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writing on science, medicine, &amp; culture

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## A Revealing Reflection

Mirror Neurons seem to effect everything from how we learn to speak to how we build culture

by David Dobbs

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Sometime just before my second child was born, I read that if you stuck your tongue out at a newborn, he'd do the same. So in young Nicholas's first hour, even as my wife was still in the O.R. getting stitched up (40-hour labor, C-section, epic saga), I tried it. Holding the gooing, alert young lad before me in my hands — he was no bigger than a ball of pizza dough — I stuck my tongue out at him. He immediately returned the gesture. I hadn't slept in 40 hours. I laughed till I cried.

I didn't know it then, but Nick was showing off what some consider both one of the greatest drivers of human progress and one of the prime discoveries in recent neuroscience: mirror neurons. These are neurons in key parts of our brain — the premotor cortex, centers for language, empathy, pain — that fire not only as we perform a certain action but when we watch someone else perform that action. The discovery of this mechanism, made about a decade ago, suggests that everything we watch someone else do, we do as well, on a mental scale. At its most basic, this means we mentally rehearse or imitate every action we observe, whether a somersault or a subtle smile. It explains much about how we learn to smile, walk, talk, or play tennis. At a deeper scale, it suggests a common neurobiologic dynamic for our understanding of others, the complex exchange of ideas we call culture, and psychosocial dysfunctions ranging from lack of empathy to autism. It makes sense of why yawns are contagious — to why, watching Olivier fall to his knees, we feel Hamlet's grief for Ophelia.

For some, this explanatory power makes mirror neurons the biggest neuroscientific discovery of the past decade. "This completely changes the way we think about how the brain works," says Marco Iacoboni of UCLA, a mirror-neuron researcher. The eminent cognitive neuroscientist V.S. Ramachandran even ventured 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." In Ramachandran's view, mirror neurons may explain not only how we come to learn and to understand others, but how humans took a 'great leap forward' about 50,000 years ago, acquiring new skills in social organization, tool use, and language that made possible human culture.

### Stumbling onto the Looking Glass

You needn't rely on big-picture speculation, however, to see the wonder of mirror neurons. Even their basics astonish.

The discoverers of mirror neurons, a team of neuroscientists at the University of Parma, Italy, led by Giacomo Rizzolatti, Vittorio Gallese, and Leonardo Fogassi, found them by happenstance. For a study of premotor neuron dynamics, the three men had run electrodes into a few individual neurons in a macaque monkey's premotor cortex to monitor neural activity as the monkey reached for different objects. The eureka moment came when Fogassi (as Rizzolatti remembers it) walked into the room where the monkey was and reached out and picked up a raisin. As the monkey watched, its premotor neurons fired just as they had when the monkey had picked up the raisin. The men could hardly believe what they had witnessed: a sort of sympathetic, observation-driven firing of neurons they thought fired only in action. But after replicating that and similar experiments many times, they realized they had discovered something new, and in a series of 1996 papers they gave the neurons their name.

Since then, the Parma team, working often with teams led by Marco Iacoboni of UCLA, Michael Arbib at USC, and Christian Keysers of the University of Groningen (Netherlands), has spearheaded an effort that has greatly expanded those findings. They've learned, for instance, that it isn't just watching someone take an action that fires mirror neurons. Even in monkeys, mirror neurons fire if they hear the sound of someone doing something — say, tearing a piece of paper. And as researchers began studying humans (using brain imaging rather than electrodes), they found human mirror-neuron systems more robust and numerous than those of monkeys, existing not just in the premotor cortex and the inferior parietal areas but also the posterior parietal lobe, the superior temporal sulcus, and the insula — areas that correspond to our abilities to feel empathy, understand intention, and use language.

### From Action to Understanding

Unlike monkeys, humans can and do use mirror neurons not just to recognize actions but to directly to imitate actions and to understand their meanings. It appears we use mirror neurons to learn everything from our first smiles and steps to our most suave expressions and graceful dance moves. Likewise we use them to appreciate these things — to feel the meaning behind a smile or to enjoy, by experiencing it and in a sense doing it at a premotor neural level, the touch of a hand we see laid on someone else's brow or the thrill of hitting a Sampras backhand.

These functions became evident in the first round of mirror-neuron studies in the late 1990s. Since then, imaging studies have shown that the mirror neuron system in humans encompasses many more areas and functions. In 1998, Rizzolatti and University of South California's Michael Arbib found that one of the areas with the most active mirror-neuron systems is the famous "Broca's area," which Paul Broca found in the 1950s to be critical for language processing. Mirror-neuron theory began to mesh with existing language theory that held actions to have a syntax similar to that of spoken or signed language. It's "Hand grasps ball" in action, sign language, a spoken sentence, and neural dynamics as well; language, in short, rises from the same syntactic understanding that our mirror neurons generate. This idea gained credence in 2005 when an international team including Gallese and Rizzolatti found that when people listened to sentences describing actions, the same mirror neurons fired as would have fired had they performed the actions described or witnessed them being performed — a stunning abstraction of a process that would seem to be quite visual and visceral.

The other great expansion of human mirror neuron systems appears to be in our understanding of others' intentions and even their emotions. Several findings have demonstrated this, two with particular elegance.

One, described by UCLA's Iacoboni in 2005, shows that our mirror neurons work in elaborate sets, so that we possess a basic set of mirror neurons corresponding to an action's most essential form — reaching, for instance — that is supplemented by other mirror neuron groups that selectively fire according to the action's perceived purpose. Iacoboni had volunteers watch films of people reaching for various objects within a tea-time setting — a teapot, a mug, a pitcher of cream, a plate of pastries, napkins — in different contexts. In every instance, a basic set of "reaching" mirror neurons fired. But different additional sets of mirror neurons would also fire depending on what expected action was suggested by the setting — neatly set for the beginning of tea time, for instance, versus looking as if tea had just been finished (pastries eaten, cup dirty) so that it looked ready to be cleaned up. If the viewer expected the hand to pick up a teacup to drink, one set fired; if the viewer expected the hand to pick up a cup to clean it, another set would fire. Thus mirror neurons seem to play a key role in perceiving intentions — the first step not just in understanding others but in building social relations and empathy.

Several experiments, meanwhile, have shown that mirror neurons help us share others' experience as reflected in their expressions, providing a biological basis for empathy and for the well-known contagiousness of yawns, laughter, and good or bad moods. One of the most convincing (and certainly the most memorably titled) such paper is Bruno Wicker's "Both of Us Disgusted in My Insula: The Common Neural Basis of Seeing and Feeling Disgust," published in 2003. For that paper, a European team using fMRI imaging found that feeling disgust or seeing a disgusted look on someone else's face fired the same set of mirror neurons in the insula, a part of the cortex active in synthesizing convergent information to experience disgust and pain.

### When the Mirror Fogs

Faults in a system so central should create profound problems. And indeed it appears that dysfunctions or deficits in mirror-neuron systems may help account for problems ranging from personal coolness to autism. The apparent failure of mirror neuron systems in autism is particularly intriguing. The cause and even the nature of this strange, isolating condition has eluded researchers for decades, leaving sufferers and their families and caregivers grasping uncertainly for understanding, much less a fix. But research suggests that an inactive mirror neuron system may explain the failures in language, learning, and empathy that do so much to isolate the autistic.

The findings suggest breakdowns in both basic and complex mirror-neuron dynamics. One study, for instance, found that mirror neurons that fired in nonautistic people when they watched someone else make meaningless finger movements didn't fire in autistic children. This suggests a failure of mirror neurons' most basic function, that of recognizing others' action. In another study, researchers showed both autistic and nonautistic adolescents pictures of people with distinctive facial expressions. Both the autistic and nonautistic subjects could imitate the expressions and say what emotions they expressed. But while the nonautistic teens showed robust activity in mirror neurons corresponding to the emotions expressed, the autistic teens showed no such activity. They understood the expressions cognitively but felt no empathy. Whether or how these discoveries might lead to treatments isn't clear. Yet identifying this apparent deficit, if the findings hold up, should prove a major advance in understanding autism's neural dynamics.

### Reflections Deep and Dark

Mirror neurons' role in understanding others lies at the heart of the deeper claims about them. Some, like V.S. Ramachandran, believe that this dynamic made mirror neurons crucial in the development of the elaborate social skills, social networks, and knowledge infrastructure we call culture — everything from too use to Shakespeare, collaborative hunting to hip-hop. This assertion gains weight from language's importance to social understanding and the roughly simultaneous emergence of more complex mirror-neuron systems and human cultures roughly 5,000 to 10,000 years ago. Mirror neurons, say proponents of this theory such as Michael Arbib, allowed early humans to first understand crude, possibly pantomime-like gestures, then more elaborate gestures, and finally rudimentary language, after which the process snowballed. As more elaborate and abstract communication became possible, information could be spread, built upon, and modified to create the intellectual and social dynamic we call culture.

Mirror neurons don't always reflect on us so kindly, of course. Mirror neurons may reveal a new, more sinister perspective on the dynamics of and lessons taught by violent video games, for instance. UCLA's Iacoboni is pursuing studies that suggest that such games reinforce, at a basic neuronal level, an association of pleasure and accomplishment with inflicting harm — a dynamic it would seem we wouldn't want to encourage. Iacoboni speculates that the strength of mirror neuron systems may be great enough that imitative violence, of so reinforced, may be harder to resist than we'd like to think. The power of mirror neurons systems, says Iacoboni, "suggest that imitative violence may not always be a consciously mediated

process.” – in other words, less subject to control than we would like.

Work on mirror neurons has greatly accelerated in the last five years and seems sure to upshift even more. Whether Rizzolatti and Gallese, 1996, will turn out to be as big as Watson and Crick, 1953 remains to be seen. Yet mirror neurons already constitute one of the richest areas in neuroscience, both intellectually and in terms of experimental results. If their enormous explanatory power is backed by more robust experimental results, they might indeed become the DNA of neuroscience. And in the meantime, mirror neurons already explain some intriguing wonders. My young Nicholas, for instance, is now four – which is old enough, it turns out, to stick his tongue out at me of his own accord. I have no idea where he learned such a thing. But at least I know how.

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