-belief tasks, and thus seem not to possess the TOMM module (Bjorklund & Pellegrini, 2002; Call & Tomasello, 1999; Tomasello & Call, 1997). Mother-raised chimpanzees also seem not to engage in shared-joint attention, suggesting they do not possess (or do not use) the SAM module. And there is even debate about whether chimpanzees possess the EDD module. For example, Povinelli and his colleagues (Povinelli & Eddy, 1996; Reaux, Theall, & Povinelli, 1999) reported that chimpanzees were just as likely to make food requests of a human caretaker whose eyes were obstructed (e.g., by wearing a blindfold, by having a bucket over her head) as a sighted caretaker, indicating that they are not aware that "eyes possess knowledge." Other research, however, in a food-competition paradigm with a conspecific, reached the opposite conclusion (Hare, Call, Agentta, & Tomasello, 2000; Hare, Call, & Tomasello, 2001). Although it seems clear that chimpanzees posses substantial social-cognitive abilities, as reflected, for instance, in their transmission of "culture" from one generation to the next (Whiten et al., 1999), they seem not to have fully developed the more advanced components of the mindreading system, TOMM, SAM, , suggesting that these are late-evolving mechanisms, fully developed only in *Homo sapiens* (or perhaps in earlier members of the *Homo* line).

The Empathizing System

Ten years on, the 1994 model of the Mindreading System is still broadly able to explain the pattern of developmental and clinical data, as outlined above. However, to my mind, it is in need of minor but important revision because of certain omissions and too narrow a focus. The key omission is that information about ***affective*** states, available to the infant perceptual system, has no dedicated neurocognitive mechanism. In Figure 2, the revised model is shown and now includes a new fifth component: TED, or The Emotion Detector. But the concept of mindreading (or theory of mind) itself I find too narrow, in that it makes no reference to the affective state in the observer ***triggered by*** recognition of another's mental state. This is a particular problem for any account of the distinction between autism and psychopathy. For this reason, the model is no longer of 'mindreading' but is of 'empathizing', and the revised model also includes a new sixth component, TESS, or The Empathizing SyStem. (TESS is spelt as it is to playfully populate the Mindreading Model with apparently anthropomorphic components.) Where the 1994 Mindreading System was a model of a passive ***observer*** (because all the components had simple decoding functions), the 2004 Empathizing System is a model of an observer impelled towards ***action*** (because an emotion is triggered in the observer which typically motivates the observer to ***respond*** to the other person). Both of these new additions are elaborated and justified further below.

Figure 2: Baron-Cohen's (2004) model of empathizing



Key: As in Figure 1, but:

TED = The Emotion Detector; and

TESS = The Empathising SyStem

Like the other infancy perceptual input mechanisms of ID and EDD, the new component of TED can build dyadic representations of a special kind, namely, it can represent *affective* states. An example would be 'Mother - is *unhappy*', or even 'Mother - is *angry* - with me'. Formally, we can describe this as **Agent-affective state-proposition**. We know that infants can represent affective states from as early as 3 months of age (Walker, 1982). As with ID, TED is amodal, in that affective information can be picked up from facial expression, or vocal intonation, 'motherese' being a particularly rich source of the latter (Field, 1979). Another's affective state is presumably also detectable from their touch (e.g., tense, vs. relaxed), which implies that congenitally blind infants should find affective information accessible through both auditory and tactile modalities. TED allows the detection of the basic emotions (Ekman & Friesen, 1969), though it should be noted that questions have been raised about the use of the term 'basic' in relation to emotion recognition (Baron-Cohen, Wheelwright, Hill, & Golan, submitted).

When SAM becomes available, at 9-14 months of age, it can receive inputs from any of the 3 infancy mechanisms, ID, EDD, or TED. Here, we focus on how a dyadic representation of an affective state can be converted into a triadic representation by SAM. An example would be that the dyadic representation 'Mother is unhappy' can be converted into a triadic representation 'I am unhappy that Mother is unhappy', or 'Mother is unhappy that I am unhappy', etc. Again, as with perceptual or volitional states, SAM's triadic representations of affective states have this special embedded, or recursive property.

TESS in the 2004 model is the real jewel in the crown. This is not to minimize the importance of ToMM, which has been celebrated for the last 20 years in research in developmental psychology (Leslie, 1987; Whiten, 1991; Wimmer, Hogrefe, & Perner, 1988) . ToMM is of major importance in allowing the child to represent the full range of mental states, including epistemic ones (such as false belief), and is important in allowing the child to pull mentalistic knowledge into a useful theory with which to predict behaviour (Baron-Cohen, 1995; Wellman, 1990). But TESS allows more than behavioural explanation and prediction (itself a powerful achievement). TESS allows an empathic reaction to another's emotional state. And relevant to the evolutionary focus of this book, TESS carries with it the adaptive benefit of ensuring that organisms feel a drive to help each other.

To see the difference between TESS and ToMM, consider this example: *I see you are in pain*. Here, ToMM is needed, to interpret your facial expressions and writhing body movements in terms of your underlying mental state (pain). But now consider this further example: *I am devastated - that you are in pain*. Here, TESS is needed, since an appropriate affective state has been triggered in the observer by the emotional state identified in the other person. And where ToMM employs M-Representations (Leslie, 1995) of the form **Agent-attitude-proposition** (e.g., Mother – believes - Johnny – took-the - cookie), TESS employs a new class of representations, which we can all E-Representations of the form **Self-Affective state-[Self-Affective state-proposition]** (e.g 'I feel sorry that – Mom feels sad about – the news in the letter') (Baron-Cohen, 2003).

The critical feature of this E-Representation is that the self's affective state is *appropriate to* and *triggered by* the other person's affective state. Thus, TESS can represent

> *I am horrified - that you are in pain*, or
>
> *I am concerned - that you are in pain*, or
>
> *I want to alleviate- that you are in pain*,

but it cannot represent

> *I am happy – that you are in pain*.

At least, it cannot do so if TESS is functioning normally. One could imagine an abnormality in TESS leading to such inappropriate emotional states being triggered, or one could imagine them arising from other systems (such as a competition system, or a sibling-rivalry system), but these would not be evidence of TESS per se.

Before leaving this revision of the model, it is worth discussing why the need for this has arisen. First, emotional states are an important class of mental states to detect in others, and yet the earlier model focused only on volitional, perceptual, informational, and epistemic states. Secondly, when it comes to pathology, it would appear that in autism TED may function, although this may be delayed (Baron-Cohen, Spitz, & Cross, 1993; Baron-Cohen, Wheelwright, & Jolliffe, 1997; Hobson, 1986), at least in terms of detecting basic emotions. Even high-functioning people with autism or Asperger Syndrome have difficulties both in ToMM (when measured with mental-age appropriate tests) (Baron-Cohen, Joliffe, Mortimore, & Robertson, 1997; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Happe, 1994) and TESS (Attwood, 1997; Baron-Cohen, O'Riordan, Jones, Stone, & Plaisted, 1999; Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003; Baron-Cohen & Wheelwright, in press; Baron-Cohen, Wheelwright, Stone, & Rutherford, 1999). This suggests TED and TESS may be fractionated.

In contrast, the psychiatric condition of psychopathy may entail an intact TED and ToMM, along side an impaired TESS. The psychopath (or sociopath) can represent that *you are in pain*, or that *you believe - that he is the gas-man*, thereby gaining access to your house or your credit card. The psychopath can go on to hurt you or cheat you without having the appropriate affective reaction to your affective state . In other words, he or she doesn't *care* about your affective state (Blair, Jones, Clark, & Smith, 1997; Mealey, 1995). Lack of guilt or shame or compassion in the presence of another's distress are diagnostic of psychopathy (Cleckley, 1977; Hare, Hakstian, Ralph, Forth-Adelle, & al, 1990). Separating TESS and ToMM thus allows a functional distinction to be drawn between the neurocognitive causes of autism and psychopathy.

Developmentally, one can also distinguish TED from TESS. We know that at 3 months of age, infants can discriminate facial and vocal expressions of emotion (Trevarthen, 1989; Walker, 1982) but that it is not until about 14 months that they can respond with appropriate affect (e.g., a facial expression of concern) to another's apparent pain (Yirmiya, Kasari, Sigman, & Mundy, 1990) or show 'social referencing'. Clearly, this account is skeletal in not specifying how many emotions TED is capable of recognizing. Our recent survey of emotions identities that there are 412 discrete emotion concepts that the adult English language user recognizes (Baron-Cohen et al., submitted). How many of these are recognized in the first year of life is not clear. It is also not clear exactly how empathizing changes during the second year of life. We have assumed the same mechanism that enables social referencing at 14 months old also allows sympathy and the growth of empathy across development. This is the most parsimonious model, though it may be that future research will justify further mechanisms that affect the development of empathy.

In the second half of this chapter, we consider the development of empathizing in more detail, particularly focusing on normal sex differences. This is not only relevant to evolutionary theories of sexual dimorphism, but also to the 'extreme male brain' (EMB) theory of autism.

Sex differences in empathizing and systemizing

Empathizing allows you to *predict* a person's behaviour, and to care about how others feel. In this section, I review the evidence that on average, females spontaneously empathize to a greater degree than do males. But I want to broaden the discussion to another psychological process, 'systemizing', because this will help us understand normal sex differences, and autism. Systemizing is the drive to analyse the variables in a system, to derive the underlying rules that govern the behaviour of a system. Systemizing also refers to the drive to construct systems. Systemizing allows you to *predict* the behavior of a system, and to control it. In this section, I also review the evidence that, on average, males spontaneously systemize to a greater degree than do females (Baron-Cohen, Wheelwright, Griffin, Lawson, & Hill, 2002).

Empathizing has already been considered in relation to TESS. 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. When you systemize, you use '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 as a variable. Typically, the person actively manipulates this variable (hence the English word, systematically). The brain notes the effect(s) of operating on this one input in terms of its effects elsewhere in the system (the output). The key data structure or representation used in systemizing has the following form: [input-operation-output]. We can call these S representations. If I do x, a changes to b. If z occurs, p changes to q. Systemizing therefore needs an exact eye for detail.

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

- **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, or syntax)
- **Social** systems (e.g. a political election, a legal system, a business)

- **Organisable** systems (e.g. a taxonomy, a collection, a library)
- **Motoric** systems (e.g. a sports technique, a performance, a musical technique)

Systemizing 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 one exception occurs, the rule is refined or revised. Otherwise, the rule is retained.

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

Although systemizing and empathizing are in one way similar – they are processes that allow us to make sense of events and make predictions – they are in another way almost the opposite of each other. Empathizing involves an imaginative leap in the dark, in the absence of much 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 lawgoverned inanimate universe. Empathizing is our most powerful way of understanding and predicting the social world. Ultimately empathizing and systemizing depend on independent regions in the human brain (Baron-Cohen, Ring et al., 1999; Ring et al., 1999).

The main brain types

I will be arguing that systemizing and empathizing are two key dimensions in defining the male and female brain. We all have both systemizing and empathizing skills. One can envisage five broad types of brain immediately.

- Individuals in whom empathizing is more developed than systemizing. For shorthand, E>S (or Type E). This is what we'll call the female brain.

- Individuals in whom systemizing is more developed than empathizing. For shorthand, S>E (or Type S). This is what we'll call the male brain.

- Individuals in whom systemizing and empathizing are both equally developed. For shorthand, S=E. This is what we'll call the 'balanced brain' (or Type B).

- Individuals with the extreme of the male brain. For shorthand, S>>E. In their case, systemizing is hyper-developed whilst empathizing is hypo-developed. That is, they may be talented systemizers but at the same time they may be 'mind-blind' (Baron-

Cohen, 1995). Later, we look at individuals on the autistic spectrum to see if they fit the profile of being an extreme of the male brain.

- Finally, we postulate the existence of the extreme of the female brain. For shorthand, E>>S. These people have hyper-developed empathizing skills, whilst their systemizing is hypo-developed - they may be 'system-blind'.

The evidence reviewed below 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. 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. The evidence for these profiles is shown below. In the final section, I 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 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, whilst boys share less. In one study, boys showed fifty times more competition, whilst girls showed twenty times more turn-taking (Charlesworth & Dzur, 1987).

(2) *Rough and tumble play or 'rough housing'* (wrestling, mock fighting, etc). Boys show more of this than girls do. Although there's a playful component, it can hurt or be intrusive, so it needs lower empathizing to carry it out (Maccoby, 1999).

(3) *Responding empathically to the distress of other people.* Girls from 1 yr 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 (Hoffman, 1977).

(4) *Using a 'theory of mind'*. By 3 years old, little girls are already ahead of boys in their ability to infer what people might be thinking or intending (Happe, 1995). This sex difference appears in some but not all studies (Charman, Ruffman, & Clements, 2002).

(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 (Hall, 1978).

(6) *Questionnaires measuring empathy*. Many of these find that women score higher than men (Davis, 1994).

(7) *Values in relationships*. More women value the development of altruistic, reciprocal relationships, which by definition require empathizing. In contrast, more men value power, politics, and competition (Ahlgren & Johnson, 1979). Girls are more likely to endorse co-

operative 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 (Knight, Fabes, & Higgins, 1989).

(8) *Disorders of empathy* (such as psychopathic personality disorder, or conduct disorder) are far more common among males (Blair, 1995; Dodge, 1980).

(9) *Aggression*, even in normal quantities, 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.,) whilst females tend to show more ‘indirect’ (or ‘relational’, covert) aggression (gossip, exclusion, bitchy remarks, etc.,). Direct aggression may require an even lower level of empathy than indirect aggression. Indirect aggression needs better mindreading skills than does direct aggression, because its impact is strategic (Crick & Grotpeter, 1995).

(10) *Murder* is the ultimate example of a lack of empathy. Daly and Wilson (Daly & Wilson, 1988) analysed homicide records dating back over 700 years, from a range of different societies. 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 these. This in part may reflect their lower empathizing skills, because often a hierarchy is established by one person pushing others around, to become the leader (Strayer, 1980).

(12) *Language style.* Girls' speech is more co-operative, 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) (Smith, 1985).

(13) *Talk about emotions.* Women's conversation involves much more talk about feelings, whilst men's conversation with each other tends to be more object- or activity-focused (Tannen, 1991).

(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, whilst fathers are more likely to impose their own topic. And mothers fine-tune their speech more often to match what the child can understand (Power, 1985).

(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 (Connellan, Baron-Cohen, Wheelwright, Ba'tki, & Ahluwalia, 2001).

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, & Crowson, 1997) and vice versa, so these may not be independent.

The male brain: systemizing

The relevant domains in which to look for evidence of sex differences in systemizing would include any that are in principle rule-governed. Thus, chess and football are good examples of systems, whilst faces and conversations are not. Systemizing involves monitoring 3 things: Input-operation-output. The operation is what you did to the input, or what happened to the input, to produce the output. What kind of evidence is there?

(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 'systemized' (Jennings, 1977).

(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 (Geary, 1998).

(3) *Maths, physics, and engineering* all require high systemizing, 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 (Benbow & Stanley, 1983). By the time you look at those people scoring above 700, the sex ratio is 13:1 (men to women) (Geary, 1996).

(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 are also faster at copying 3-D models of outsized Lego pieces, and older boys, from age 9, are better at imagining what a 3D object will look like if it is laid out flat. They are also better at constructing a 3D structure from just an aerial and frontal view in a picture (Kimura, 1999).

(5) *The Water Level Task*, originally devised by Swiss child psychologist Jean Piaget, is where you show someone a bottle, tipped at an angle, and then ask them to predict the water level. Women more often draw the water level aligned with the tilt of the bottle, and not horizontal, as it should be (Wittig & Allen, 1984). We can think of this as involving

systemizing because one has to predict the output after performing an operation on the input.

(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 – i.e., 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 (Witkin, Dyk, Faterson, Goodenough, & Karp, 1962).

(7) *Good attention to relevant detail* 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 Test. On average, males are quicker and more accurate in locating the target from the larger, complex pattern (Elliot, 1961). Males, on average, are also better at detecting a particular feature (static or moving) (Voyer, Voyer, & Bryden, 1995).

(8) *The Mental Rotation Test.* Here again, males are quicker and more accurate. This test involves systemizing 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) (Collins & Kimura, 1997).

(9) *Reading maps* is another everyday test of systemizing, because you have to take features from 3D input and predict how it will appear when transformed to 2D. 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 3D. If you ask boys to make a map of an area that they have only visited once, their 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. 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 using landmark cues – have been widely studied. 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 (Galea & Kimura, 1993).

(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, on average men are more accurate (Schiff & Oldak, 1990).

(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. Men's classification systems had more sub-categories (i.e., they introduced greater

differentiation) and more consistency between each other. 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 organisation involves systemizing because categories are predictive. The more fine-grained your categories, the better your system of prediction will be.

(12) *The Systemizing Quotient.* This questionnaire has been tested among adults in the general population. It has 40 items asking about the person'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).

(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, compared to women (Lawson, Baron-Cohen, & Wheelwright, in press).

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 1 yr of age (Lutchmaya & Baron-Cohen, 2002). 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. This is because 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 systemize), and girls at 24 hours old show the opposite profile (Connellan et al., 2001). These sex differences are therefore present very early in life. This raises the possibility that, whilst culture and socialisation may partly determine if you develop a male brain (stronger interest in systems) or a female brain (stronger interest in empathy), biology may also partly determine this. There is ample evidence for both cultural and biological influence (Eagly, 1987; Gouchie & Kimura, 1991). For example, the amount of eye contact a child makes at 1 yr old is inversely related to their level of *prenatal* testosterone (Lutchmaya, Baron-Cohen, & Raggatt, 2002; Lutchmaya, Baron-Cohen, & Raggett, 2002). The evidence for the biological basis of sex differences in the mind is reviewed elsewhere (Baron-Cohen, 2003).

Evolution and Social Development

From an evolutionary perspective, sex difference in empathizing and systematizing are likely to have been shaped by sexual selection and follow, at least in part, from sex differences in reproductive strategies. Female superiority in empathizing would not only facilitate development of stable social relationships, garnering of social support, and sensitivity to the needs of others (all of which are important for child-rearing), but it would also be adaptive in negotiating the more subtle dominance hierarchies that develop among girls and women (e.g., relational aggression). These dominance hierarchies are important to women in obtaining access to mates and resources and for controlling the behavior of other group members (Geary, 1998). Selection pressures were thus especially likely to have favored emphathizing skills in women. Conversely, high levels of empathy were unlikely to have been selected for in males. Too much empathy may impede success in rough-and-tumble play and other aggressive activities in male peer groups that function to prepare boys for later within-group dominance striving and intergroup competition and aggression. In addition, the evolutionary significance of a male superiority in systemizing has long been discussed in terms of hunting and warfare and associated sex differences in use of tools and weaponry and navigation of three-dimensional space (Geary, 1998); (see Pellegrini & Archer, this volume, for further discussion of the evolutionary-developmental bases of sex differences in social behavior).

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 (APA, 1994). 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 (Frith, 1991). Autism spectrum conditions affect males far more often than females. In the people with high-functioning autism or AS, the sex ratio is at least 10 males to every one female. These conditions are also strongly heritable (Bailey, Bolton, & Rutter, 1998) 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) (Baron-Cohen et al., 2000).

The extreme male brain (EMB) 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” (Asperger, 1944). The above is Uta Frith’s translation in 1991. In 1997 this controversial hypothesis was resurrected (Baron-Cohen & Hammer, 1997a). We can test the EMB theory empirically, now that we have definitions of the female brain (E>S), the male brain (S>E), the balanced brain (E=S).

Evidence for the extreme male brain theory (EMB)

To reiterate, the EMB theory predicts that females will perform better on tests of empathizing (E), males will perform better on tests of systemizing (S), and that people with autism spectrum conditions will show impaired E alongside intact or even superior S. Initial tests of this theory are proving positive (Baron-Cohen, 2000). Some of the convergent lines of evidence are summarised here.

Impaired empathizing

(1) *Mindreading.* Girls are better than boys on standard ‘theory of mind’ tests, and children with autism or AS are even worse than normal boys (Happe, 1995). 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’ (Baron-Cohen, 1995).

(2) *The Empathy Quotient* (or EQ). On this self-report questionnaire, females score higher than males, and people with AS or high-functioning autism (HFA) score even lower than males (Baron-Cohen et al., 2003; Baron-Cohen & Wheelwright, in press);

(3) *The ‘Reading the Mind in the Eyes’ Test.* Females score higher than males on this subtle test of emotion-recognition, but people with AS score even lower than males (Baron-Cohen et al., 1997);

(4) The *Complex Facial Expressions Test.* Females score higher than males on this test of a range of emotional expressions, but people with AS score even lower than males (S Baron-Cohen, S Wheelwright et al., 1997);

(5) *Eye contact.* Females make more eye contact than do males, and people with autism or AS make less eye contact than males (Lutchmaya, Baron-Cohen, & Raggett, 2002; Swettenham et al., 1998).

(6) *Language development*. Girls develop vocabulary faster than boys, and children with autism are even slower than males to develop vocabulary (Lutchmaya, Baron-Cohen, & Raggatt, 2002);

(7) *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 (Baron-Cohen, 1988);

(8) *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 (Baron-Cohen, O'Riordan et al., 1999);

(9) *The Friendship Questionnaire* (FQ). This assesses empathic styles of relationships. Women score higher on this than males, and adults with AS score even lower than normal males on the FQ (Baron-Cohen & Wheelwright, 2003)

Superior systemizing

(1) *Islets of ability.* A proportion of people with autism spectrum disorders have “islets of ability”. The more common domains in which these occur are mathematical calculation, calendrical calculation, syntax acquisition, music, or memory (e.g., for railway timetable information to a precise degree) (Baron-Cohen & Bolton, 1993). 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 systemizable domains. Most of them are also domains where males in the general population have a greater interest.

(2) *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 HFA score even higher than males. The EFT is a good measure of detailed local perception, a prerequisite for systemizing (Jolliffe & Baron-Cohen, 1997). On visual search tasks, males have better attention to detail than females do, and people with autism or AS have even faster, more accurate visual search (O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001).

(3) *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.

(4) *Tests of intuitive physics.* Males score higher than females in solving these physics problems, and people with AS score higher than males (Baron-Cohen, Wheelwright, Scahill, Lawson, & Spong, 2001).

(5) *Toy preference.* Boys prefer constructional and vehicle toys, more than girls do, (Maccoby, 1999) and clinical reports suggest that children with autism or AS have this as a very strong toy preference.

(6) *Collecting.* Boys appear to engage in more collecting or organising of items (e.g. CD's) than girls do, (and this would benefit from a careful study) and clinical accounts suggest that people with autism show this to an even greater extent.

(7) *Obsessions with closed systems.* Individuals with autism are often naturally drawn to predictable things, such as computers. Unlike people, computers do follow strict laws. Computers are closed systems – all the variables are well-defined within the system, 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 train spotting) (Baron-Cohen & Wheelwright, 1999). Again, such interests in the general population are more often associated with males (Baron-Cohen, 2003).

(8) *The Systemizing Quotient.* As mentioned earlier, males score higher on this instrument, and people with autism and Asperger Syndrome score even higher than normal males (Baron-Cohen et al., 2003).

(9) 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 (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001).

The above evidence points to people with autism showing an extreme male profile, as defined earlier, but what might this be due to?

Family-genetic evidence

Familiality of talent. Fathers and grandfathers of children with autism (on both sides of the family) are over-represented in occupations such as engineering, which require good systemizing but where a mild impairment in empathizing (as has been documented) would not necessarily be an impediment to success (Baron-Cohen & Hammer, 1997b; Baron-Cohen, Wheelwright, Stott, Bolton, & Goodyer, 1997). There is a higher rate of autism in the families of those talented in fields such as maths, physics, and engineering, as compared to those talented in the humanities (Baron-Cohen et al., 1998). These latter two findings suggest that the extreme male cognitive style is in part inherited.

Conclusions and future research

In this chapter I have introduced the first major revision to the 1994 model of the Mindreading System by adding two neurocognitive mechanisms (the Emotion Detector and the Empathising SyStem). I have also explained the need for taking a broader view, such that the new model is of the Empathizing System. One of the key benefits of this is that we can distinguish between two types of condition, autism vs. psychopathy.

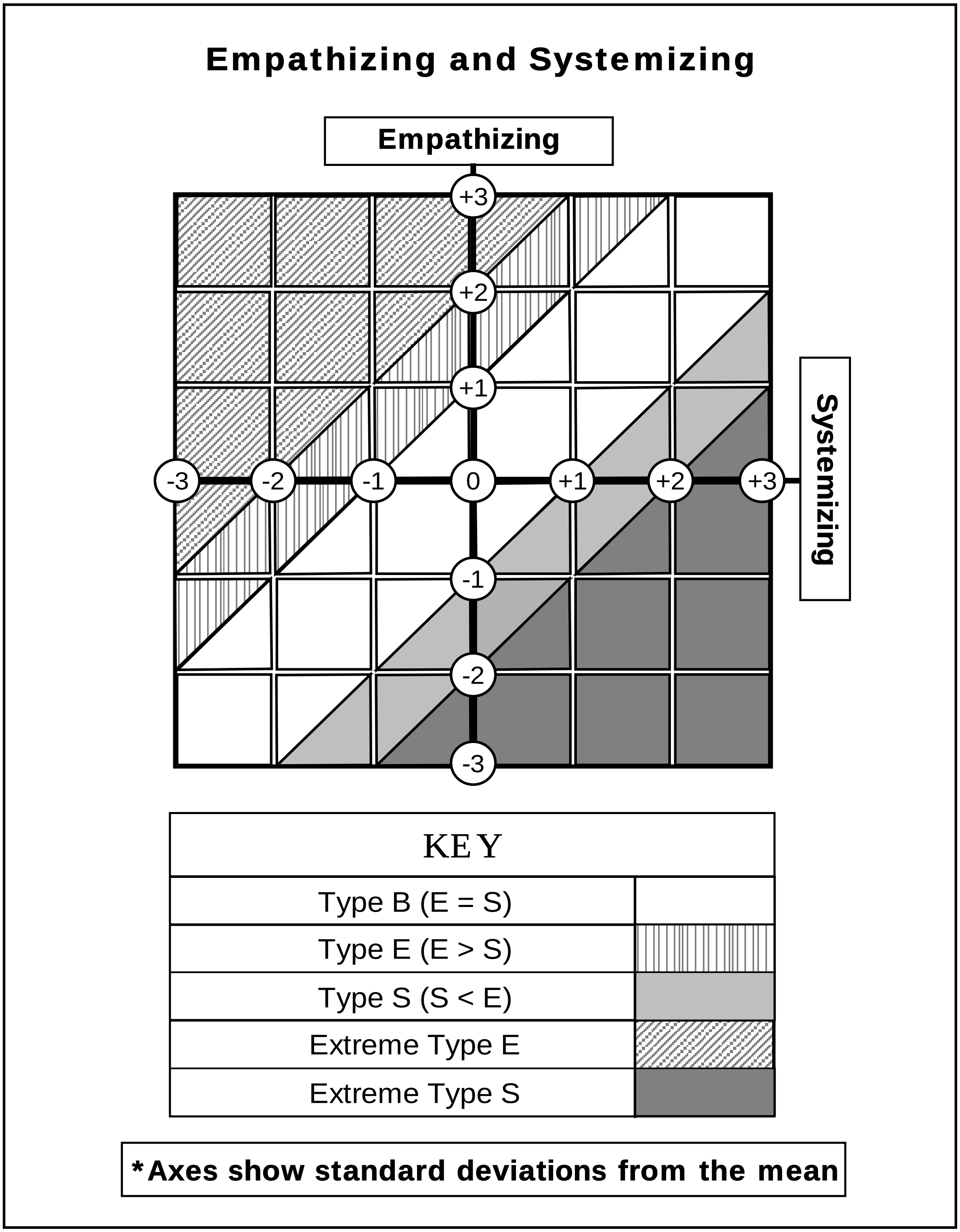
We have also considered the relevance of sex differences in both empathizing (female advantage) and systemizing (male advantage) and in terms of the 'extreme male brain' theory of autism. In Figure 3, these sex differences, and the extremes, are shown in a model that assumes empathizing and systemizing are two independent dimensions. Future research will need to test an alternative model: there is a trade-off such that the better one scores on one dimension, the worse one scores on the other. This would suggest a single mechanism (e.g. foetal testosterone?) may be involved in both. This is currently being tested.

We know something about the neural circuitry of empathizing (Baron-Cohen, Ring et al., 1999; Frith & Frith, 1999; Happe et al., 1996), but at present we know very little about the neural circuitry of systemizing (Ring et al., 1999). It is expected that research will begin to reveal the key brain regions.

Finally, in terms of the focus of this book on the origins of the social mind, the new model of empathizing, it is hoped that one benefit of delineating these separable components will be to test not only for their neurological dissociability from one another, but also to consider each of their adaptive importance. It is apparent that each of these mechanisms would have conferred unique advantages on the individual such that each could be the result of natural selection. Testing evolutionary hypotheses is of course notoriously difficult, but naturally occurring developmental conditions (such as autism and psychopathy) may provide a fruitful window into their neurological independence.

Insert Figure 3 here

Figure 3: A model of empathizing and systemizing



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