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BIOLOGY

# AUTISM AND THE TECHNICAL MIND

## Children of scientists and engineers may inherit genes that not only confer intellectual talents but also predispose them to autism

*By Simon Baron-Cohen*

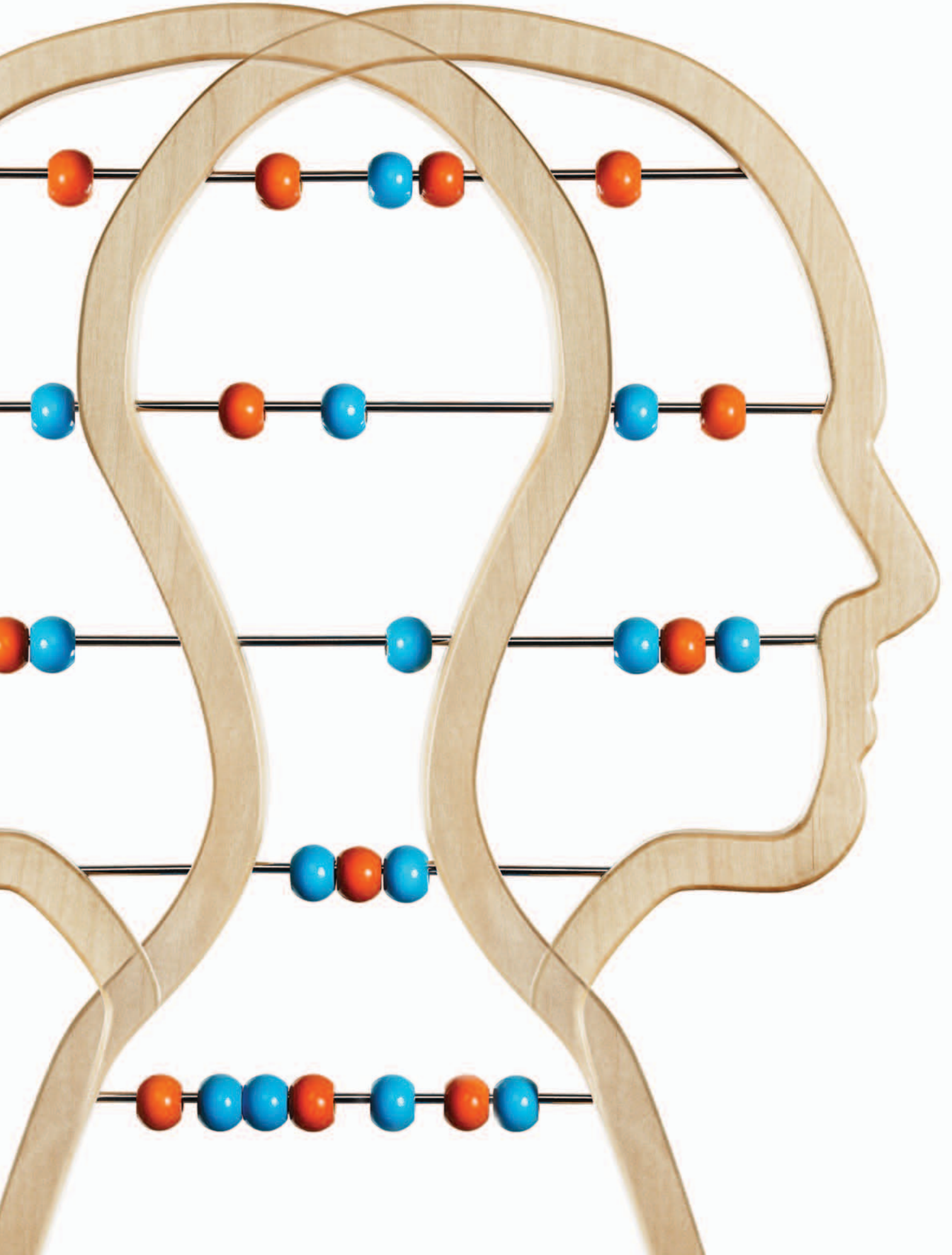
IN 1997 MY COLLEAGUE SALLY WHEELWRIGHT AND I CONDUCTED A STUDY INVOLVING nearly 2,000 families in the U.K. We included about half these families because they had at least one child with autism, a developmental condition in which individuals have difficulty communicating and interacting with others and display obsessive behaviors. The other families had children with a diagnosis of Tourette's syndrome, Down syndrome or language delays but not autism. We asked parents in each family a simple question: What was their job? Many mothers had not worked outside the home, so we could not use their data, but the results from fathers were intriguing: 12.5 percent of fathers of

IN BRIEF

**Silicon Valley** and other tech-savvy communities report exceptionally high rates of autism. These trends might reflect a link between genes that contribute to autism and genes behind technical aptitude. **When two technical-minded** individuals pair up, their children may inherit genes for useful cognitive skills, as well as genes involved in the development of autism. **Furthermore, high levels** of testosterone in the womb may play a role in the development of both technical and autistic minds.



*Photograph by Dan Saelinger*



children with autism were engineers, compared with only 5 percent of fathers of children without autism.

Likewise, 21.2 percent of grandfathers of children with autism had been engineers, compared with only 2.5 percent of grandfathers of children without autism. The pattern appeared on both sides of the family. Women who had a child with autism were more likely to have a father who had been an engineer—and they were more likely to have married someone whose father had been an engineer.

Coincidence? I think not.

A possible explanation involves a phenomenon known as assortative mating, which usually means "like pairs with like." I first encountered the concept in an undergraduate statistics tutorial at the University of Oxford in 1978, when my tutor told me (perhaps to make statistics a little more lively) that whom you have sex with is not random. When I asked her to elaborate, she gave me the example of height: tall people tend to mate with tall people, and short people tend to mate with short people. Height is not the only characteristic that consciously and subconsciously influences partner selection—age is another example, as are personality types. Now, more than 30 years later, my colleagues and I are testing whether assortative mating explains why autism persists in the general population. When people with technical minds—such as engineers, scientists, computer programmers and mathematicians—marry other technical-minded individuals, or their sons and daughters do, do they pass down linked groups of genes that not only endow their progeny with useful cognitive talents but also increase their children's chances of developing autism?

## SYSTEM CHECK

I BEGAN STUDYING AUTISM in the 1980s. By then, the psychogenic theory of autism—which argued that emotionally disinterested mothers caused their children's autism—had been soundly refuted. Michael Rutter, now at King's College London, and others had begun to study autism in twins and had shown that autism was highly heritable. Genetics, not parenting, was at work.

Today researchers know that an identical twin of someone with autism is around 70 times more likely to develop autism, too, compared with an unrelated individual. Although researchers have uncovered associations between specific genes and autism, no one has identified a group of genes that reliably predicts who will develop the condition. The genetics of autism are far more complex than that. What I have been interested in understanding, however, is how genes for autism survive in the first place. After all, autism limits one's abilities to read others' emotions and to form relationships, which in turn may reduce one's chances of having children and passing on one's genes.

One possibility is that the genes responsible for autism persist, generation after generation, because they are co-inherited with genes underlying certain cognitive talents common to both people with autism and technical-minded people whom some might call geeks. In essence, some geeks may be carriers of genes for autism: in their own life, they do not demonstrate any signs of severe autism, but when they pair up and have kids, their children may get a double dose of autism genes and traits. In this way, assortative mating between technical-minded people might spread autism genes.

Because "geek" is not the most scientific term, and for some may be pejorative, I needed to formulate a more precise definition of the cognitive talents shared by technical-minded people and people with autism. In the early 2000s Wheelwright and I surveyed nearly 100 families with at least one child with autism and asked another basic question: What was their child's obsession? We received a diverse array of answers that included memorizing train timetables, learning the names of every member of a category (for instance, dinosaurs, cars, mushrooms), putting electrical switches around the house into particular positions, and running the water in the sink and rushing outside to see it flowing out of the drainpipe.

On the surface, these very different behaviors seem to share little, but they are all examples of systemizing. I define systemizing as the drive to analyze or construct a system—a mechanical system (such as a car or computer), a natural system (nutrition) or an abstract system (mathematics). Systemizing is not restricted to technology, engineering and math. Some systems are even social, such as a business, and some involve artistic pursuits, such as classical dance or piano. All systems follow rules. When you systemize, you identify the rules that govern the system so you can predict how that system works. This fundamental drive to systemize might explain why people with autism love repetition and resist unexpected changes.

Collaborating once again with Wheelwright, who is now at the University of Southampton in England, I put the link between systemizing and autism to the test. We found that children with Asperger's syndrome—a form of autism with no language or intelligence impairments—outperformed older, typically developing children on a test of understanding mechanics. We also found that on average, adults and children with Asperger's scored higher on self-report and parent-report measures of systemizing. Finally, we found that people with Asperger's scored higher on a test of attention to detail. Attention to detail is a prerequisite for good systemizing. It makes a world of difference when trying to understand a system if you spot the small details or if you mistake one tiny variable in the system. (Imagine getting one digit wrong in a math calculation.) When we gave the test of attention to detail to parents, both the mothers and fathers of children with autism were also faster and more accurate than those of typically developing children.

Engineers aren't the only technical-minded people who might harbor autism genes. In 1998 Wheelwright and I found that math students at the University of Cambridge were nine times more likely than humanities students to report having a formal diagnosis of autism, including Asperger's, which will be folded into the broader "autism spectrum disorder" in the newest edition of psychiatry's guidebook, the *DSM-5*. Whereas only 0.2 percent of students in the humanities had autism, a figure not so different from the rate of autism reported in the wider population at the time, 1.8 percent of the math students had it. We also found that the siblings of mathematicians were five times more likely to have autism, compared with the siblings of those in the humanities.

In another test of the link between autism and math, Wheelwright and I developed a metric for measuring traits associated with autism in the general population, called the Autism Spectrum Quotient (AQ). It has 50 items, each representing one such trait. No one scores zero on the test. On average, typically developing men score 17 out of 50, and typically developing women score 15 out of 50. People with autism usually score above 32. We gave the AQ to winners of the British Mathematical Olympiad.

They averaged 21 out of 50. This pattern suggested that—regardless of official diagnoses—mathematical talent was also linked to a higher number of traits associated with autism.

### THE SILICON VALLEY PHENOMENON

ONE WAY TO TEST the assortative mating theory is to compare couples in which both individuals are strong systemizers with couples who include only one strong systemizer—or none. Two-systemizer couples may be more likely to have a child with autism. My colleagues and I created a Web site where parents can report what they studied in college, their occupations, and whether or not their children have autism (www.cambridgepsychology.com/graduate parents).

Meanwhile we are exploring the theory from other angles. If genes for technical aptitude are linked to genes for autism, then autism should be more common in places around the world where many systemizers live, work and marry—places such as Silicon Valley in California, which some people claim has autism rates 10 times higher than the average for the general population.

In Bangalore, the Silicon Valley of India, local clinicians have made similar observations. Alumni of the Massachusetts Institute of Technology have also reported rates of autism 10 times higher than average among their children. Unfortunately, no one has yet conducted detailed and systematic studies in Silicon Valley, Bangalore or M.I.T., so these accounts remain anecdotal.

My colleagues and I, however, have investigated the rates of autism in Eindhoven, the Silicon Valley of the Netherlands. Royal Philips Electronics has been a major employer in Eindhoven since 1891, and IBM has a branch in the city. Indeed, some 30 percent of jobs in Eindhoven are in the IT sector. Eindhoven is also home to Eindhoven University of Technology and High Tech Campus Eindhoven, the Dutch equivalent of M.I.T. We compared rates of autism in Eindhoven with rates of autism in two similarly sized cities in the Netherlands: Utrecht and Haarlem.

In 2010 we asked every school in all three cities to count how many children among their pupils had a formal diagnosis of autism. A total of 369 schools took part, providing information on about 62,505 children. We found that the rate of autism in Eindhoven was almost three times higher (229 per 10,000) than in Haarlem (84 per 10,000) or Utrecht (57 per 10,000).

### MALE MINDS

IN PARALLEL WITH TESTING the link between autism and systemizing, we have been examining why autism appears to be so much more common among boys than among girls. In classic autism, the sex ratio is about four boys to every girl. In Asperger's, the sex ratio may be as high as nine boys for every girl.

Likewise, strong systemizing is much more common in men than in women. In childhood, boys on average show a stronger interest in mechanical systems (such as toy vehicles) and constructional systems (such as Lego). In adulthood, men are overrepresented in STEM subjects (*s*cience, *t*echnology, *e*ngineering and *m*ath) but not in people-centered sciences such as clinical psychology or medicine. We have been investigating whether high levels of the hormone testosterone in the fetus, long known to play a role in "masculinizing" the developing brain in animals, correlate with strong systemizing and more traits associated with autism. A human male fetus produces at least twice as much testosterone as a female fetus does.

To test these ideas, my colleague Bonnie Auyeung of the Cambridge Autism Research Center and I studied 235 pregnant women undergoing amniocentesis—a procedure in which a long needle samples the amniotic fluid surrounding a fetus. We found that the more testosterone surrounding a fetus in the womb, the stronger the children's later interest in systems, the better their attention to detail and the higher their number of traits associated with autism. Researchers in Cambridge, England, and Denmark are now collaborating to test whether children who eventually develop autism were exposed to elevated levels of testosterone in the womb.

Genes that contribute to autism may overlap with genes for the uniquely human ability to understand how the world works in detail—to see beauty in patterns inherent in nature, music and math.

If fetal testosterone plays an important role in autism, women with autism should be especially masculinized in certain ways. Some evidence suggests that this is true. Girls with autism show "tomboyism" in their toy-choice preferences. On average, women with autism and their mothers also have an elevated rate of polycystic ovary syndrome, which is caused by excess testosterone and involves irregular menstrual cycles, delayed onset of puberty and hirsutism (excessive body hair).

Prenatal testosterone, if it is involved in autism, is not acting alone. It behaves epigenetically, changing gene expression, and interacts with other important molecules. Similarly, the link between autism and systemizing, if confirmed through further studies, is unlikely to account for the full complexity of autism genetics. And we should not draw the simplistic conclusion that all technical-minded people carry genes for autism.

Investigating why certain communities have higher rates of autism, and whether genes that contribute to the condition are linked to genes for technical aptitude, may help us understand why the human brain sometimes develops differently than usual. People with autism, whose minds differ from what we consider typical, frequently display both disability and exceptional aptitude. Genes that contribute to autism may overlap with genes for the uniquely human ability to understand how the world works in extraordinary detail—to see beauty in patterns inherent in nature, technology, music and math. SA

MORE TO EXPLORE

**The Essential Difference: The Truth about the Male and Female Brain.** Simon Baron-Cohen. Basic Books, 2004.

**Sex Differences in the Brain: Implications for Explaining Autism.** Simon Baron-Cohen et al. in *Science*, Vol. 310, pages 819–823; November 4, 2005.

**Autism and Asperger Syndrome: The Facts.** Simon Baron-Cohen. Oxford University Press, 2008.

**Why Are Autism Spectrum Conditions More Prevalent in Males?** Simon Baron-Cohen et al. in *PloS Biology*, Vol. 9, No. 6, Article No. e1001081; June 14, 2011.

**SCIENTIFIC AMERICAN ONLINE**

Participate in a live chat with Baron-Cohen about autism and the technical mind. For details, visit ScientificAmerican.com/nov2012/baron-cohen