17 The Assortative Mating Theory of Autism

Simon Baron-Cohen

There are two major ways to predict changing events. If the event is agentive, one can adopt the "intentional stance" (or "empathize"). If the event is nonagentive, one can "systemize." In this chapter I outline a new theory, which holds that the systemizing mechanism has variable settings and that people with autism spectrum conditions are hypersystemizers, who therefore can process only highly systemizable (law-governed) information. In keeping with the focus of this book on evolutionary perspectives, I explore the evidence for the assortative mating theory, according to which autism is the result of both parents being high systemizers.

Systemizing Nonagentive Change

A universal feature in the environment that the brain has to react to is change. There are at least two types of structured change, agentive change and nonagentive change. Regarding the former, if change is perceived to be *self-generated* or *self-propelled* (i.e., there is no apparent external cause), the brain interprets it as agentive, that is, the individual is functioning as an agent with a goal. Goal detection (or intentionality detection, ID) is a fundamental aspect of how the human brain interprets and predicts the behavior of other animals (Baron-Cohen, 1994; Heider & Simmel, 1944; Perrett et al., 1985). Structured nonagentive change, by contrast, is any change that is not self-propelled and where there is a precipitating event (interpreted as a possible cause of the change) or a pattern to the change. Some patterns are cyclical (the pattern repeats every fixed number of units), but there are many other types of pattern.

Structured nonagentive change occurs by degrees. Some change occurs with total (100%) regularity or pattern (e.g., the sun always rises in the east and sets in the west). Other change occurs with a lower frequency or regularity, but there is still a pattern to be discerned. The perception of structured nonagentive change matters because the change might be injurious or have a negative impact (e.g., planting crops in February leads to them withering) or a positive impact (e.g., planting in March leads to the crops thriving). Being able to anticipate change thus allows the organism to avoid negative consequences or benefit from positive change.

Systemizing is the most powerful way to predict change. Systemizing involves law detection via observation of *input-operation-output* relationships (Baron-Cohen, 2002). Systemizing prompts a search for structure (patterns, rules, regularities, periodicity) in data. The goal of systemizing is to test whether the changing data are part of a system. Systems may be mechanical (e.g., machines), natural (e.g., a leaf), abstract (e.g., mathematics), collectible (e.g., a collection), motoric (e.g., a tennis stroke), or even social (e.g., the rules of etiquette). Thus, an engineer, a lawyer, a mathematician, a film editor, a librarian, an astronomer, a meteorologist, a chemist, a musician, a grammarian, a company CEO, and a zoologist all systemize; they are all concerned with formulating laws governing change—laws of physics, laws of nature, mathematical laws, social laws, and so on.

Systemizing allows the brain to predict that event x will occur with probability P—that is, to identify laws driving the system. Some systems are 100% lawful (e.g., an electrical light switch or a mathematical formula). During systemizing, the brain represents the information as input and output separately, so that the pattern emerges (table 17.1). Systems that are 100% lawful have zero (or minimal) variance and can therefore be predicted and controlled 100%. A computer might be an example of a 90% lawful system: the variance is wider, because the operating system may work differently depending on what other software is installed or which version of the software is running, and so on. The weather may be a system with only moderate lawfulness.

A key feature of systemizing is that single observations are recorded in a standardized manner. A meteorologist makes measurements at fixed times and fixed places, measuring rainfall (in a cup), temperature (with a thermometer), pressure (with a barometer), wind speed (with an anemometer), and so on. An astronomer records the position of a planet at fixed times and fixed places, tracking its movement. Such systematic data collection (phase 1 of systemizing) can then lead to the observation

Table 17.1
Two Examples of 100% Lawful Systems

A. Electricity Switch	
Input = Switch position	Output = Light Operation = Switch change
Up Down	On Off
B. Mathematical Rule	
Input = Number	Output = Number Operation = Add 2
2 3 4	4 5 6

of the pattern of law (phase 2 of systemizing). Systemizing thus has the power to reveal the structure or laws of nature.

Systemizing Agentive Change

Some aspects of agentive behavior are highly lawful (e.g., cats typically use their right paw to swipe at a moving object). Some human behavior is also sufficiently *scripted* to be moderately lawful (e.g., ballroom dancing). Human behavior that has been recorded on film is of course highly lawful, since each time the film is replayed, the actors do and say the same thing. But outside of these special cases, if there are laws governing human behavior, they are complex, and the variance is maximal. Maximal variance means that when change occurs, it could occur in a virtually infinite number of ways. Thus, a person's hands, eyes, mouth, posture, and facial expression might change in one of hundreds if not thousands of possible combinations. Nor is there a one-to-one mapping between facial expression and the underlying mental state that might be causing such changes in the face (Baron-Cohen, Golan, & Wheelwright, 2004). Situations do not predict the subtlety of emotions, since in the same situation different people react differently. Finally, humans as moving, changing objects also require the agent they are interacting with to respond. They talk, and their words appear as novel, unique combinations on each occasion, unlike scripted behavior. The right response to their words isn't to reply with a script. Agentive change in the social world is too fast, and the laws—if they exist—are thus too complex to systemize. Skinner (1976) claimed that human behavior could be systemized if one had a complete record of all the historical antecedents (A) and all the consequences (C) for any piece of behavior (B), such that A → B ← C. The real social world, of course, is not a Skinner Box.

Systemizing only works when one can measure or count one thing at a time, ignoring or holding everything else constant. Systemizing is enormously powerful as a way of predicting and controlling events in the nonagentive world and has led to the technological achievements of the modern world. It has this power because nonagentive changes are simple changes to predict: the systems are at least moderately lawful, with narrow variance.

Because ordinary social behavior defies a systematic approach, the second-by-second changes in agentive behavior are more parsimoniously interpreted in terms of the agent's goals (Baron-Cohen, 1994; Heider & Simmel, 1944; Perrett et al., 1985). It appears that humans have specialized, inherited "hardware" for dealing with the complex social world. The "empathizing system" comprises basic instruments—analogous to barometers, thermometers, and anemometers—that come compiled to help the normal infant make sense of the social world and react to it, without having to learn it all from scratch. Empathizing is explained in more detail elsewhere (Baron-Cohen, 1995, 2003, 2005; Baron-Cohen & Goodhart, 1994). Such basic modules or neurocognitive mechanisms give the normal infant a foothold in making sense of and responding to the social world. The neural circuitry of empathizing has been extensively investigated (Baron-Cohen et al., 1999; Frith & Frith, 1999; Happé et al., 1996); key brain areas involved in empathizing include the amygdala, the orbito- and medial frontal cortex, and the superior temporal sulcus. Experience allows us to learn the subtleties of empathy, but such hard-wired, innate mechanisms bootstrap the brain to make rapid sense of social change.

The hypersystemizing theory posits that we all have a systemizing mechanism (SM), which is set at different levels in different individuals. The SM is like a volume control or a dimmer switch. Genes and other biological factors (possibly fetal testosterone) turn this mechanism up or down (Knickmeyer, Baron-Cohen, Raggatt, & Taylor, 2004). In some people the SM is set high, so that they systemize *any* changing input, analyzing it for possible structure. A high systemizer searches all data for patterns and regularities. In other people the SM is set at a medium level, so that they systemize some but not all of the time. In yet other people the SM is set so low that they would hardly notice if regularity or structure was in the input or not.

Systemizing in the General Population (Levels 1–4)

Evidence suggests that within the general population, there are four degrees of systemizing. Level 1 corresponds to having little or no interest or drive to systemize, and consequently persons at this level of SM can cope with total change. This might be expressed as a talent at socializing, joined to a vagueness over details, and the ability to cope with change easily. Most people, however, have some interest in systems, and there are sex differences observable in the level of interest. More females in the general population have the SM turned up to Level 2, and more males have it turned up to Level 3. Those with an SM at Level 2 might show typical female interests (e.g., emotions; Baron-Cohen & Wheelwright, 2003), and those with an SM at Level 3 might show typical male interests (e.g., in mechanics; Baron-Cohen, 2003). These differences can be quite subtle, but, for example, on a test of map reading or mental rotation, males might score higher than females because of the higher-level SM (Kimura, 1999). Some evidence comes from the Systemizing Quotient, on which males score higher than females (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003). Another piece of evidence comes from the Physical Prediction Questionnaire, an instrument administered to select applicants for engineering careers. The task involves predicting which direction levers will move when an internal mechanism (consisting of cogwheels and pulleys) is activated. Men score significantly higher on this test than women do (Lawson, Baron-Cohen, & Wheelwright, 2004).

Level 4 denotes a higher than average level of systemization. There is some evidence that above-average systemizers have more autistic traits. Thus, scientists, who by definition are good systemizers, score higher than nonscientists on the Autism Spectrum Quotient (AQ). Mathematicians, who by definition focus on abstract systems, have the highest AQ score of all scientists (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). Another group of people who are above-average systemizers are parents of children with autism spectrum conditions (Baron-Cohen & Hammer, 1997; Happé, Briskman, & Frith, 2001). The genetic implications of this are discussed shortly, as these parents have been described as having the "broader phenotype" of autism (Bolton, 1996). One would expect a person at Level 4 to be talented at understanding systems with moderate variance (the stock market, running a company, the law, engineering).

Systemizing in the Autistic Spectrum (Levels 5–8)

The autistic spectrum comprise at least four subgroups: Asperger syndrome (AS) (Asperger, 1944; Frith, 1991), and high-, medium-, and low-functioning autism (Kanner, 1943). All share the phenotype of social difficulties and obsessional interests (American Psychiatric Association, 1994). An individual with AS has normal or above-average IQ and no language delay. In the three autism subgroups (high, medium, and low functioning), there is invariably some degree of language delay, and the level of functioning is indexed by overall IQ.[1]

Evidence suggests that people on the autistic spectrum have their SM set at levels above those in the general population—anywhere from Level 5 to Level 8. Level 5 can be seen as corresponding to AS: the person can easily systemize totally lawful systems (those that are 100% lawful, such as train timetables or historical chronologies) or highly lawful systems (e.g., computers) (Hermelin, 2002). They might also show an interest in systems like the weather, where the variance is quite high, so that the system is only moderately lawful (perhaps 60% lawful). The clinical literature is replete with anecdotal examples (e.g., one man with AS collected information of the type shown in table 17.2 or figure 17.1), but there is also experimental evidence for superior systemizing in AS: (1) People with AS have a higher than average Systemizing Quotient score (Baron-Cohen et al., 2003). (2) People with AS perform at a normal or high level on tests of intuitive physics (Baron-Cohen, Wheelwright, Skinner et al., 2001; Jolliffe & Baron-Cohen, 1997; Lawson et al., 2004; Shah & Frith, 1983). (3) People with AS can achieve extremely high levels in systemizing domains such as mathematics, physics, or computer science (Baron-Cohen, Wheelwright, Stone, & Rutherford, 1999). (4) People with AS have an "exact mind" when it comes to art (Myers, Baron-Cohen, & Wheelwright, 2004) and show superior attention to

---

1 High-functioning autism can be thought of as within 1 SD of population mean IQ (i.e., an IQ of 85 or above); medium-functioning autism can be thought of as between 1 and 3 SD below the population mean (i.e., an IQ of 55–84). Low-functioning autism can be thought of below this (i.e., an IQ of 54 or below).

Table 17.2
An Example of Systemizing Hydrangea Coloration

Hydrangea Name	Acidic Soil	Neutral Soil	Alkaline Soil
Annabelle	White	White	White
Ayesha	Blue	Purple	Pink
Alpengluhen	Purple	Red	Red
Altona	Blue	Purple	Red
All Summer Beauty	Blue	Purple	Pink
Ami Pasquier	Purple	Red	Red
Amethyst	Blue	Purple	Pink
Bodensee	Blue	Purple	Pink
Blauer Prinz	Blue	Purple	Purple
Bouquet Rose	Blue	Purple	Pink
Breslenburg	Blue	Purple	Pink
Deutschland	Purple	Red	Red
Domotoi	Blue	Purple	Pink
Dooley	Blue	Purple	Pink
Enziandom	Blue	Purple	Red

Source: http://www.hydrangeasplus.com.

detail (O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Plaisted, O'Riordan, & Baron-Cohen, 1998a).

There is some evidence that in people with high-functioning autism, the SM is set at Level 6, in those with medium-functioning autism it is at Level 7, and in low-functioning autism it is at the maximum setting, Level 8. Thus, the high-functioning individuals who try to mentalize are thought to do this by "hacking" (i.e., systemizing) the solution (Happé, 1996), and on a picture-sequencing task they perform above average on sequences that contain temporal or physical-causal (i.e., systemizable) information (Baron-Cohen, Leslie, & Frith, 1986). Medium-functioning individuals, in contrast to their difficulty on the false belief task (an empathizing task), perform normally or above average on two equivalent systemizing tasks, the false photograph task (Leslie & Taiss, 1992) and the false drawings task (Charman & Baron-Cohen, 1992). In the low-functioning group, their obsessions cluster in the domain of systems (Baron-Cohen & Wheelwright, 1999), and, given a set of colored counters, they show their hypersystemizing as extreme pattern imposition (Frith, 1970). Table 17.3 lists 16 behaviors that would be expected if an individual had an SM turned up to the maximum setting of Level 8.

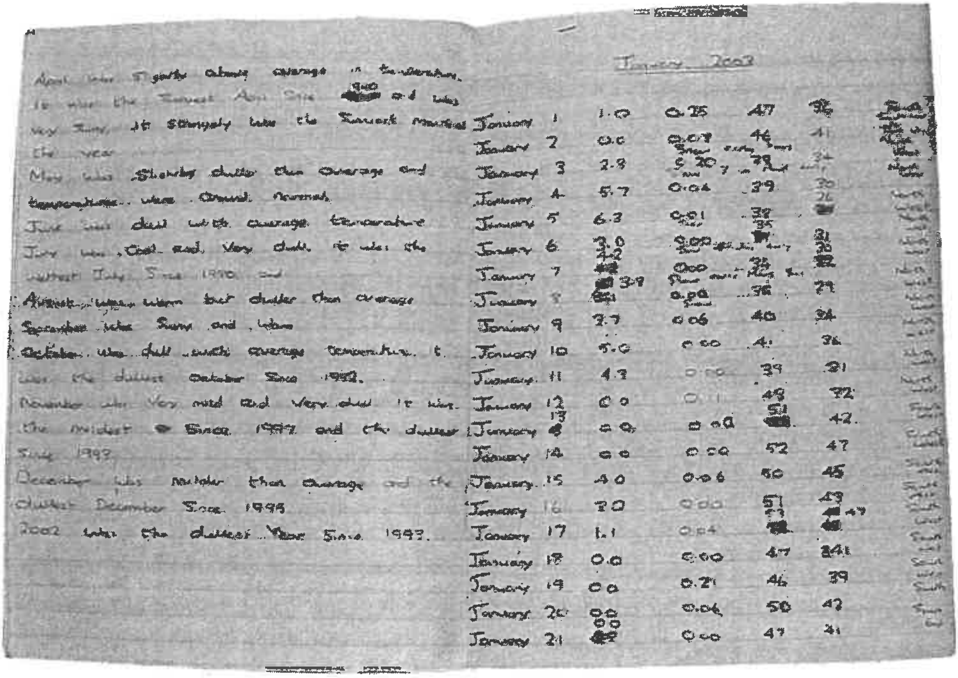

Figure 17.1
An example of systemizing the weather, from the notebook of Kevin Phillips, a man with Asperger syndrome. Reproduced with Mr. Phillips's kind permission.

The hypersystemizing theory thus has the power to explain not only what unites individuals across the autistic spectrum but why the particular constellation of symptoms is seen in this syndrome. It also explains why some people with autism may have more or less language, or a higher or lower IQ, or differing degrees of mindblindness (Baron-Cohen, 1995). This is because, according to the theory, as the SM dial is turned down from the maximum level of 8, at each point on the dial the individual at that point should be able to tolerate a greater amount of change or variance in the system. Thus, if the SM is set at Level 7, the person should be able to deal with systems that are less than 100% lawful but still highly (e.g., at least 90%) lawful. The child could achieve a slightly higher IQ (since there is a little more possibility for learning about systems that are less than 100% lawful), and the child would have a little more ability to generalize than someone with classic

Table 17.3
Systemizing Mechanism at Level 8: Classic, Low-Functioning Autism

What does it mean for one's SM to be turned up to Level 8? The person by definition systemizes everything. Since in the social world the information is too complex to be systemized, such individuals focus on systems that are totally lawful (that is, with zero [or minimal] variance). Key behaviors that follow from extreme systemizing include the following:

- *Highly repetitive behavior* (e.g., producing a sequence of actions, sounds, or set phrases, or bouncing on a trampoline)
- *Self-stimulation* (e.g., a sequence of repetitive bodyrocking, finger-flapping in a highly stereotyped manner, spinning oneself round and round)
- *Repetitive events* (e.g., spinning objects round and round, watching the cycles of the washing machine; replaying the same video 1,000 times; spinning the wheels of a toy car)
- *Preoccupation with fixed patterns or structure* (e.g., lining things up in a strict sequence, electrical light switches being in either an on or off position throughout the house; running water from the taps/faucet)
- *Prolonged fascination with systemizable change* (e.g., sand falling through one's fingers, light reflecting off a glass surface, playing the same video over and over again, preference for simple, predictable material such as *Thomas the Tank Engine* movies)
- *Tantrums at change:* As a means to return to predictable, systemizable input with minimal variance
- *Need for sameness:* The child attempts to impose lack of change onto the world, to turn the world into a totally controlled or predictable environment (a Skinner Box), to make it systemizable
- *Social withdrawal:* Since the social world is unsystemizable
- *Narrow interests:* In just one or two systems (types of windows, catalogues of information)
- *Mindblindness:* Since the social world is largely unsystemizable
- *Immersion in detail:* Since a high-systemizing mechanism needs to record each data point (e.g., noticing small changes)
- *Reduced ability to generalize:* Since high systemizing means a reluctance to formulate a law until there has been massive and sufficient data collection (this could also reduce IQ and breadth of knowledge)
- *Severe language delay:* Since other people's spoken language varies every time it is heard, so it is hard to systemize
- *Islets of ability:* Since the high systemizer will channel attention into the minute detail of one lawful system (the script of a video, or the video player itself, spelling of words, prime numbers), going round and round in this system to obtain evidence of its total lawfulness

autism.[2] The higher the SM level, the less generalization is possible, because systemizing involves identifying laws that might apply only to the current system under observation. Systemizing a *Thomas the Tank Engine* video (a favorite of many children with autism) may not lead to a rule about *all* such videos but just a rule that applies to *this* particular one with *this* unique sequence of crackles and hisses.[3]

At Level 7, some language delay is to be expected, but it might be only moderate, since someone whose SM is set at Level 7 can tolerate a little variance in the way language is spoken and still see meaningful patterns. The child's mindblindness would be less than total. If the SM is set at Level 6, the theory predicts that such an individual would be able to deal with systems that are slightly less (e.g., at least 80%) lawful. This would therefore be expressed as only mild language delay, mild obsessions, mild delay in theory of mind, and stilted social behavior, such as attempts at systemizing social behavior (e.g., asking for affirmation of the rule, "You mustn't shout in church, must you?") (Baron-Cohen, 1992).

Autism as a Result of Assortative Mating of Two High Systemizers

It is well established that autism arises for genetic reasons (Bailey et al., 1995; Folstein & Rutter, 1988; Gillberg, 1991). The evidence for systemizing being part of the genetic mechanism for autism includes the following: fathers and grandfathers of children with autism are twice as likely to work as engineers (chosen as a clear example of a systemizing occupation) than are men in the general population (Baron-Cohen, Wheelwright, Stott, Bolton, & Goodyear, 1997). The implication is that these fathers and grandfathers (both maternal and paternal) have their SM set higher than average (Level 4). Consistent with this observation,

2 I am indebted to Nigel Goldenfeld for suggesting this connection between hypersystemizing and IQ.

3 The "reduced generalization" theory of autism (Plaisted et al., 1998) is thus seen as a consequence of hypersystemizing rather than as an alternative theory. Reduced generalization has been noted in autism for many decades (Rimland, 1964) but is not discussed in any functional or evolutionary context. In contrast, systemizing (an evolved function of the human brain) presumes that one does not generalize from one system to another until one has enough information that the rules of system A are identical to those of system B. Good generalization may be a feature of average or poor systemizers, while "reduced" generalization can be seen as a feature of hypersystemizing.

students in the natural sciences—engineering, mathematics, physics, all of which require developed systemizing in relation to mechanical or abstract systems—have a higher number of relatives with autism than do students in the humanities (Baron-Cohen et al., 1998). If systemizing talent is genetic, such genes appear to cosegregate with genes for autism.

The evidence that autism could be the genetic result of having *two* systemizers as parents (assortative mating) includes the following: (1) Both mothers *and* fathers of children with AS have been found to be strong in systemizing on the Embedded Figures test (Baron-Cohen & Hammer, 1997). This study suggests that both parents may be contributing their systemizing genotypes. (2) Both mothers and fathers of children with autism or AS have elevated rates of systemizing occupations among their fathers (Baron-Cohen et al., 1997). (3) Mothers of children with autism show hypermasculinized patterns of brain activity during a systemizing task (Baron-Cohen et al., 2006). (4) The probability of having a brain of Type S (Level 3) in the male population is 0.44, and the probability of having a brain of Type S in the female population is 0.14 (Goldenfeld, Baron-Cohen, Wheelwright, Ashwin, & Chakrabarti, in press). If autism arises from assortative mating of two strong systemizers, then the probability of autism in the population should be $(0.44 \times 0.14) = 0.062$. This is remarkably close to the actual rate of autism spectrum conditions in the general population (Baird et al., 2000; Fombonne, 2001). It is unlikely that the liability genes for autism in males in the general population are common polymorphisms but that these are relatively rare in females in the general population. Rather, it may be that in males the liability genes interact with some other (endocrine?) factor to increase risk, or that in females there is some protective factor that decreases risk.

Hypersystemizing versus Weak Central Coherence versus Executive Dysfunction Theories

The hypersystemizing theory predicts that when presented with information or tasks that can be systemized, and especially when presented with information that derives from a highly lawful system, people with autism spectrum conditions will perform at an intact or even superior level, always relative to a mental-age-matched control group. Such an account differs from the two dominant theories of the nonsocial features of autism, the weak central coherence theory (Frith, 1989) and the executive dysfunction theory (Russell, 1997).

Regarding the former, people with autism perform well on the Embedded Figures test and on the Block Design subtest (Shah & Frith, 1983, 1993), and these results have been interpreted as signs of weak central coherence. But given that both of these are lawful systems, the same data can be taken as evidence of hypersystemizing. People with autism have been shown to have deficits in contextual processing (Jolliffe & Baron-Cohen, 1999), but such material is harder to systemize. Regarding the latter, people with autism show perseveration on the Wisconsin Card Sorting test (Rumsey & Hamberger, 1988), taken as a sign of an executive dysfunction. But their perseveration on this task suggests that people with autism spectrum conditions are focused on establishing a rule (a key aspect of systemizing), and as good systemizers they would not be expected to stop testing the rule but instead to keep on testing the rule, ignoring the experimenter's request to shift to a new, arbitrary rule. What appears as perseveration may therefore be a sign of hypersystemizing. Equally, people with autism may make more moves on the Tower of London test (or its equivalent) (Hughes, Russell, & Robbins, 1994), but if they are more focused on systemizing the task (identifying any lawful regularities), issues such as solving the task in the minimum number of moves may be irrelevant to them. We should be careful not to attribute a deficit to people with autism spectrum conditions when they may simply be approaching the task from a different standpoint from the experimenter's.

Conclusion

According to the hypersystemizing theory, the core of autism is both a social deficit (since the social world is the ultimate unsystemizable domain) and what Kanner (1943) astutely observed and aptly named "the need for sameness." Autism is the result of a normative systemizing mechanism—the adaptive function of which is to serve as a law detector and a change-predicting mechanism—being set too high. This theory explains why people with autism prefer either no change or systems that change in highly lawful or predictable ways (i.e., systems with simple change, such as mathematics, physics, repetition, objects that spin, routine, music, machines, collections) and why they become disabled when faced with systems characterized by complex change (such as social behavior, conversation, people's emotions, or fiction). Because they cannot systemize complex change, they become "change resistant" (Gomot et al., 2005).

While autism spectrum conditions are disabling in the social world, their strong systemizing can lead to talent in areas that are systemizable. For many people with autism spectrum conditions, the hypersystemizing never moves beyond phase 1: the massive collection of facts and observations (lists of dates and the rainfall on each of these, lists of trains and their departure times, lists of records and their release dates, watching the spin cycle of a washing machine) or highly repetitive behavior (spinning a plate or the wheels of a toy car). But for those who go beyond phase 1 to identify a law or a pattern in the data (phase 2 of systemizing), this can constitute original insight. In this sense, it is likely that the genes for increased systemizing have made remarkable contributions to human history (Fitzgerald, 2000, 2002; James, 2003).

Acknowledgments I am grateful for the support of the Medical Research Council during this work. Matthew Belmonte, Marie Gomot, Johnny Lawson, Jac Billington, Nigel Goldenfeld, and Sally Wheelwright all contributed in important ways to the discussion of these ideas. Portions of this chapter appeared in *Neuropsychopharmacology and Biological Psychiatry* (2005).

References

American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.

Asperger, H. (1944). Die "Autistischen Psychopathen" im Kindesalter. *Archiv für Psychiatrie und Nervenkrankheiten*, *117*, 76–136.

Bailey, A., Le Couteur, A., Gottesman, I., Bolton, P., Simonoff, E., Yuzda, E., et al. (1995). Autism as a strongly genetic disorder: Evidence from a British twin study. *Psychological Medicine*, *25*, 63–77.

Baird, G., Cox, A., Charman, T., Baron-Cohen, S., Wheelwright, S., Swettenham, J., et al. (2000). A screening instrument for autism at 18 months of age: A six-year follow-up study. *Journal of the American Academy of Child and Adolescent Psychiatry*, *39*, 694–702.

Baron-Cohen, S. (1992). The girl who liked to shout in church. In R. Campbell (Ed.), *Mental lives: Case studies in cognition*. Oxford: Basil Blackwell.

Baron-Cohen, S. (1994). How to build a baby that can read minds: Cognitive mechanisms in mindreading. *Cahiers de Psychologie Cognitive/Current Psychology of Cognition*, *13*, 513–552.

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

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

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

Baron-Cohen, S. (2005). The empathizing system: A revision of the 1994 model of the mindreading system. In B. Ellis & D. Bjorklund (Eds.), *Origins of the social mind.* Surrey, UK: Guilford Publications.

Baron-Cohen, S., Bolton, P., Wheelwright, S., Short, L., Mead, G., Smith, A., et al. (1998). Does autism occurs more often in families of physicists, engineers, and mathematicians? *Autism, 2,* 296–301.

Baron-Cohen, S., Golan, O., Wheelwright, S., & Hill, J. J. (2004). *Mindreading: The interactive guide to emotions.* London: Jessica Kingsley.

Baron-Cohen, S., & Goodhart, F. (1994). The mindreading system: New directions for research. *Current Psychology of Cognition, 13,* 724–750.

Baron-Cohen, S., Ring, H., Chitnis, X., Wheelwright, S., Gregory, L., Willams, S., Brammer, M. J., & Bullmore, E. T. (2006). Mothers of children with autism: An fMRI study of the "Eyes" and Embedded Figures test and the "extreme male brain" theory. Unpublished manuscript, University of Cambridge.

Baron-Cohen, S., & Hammer, J. (1997). Parents of children with Asperger syndrome: What is the cognitive phenotype? *Journal of Cognitive Neuroscience, 9,* 548–554.

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

Baron-Cohen, S., Richler, J., Bisarya, D., Gurunathan, N., & Wheelwright, S. (2003). The Systemising Quotient (SQ): An investigation of adults with Asperger syndrome or high functioning autism and normal sex differences. In *Autism: Mind and brain* [Special issue]. *Philosophical Transactions of the Royal Society, Series B, 358,* 361–374.

Baron-Cohen, S., Ring, H., Wheelwright, S., Bullmore, E. T., Brammer, M. J., Simmons, A., et al. (1999). Social intelligence in the normal and autistic brain: An fMRI study. *European Journal of Neuroscience, 11,* 1891–1898.

Baron-Cohen, S., & 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,* 484–490.

Baron-Cohen, S., & Wheelwright, S. (2003). The Friendship Questionnaire (FQ): An investigation of adults with Asperger syndrome or high functioning autism, and normal sex differences. *Journal of Autism and Developmental Disorders, 33,* 509–517.

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

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The Autism Spectrum Quotient (AQ): Evidence from Asperger syndrome/high functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders, 31,* 5–17.

Baron-Cohen, S., Wheelwright, S., Stone, V., & Rutherford, M. (1999). A mathematician, a physicist, and a computer scientist with Asperger syndrome:

Performance on folk psychology and folk physics test. *Neurocase, 5,* 475–483.
Baron-Cohen, S., Wheelwright, S., Stott, C., Bolton, P., & Goodyear, I. (1997). Is there a link between engineering and autism? *Autism: An International Journal of Research and Practice, 1,* 153–163.
Bolton, P. (1996). Genetic advances and their implications for child psychiatry. *Child Psychology and Psychiatry Review, 1,* 82–93.
Charman, T., & Baron-Cohen, S. (1992). Understanding beliefs and drawings: A further test of the metarepresentation theory of autism. *Journal of Child Psychology and Psychiatry, 33,* 1105–1112.
Connellan, J., Baron-Cohen, S., Wheelwright, S., Ba'tki, A., & Ahluwalia, J. (2001). Sex differences in human neonatal social perception. *Infant Behavior and Development, 23,* 113–118.
Fitzgerald, M. (2000). Did Ludwig Wittgenstein have Asperger's syndrome? *European Child and Adolescent Psychiatry, 9,* 61–65.
Fitzgerald, M. (2002). Did Isaac Newton have Asperger's syndrome or disorder? *European Journal of Adolescent Psychiatry.*
Folstein, S., & Rutter, M. (1988). Autism: Familial aggregation and genetic implications. *Journal of Autism and Developmental Disorders, 18,* 3–30.
Fombonne, E. (2001). Is there an epidemic of autism? *Pediatrics, 107,* 411–412.
Frith, C., & Frith, U. (1999). Interacting minds: A biological basis. *Science, 286,* 1692–1695.
Frith, U. (1970). Studies in pattern detection in normal and autistic children. II. Reproduction and production of color sequences. *Journal of Experimental Child Psychology, 10*(1), 120–135.
Frith, U. (1989). *Autism: Explaining the enigma.* Oxford: Basil Blackwell.
Frith, U. (1991). *Autism and Asperger's syndrome.* Cambridge: Cambridge University Press.
Gillberg, C. (1991). Clinical and neurobiological aspects of Asperger syndrome in six family studies. In U. Frith (Ed.), *Autism and Asperger syndrome.* Cambridge: Cambridge University Press.
Goldenfeld, N., Baron-Cohen, S., Wheelwright, S., Ashwin, C., & Chakrabarti, B. (in press). Empathizing and systemizing in males and females, and in autism spectrum conditions. In T. Farrow (Ed.), *Empathy and mental illness.* Cambridge: Cambridge University Press.
Gomot, M., Bernard, F. A., Davis, M. H., Belmonte, M. K., Ashwin, C., Bullmore, E. T., et al. (2005). Change detection in children with autism: An auditory event-related fMRI study. *NeuroImage, 29,* 475–495.
Happé, F. (1996). *Autism.* London: University College London Press.
Happé, F., Briskman, J., & Frith, U. (2001). Exploring the cognitive phenotype of autism: Weak "central coherence" in parents and siblings of children with autism. I. Experimental tests. *Journal of Child Psychology and Psychiatry, 42,* 299–308.
Happé, F., Ehlers, S., Fletcher, P., Frith, U., Johansson, M., Gillberg, C., et al. (1996). Theory of mind in the brain: Evidence from a PET scan study of Asperger syndrome. *Neuroreport, 8,* 197–201.

Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *American Journal of Psychology, 57*, 243–259.
Hermelin, B. (2002). *Bright splinters of the mind: A personal story of research with autistic savants*. London: Jessica Kingsley.
Hughes, C., Russell, J., & Robbins, T. (1994). Evidence for executive dysfunction in autism. *Neuropsychologia, 32*, 477–492.
James, I. (2003). Singular scientists. *Journal of the Royal Society of Medicine, 96*, 36–39.
Jolliffe, T., & Baron-Cohen, S. (1997). Are people with autism or Asperger's syndrome faster than normal on the Embedded Figures task? *Journal of Child Psychology and Psychiatry, 38*, 527–534.
Jolliffe, T., & Baron-Cohen, S. (1999). Linguistic processing in high-functioning adults with autism or Asperger syndrome: Is local coherence impaired? *Cognition, 71*, 149–185.
Kanner, L. (1943). Autistic disturbance of affective contact. *Nervous Child, 2*, 217–250.
Kimura, D. (1999). *Sex and cognition*. Cambridge, MA: MIT Press.
Knickmeyer, R., Baron-Cohen, S., Raggatt, P., & Taylor, K. (2004). Foetal testosterone, social cognition, and restricted interests in children. *Journal of Child Psychology and Psychiatry, 46*, 198–210.
Lawson, J., Baron-Cohen, S., & Wheelwright, S. (2004). Empathising and systemising in adults with and without Asperger syndrome. *Journal of Autism and Developmental Disorders, 34*, 301–310.
Leslie, A. M., & Thaiss, L. (1992). Domain specificity in conceptual development: Evidence from autism. *Cognition, 43*, 225–251.
Myers, P., Baron-Cohen, S., & Wheelwright, S. (2004). *An exact mind*. London: Jessica Kingsley.
O'Riordan, M., Plaisted, K., Driver, J., & Baron-Cohen, S. (2001). Superior visual search in autism. *Journal of Experimental Psychology: Human Perception and Performance, 27*, 719–730.
Perrett, D., Smith, P., Potter, D., Mistlin, A., Head, A., Milner, A., et al. (1985). Visual cells in the temporal cortex sensitive to face view and gaze direction. *Proceedings of the Royal Society of London, B, 223*, 293–317.
Plaisted, K., O'Riordan, M., & Baron-Cohen, S. (1998a). Enhanced discrimination of novel, highly similar stimuli by adults with autism during a perceptual learning task. *Journal of Child Psychology and Psychiatry, 39*, 765–775.
Plaisted, K., O'Riordan, M., & Baron-Cohen, S. (1998b). Enhanced visual search for a conjunctive target in autism: A research note. *Journal of Child Psychology and Psychiatry, 39*, 777–783.
Premack, D. (1990). The infant's theory of self-propelled objects. *Cognition, 36*, 1–16.
Rimland, B. (1964). *Infantile autism: The syndrome and its implications for a neural theory of behavior*. New York: Appleton-Century-Crofts.
Rumsey, J., & Hamberger, S. (1988). Neuropsychological findings in high functioning men with infantile autism, residual state. *Journal of Clinical and Experimental Neuropsychology, 10*, 201–221.

Russell, J. (Ed.). (1997). *Autism as an executive disorder.* Oxford: Oxford University Press.
Scaife, M., & Bruner, J. (1975). The capacity for joint visual attention in the infant. *Nature, 253*, 265–266.
Shah, A., & Frith, U. (1983). An islet of ability in autism: A research note. *Journal of Child Psychology and Psychiatry, 24*, 613–620.
Shah, A., & Frith, U. (1993). Why do autistic individuals show superior performance on the Block Design test? *Journal of Child Psychology and Psychiatry, 34*, 1351–1364.
Skinner, B. F. (1976). *About behaviorism.* New York: Vintage Books.