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NEUROSCIENCE

Making Sense of the Brain's Mysteries

Simon Baron-Cohen

THE TELL-TALE BRAIN: A Neuroscientist's Quest for What Makes Us Human. V. S. Ramachandran. xxvi + 357 pp. W. W. Norton and Company, 2011. $26.95.

In his new book, *The Tell-Tale Brain,* V. S. Ramachandran takes us on a fascinating tour of his research regarding a wide range of neurological conditions. These include acquired atypical phenomena such as phantom limbs, innate atypical phenomena such as synesthesia, neurodevelopmental disabilities such as autism, and psychiatric syndromes such as Capgras syndrome. Writing mostly in the first person, he describes how he and his colleagues puzzled over how to explain each unusual phenomenon or syndrome. The result is a highly readable journey into his lab, and into his mind. By showing how talented neuroscientists like Ramachandran set out to make sense of the brain's mysteries, the book will educate the wider public about those mysteries and inspire a new generation of students to move into neuroscience.

The book covers a broad range of conditions. But in this review I will focus on the author's account of autism and the theory he proposes to explain it. According to Ramachandran, in autism the mirror-neuron system is broken. Is this true?

Mirror neurons are a highly appealing concept. As Ramachandran explains, they were first discovered in monkeys in 1992, when Giacomo Rizzolatti and colleagues at the University of Parma in Italy noticed that the same neurons that fired when a monkey reached for an object also fired when the monkey saw another monkey reaching for an object. Since then, scientists have hypothesized that mirror neurons are the building blocks of a number of important human cognitive skills, including imitation, mind-reading and even empathy. Given that children with autism have difficulty with all three of these skills, it seems highly plausible that their mirror-neuron systems might be underdeveloped or malfunctioning.

By January 2006, two compelling pieces of evidence for the "broken mirror" theory of autism had been published. In March 2005, with Lindsay M. Oberman as first author, Ramachandran's group at the University of California, San Diego, published a paper in *Cognitive Brain Research* reporting the results of a study that used electroencephalography (EEG) to measure the brain waves of 10 high-functioning children with autism and 10 age- and gender-matched control subjects. The researchers analyzed the EEG data looking for suppression of mu waves (those with a frequency of 8 to 13 hertz). Mu-wave suppression normally occurs both when a person performs an action and when he or she observes someone else performing an action. The study found that mu waves were suppressed in the children with autism only when they performed an action themselves, not when they observed others acting. The experiment, which is described in *The Tell-Tale Brain,* is an important plank in the mirror-neuron theory of autism.

Shortly afterward, Mirella Dapretto and colleagues at the University of California, Los Angeles, reported in the January 2006 issue of *Nature Neuroscience* the results of an fMRI study in which 10 high-functioning children with autism and 10 control subjects were asked to watch and imitate facial expressions that showed such emotions as anger, fear, happiness or sadness. The children with autism could imitate the faces but had difficulty recognizing their meaning; these children showed reduced activity in the pars opercularis of the inferior frontal gyrus, which is held to be part of the mirror-neuron system. Ramachandran notes that other researchers, including Riitta Hari and Michele Villalobos, have corroborated his hypothesis.

However, the results of a study published in *Neuron* in 2010 suggest that the mirror-neuron system in people with autism may in fact work normally. In typical people, mirror neurons are known to fire more weakly when a movement is repeated than when it is initially made. So Ilan Dinstein at the Weizmann Institute in Rehovot, Israel, together with colleagues at New York University, set out to test whether this was also the case in adults with autism. They asked 13 high-functioning adults with autism and 10 control subjects to perform hand movements, or to watch others perform them, while undergoing fMRI. In some trials the same hand movement was performed repeatedly, and in others the movements varied. The researchers found that both in the people with autism and in the control group, the anterior intraparietal sulcus and the ventral premotor cortex (components of the mirror-neuron system) were active not only while a person was making the hand movements, but also when he or she was watching them being performed by someone else. And in both groups, these mirror-neuron areas showed less activity when the same movements were performed or observed over and over again, but not when a series of novel movements was being performed.

Another recent study also challenges the "broken mirror" theory of autism. Jean Decety at the University of Chicago, working with Yang-Teng Fan and others in Taiwan, used EEG to look for mu-wave suppression in 20 males with autism and 20 controls while they were watching or performing hand movements. The findings, published in the *Journal of Child Psychology and Psychiatry* in 2010, failed to replicate those of Ramachandran's 2005 study: In Decety's subjects, mu-wave suppression while actions were being observed did not differ significantly between the two groups. Neither of these two studies that challenge Ramachandran's theory are discussed in the book.

There are also clinical and experimental reasons for being skeptical of the broken-mirror theory of autism. First, it has been noted from the earliest accounts that when children with autism speak, they often echo other people's speech (so-called *echolalia*), repeating what is said verbatim and faithfully reproducing the intonation, tempo, precise articulation and accent of the other person. Is this not excellent imitation? Would it be possible for someone to do this whose mirror-neuron system was impaired?

In addition, although autism is certainly a social disability, it also has nonsocial features that reveal a different cognitive or information-processing style. For example, people with autism have excellent attention to detail and are able to memorize not just other people's words but also inanimate information such as car license plates or railway timetables. And finally, people with autism often develop obsessions, becoming

immersed in a single topic to the exclusion of all else. How can a single factor like a broken mirror-neuron system explain these nonsocial features? In recognition of this latter point, Ramachandran has come up with a second theory (the "salience landscape theory") to account for the nonsocial features. And in fairness, I should mention that he does acknowledge in a note that the evidence for mirror-neuron dysfunction in autism is "compelling but not conclusive."

Nevertheless, Ramachandran argued in a TED talk he gave in November 2009 that 100,000 years ago mirror neurons evolved and enabled imitation, tool use, theory of mind, empathy, emulation, culture and civilization. He puts a huge weight of importance on these neurons, even though they have not really been measured in humans; this is because the single-cell recordings of brain cells that have been done in experimental animals such as monkeys cannot ethically be done in humans. All we really have are indirect or crude measures of mirror-neuron activity, using technologies such as fMRI. In an essay on the Edge website (http://www.edge.org/3rd_culture/ramachandran/ramachandran_p1.html) Ramachandran wrote, "I predict that mirror neurons will do for psychology what DNA did for biology: they will provide a unifying framework and help explain a host of mental abilities that have hitherto remained mysterious and inaccessible to experiments." Whether he has overstated the importance of mirror neurons and will decide to retract this statement remains to be seen. As an explanation of autism, the theory offers some tantalizing clues; however, some problematic counterevidence challenges the theory and particularly its scope.

But none of these debatable scientific issues diminished my enjoyment of this book, which is important as a record of its author's restless mind and seemingly infinite curiosity. Ramachandran is without doubt one of the world's most stimulating neuroscientists, and his bold ideas offer not just food for thought but explanations of what makes us human.

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CONSERVATION

Encounters with Vanishing Species

Daniel Simberloff

LISTED: Dispatches from America's Endangered Species Act. Joe Roman. viii + 360 pp. Harvard University Press, 2011. $27.95.

The U.S. Endangered Species Act of 1973 (ESA) has been variously criticized for being costly and marginally effective (by Charles C. Mann and Mark L. Plummer, for example, in their 1995 book *Noah's Choice: The Future of Endangered Species*) and lauded for having pulled many species back from the brink of extinction (by Brian Czech and Paul R. Krausman, for instance, in their 2001 book *The Endangered Species Act: History, Conservation Biology, and Public Policy*, and by the contributors to *The Endangered Species Act at Thirty*, a 2006 book edited by Dale C. Goble, J. Michael Scott and Frank W. Davis). The statute has been periodically under threat from Congress since the snail darter case in the 1970s, which resulted in amendments to the Act. In *Listed: Dispatches from America's Endangered Species Act,* Joe Roman uses the ESA as a springboard for the exploration of a broad range of conservation issues. Each chapter opens with discussion of a prominent and usually controversial species listed under the Act. Roman details the disputes that have driven the controversy over that species and then shows how those disputes or similar ones reveal problems and conflicts that are pervasive in conservation worldwide.

Many famous actors appear: the snail darter, the Florida panther, the ivory-billed and red-cockaded woodpeckers, the gray wolf, the humpback whale, the manatee. So do some not as famous: the Indiana bat, the fat threeridge and purple bankclimber snails, the gopher frog. Many of the species are members of what Roman terms the "Class of '67"—the 78 animals that the Department of the Interior declared to be threatened six years before passage of the ESA. The book's main focus is listed animals—plants are discussed only briefly.

Roman is a conservation biologist specializing in marine species and genetics. It is remarkable that even when he is discussing very well-known species, he manages to include interesting, little-known aspects of their stories. Often he has acquired this information from the people who are working on the ground to save these species. He undertakes a staggering amount of travel to interview them, and on many occasions he accompanies them on field excursions under difficult conditions.

These stories read like dispatches from a war reporter in the midst of battle. Roman superbly conveys not only the excitement and dedication of Environmental Protection Agency employees, but also the emotional stresses they face in fighting what is sometimes demonstrably a losing battle against great odds—often in the face of the active opposition of their own employer, as sometimes occurred during the administration of George W. Bush. It is painful to hear about the annihilation of dozens of species of freshwater mollusks from a biologist who has devoted his life to trying to save them, or about the serial destruction of the few ponds suitable for the gopher frog from someone who has studied the species for 30 years. In these cases, as in most of those that Roman details, the science was more than adequate to pinpoint the problem, but the scientists could only watch helplessly as the species fell to deliberate habitat destruction in the service of societal goals—goals as large as water for a burgeoning Atlanta or as small as finding a new site for a truck-repair shop displaced by Hurricane Katrina.

The book's many digressions encompass some issues not directly related to listed species—Lyme disease, AIDS, surgical patients viewing trees from their hospital rooms, the music on Roman's iPod. Usually, however, what initially seems to be an extraneous excursion eventually leads to an important point relevant to the ESA. For instance, a description of six people admitted to Flushing Hospital in New York with high