Mirror Neurons: How We Reflect on Behavior

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In the mid-1990s, scientists at the University of Parma, in Italy, made a discovery so novel that it shifted the way psychologists discuss the brain. After researchers implanted electrodes into the heads of monkeys, they noticed a burst of activity in the premotor cortex when the animals clutched a piece of food. In a wonderfully fictitious account of the discovery, neuroscientist Giacomo Rizzolatti was licking ice cream in the lab when this same region again fired in the monkeys. In an equally wonderful truthful account, the neurons in this region did, in fact, fire when the monkeys merely watched researchers handle food.

Mirror neurons — the tiny neurological structures that fire both when we perceive action and take it, exposing the true social nature of the brain — had been identified. Since that time, the term has become a powerful buzz phrase: technical enough to impress at dinner parties; simple enough to explain to Grandma; sweeter sounding than, say, the Bose-Einstein condensate. Recently, I wrote an article for this magazine about the power of movies on behavior; to my surprise, many researchers discussed, without prompting, the role mirror neurons play in explaining why viewers connect so strongly with on-screen emotions. A short while later I read an article in Time magazine that said mirror neurons might form the basis for empathy, social behavior, and even language. One psychologist placed these neurons on the same plane as DNA in the realm of scientific discovery.

Mirror neurons, it seems, are of the utmost importance in human mind, and on the tip of the collective psychological tongue.

“It’s going to make a big change,” says neuroscientist Marco Iacoboni, University of California, Los Angeles, of the discovery’s impact on psychology. “Psychological studies started with the idea that a solitary mind looks at the world in a detached way. Mirror neurons tell us we’re literally in the minds of other people.”

Multitasking Mental Cells

The striking implication of mirror neurons is that the same brain region that controls action also supports perception, writes Günther Knoblich, Rutgers University, in the June 2006 Current Directions in Psychological Science. If observing behavior occurs in the same area as actually behaving, then social interaction would seem to play a large role in cognition. It explains, for example, why spectators at a boxing match sometimes jab at the air and why seeing a violent blow to the head makes them recoil physically. The poet John Donne was on the right track: We are not islands, unto ourselves.

This social link between perception and action can be traced back to William James, says Knoblich. James explained that performing a movement required first having a mental picture of that movement. In the 1970s and 1980s, psychologists like APS Fellow Anthony Greenwald and Wolfgang Prinz extended this ideomotor principle, demonstrating that seeing and doing branch off the same tree.

But it was the work done with monkeys in Rizzolatti's lab that gave a name to the multitasking mental cells that make this possible. Mirror neurons fire when monkeys break peanuts in their hands, when they see others break peanuts — even when, in total darkness, they merely hear peanuts being broken. "That's why it's called a mirror neuron," says Iacoboni. "It's almost like the monkey is watching his own action reflected by the mirror."

Mirror neurons haven't been pinpointed in people with the same precision that electrodes can pinpoint them in monkeys. (As a result, many researchers refer to a general "mirror system.") Still, several recent functional imaging studies support a social side to human cognition, with which people internally replay the actions they view in another before acting themselves.

In a 2003 study in the Proceedings of the National Academy of Sciences, a research team that included Iacoboni found that imitating and observing facial expressions activated the same regions of the brain. A study in Science a year later showed activity in similar neural regions whether a subject actually experienced a painful stimulus or simply observed a loved one receiving the same shock. To many researchers, these and similar findings suggest that mirror neurons play a large role in empathy.

The multitalented mirror system might even understand another person's intentions, suggests research published in PLoS Biology in 2005. To test whether the mirror system simply recognizes action or also grasps the meaning of an action, Iacoboni and his colleagues showed different types of videos to 23 subjects. "Context" clips, free of action, showed a teapot, a mug, and some cookies before and after tea time. "Intention" clips showed the same before and after scene, but included a hand getting ready to either drink the cup (before tea time) or clean up the cup (after).

While mirror regions showed similar activity during context videos, they showed significantly more activity during the "drinking" intention clips than during the "cleaning" intention clips. Mirror neurons, the test suggests, might do more than acknowledge action; they might codify it.

"Our social dimension would be completely destroyed" without mirror neurons, Iacoboni says. "The only way I could understand you would be by complicated mechanisms. It would be a very different world."

Baby See, Baby Do

People don't waste much time becoming part of this social world. Babies can imitate behavior two to three weeks after they're born, says developmental psychologist and APS Fellow and Charter Member Andrew Meltzoff, University of Washington. In a 1977 issue of *Science*, decades before the term "mirror neurons" existed, Meltzoff published evidence that infants this young can imitate a mouth opening, a finger moving or a tongue peeking through lips. The discovery of mirror neurons was a neurophysiological explanation for the developmental behaviors Meltzoff had been noticing for decades.

"Human beings are not born exclusively with a set of reflexes or fixed action patterns," says Meltzoff. "A key mechanism is learning from social others by observing."

Meltzoff's findings flew in the face of Jean Piaget's solipsistic theories that people begin life in asocial isolation, slowly gaining an understanding of the relationship between the self and other. "Babies don't become social," Meltzoff says, "they're social at birth."

This early work set the stage for what he now calls the “Like Me” theory of child development. In the first months and years of life, babies realize that other people are like them. “From the moment we’re born, we’re organizing movement as ‘like me,’” or not like me, he says. “A tree blows, but it’s not moving like me. A ball flies, but it’s not moving like me. But a mother opens her hands, and suddenly the baby’s riveted. They can begin to learn.”

Over time, babies learn that they can act with intent and variety. They experience the ability to perform an action differently from the person they are imitating. Eventually they realize internal states, such as desire; further down the line they develop empathy.

The child-rearing implications for this work are powerful: Imitative social games, such as patty-cake, can help create the mental maps of others that lead to empathic feelings. “Empathy doesn’t emerge miraculously, as a virgin birth,” Meltzoff says. “It grows out of things that are simpler beginnings.”

Recently, however, Meltzoff and his colleague Betty Repacholi have found that infants aren’t simply sponges that absorb imitation only to spill it back out as processed. Infants as young as 18 months old can regulate their imitation, the researchers report in the March/April 2006 *Child Development.*

To test such regulation, the researchers played with an object in front of infant subjects. After a while, another person entered the room. Sometimes this person expressed anger toward the experimenter performing the task; other times, the person remained neutral.

After this person left the room, the infants were given the chance to play with the object. At this point, the person who had been either angry or neutral returned to the room. Infants who had seen the neutral person were more likely to play with the object than those who had witnessed the angry outbreak, the researchers report.

What’s more, infants who had seen an angry response were more likely to play with the object if the angry person either didn’t return to the room or faced away from the infant. The research, says Meltzoff, shows for the first time that 18-month-olds can modify their imitation on the basis of their surroundings.

“That’s what makes humans different from monkeys,” he says. “Mirror neurons show how what you see can be connected with what you do, but human beings can also regulate their behavior.”

My Brain’s a Blender

Psychologists are finding that the mature adult mirror system does indeed seem to regulate itself, particularly when it comes to empathy. Such checks and balances occur for our own good. If, through the mirror system, we were able to completely experience the pain of another person, we might constantly feel distressed.

Clarifying this phenomenon might require a temporary substitute for the term “mirror system.” A regulated mirror system acts not as a complete mirror, merely flipping around another’s emotions, nor as a sponge, expelling only what it soaks up. Perhaps the mind is more like a kitchen blender: We understand the raw feelings of a friend in pain, but instead of devouring them whole we mix, chop, and purée them into a more digestible serving. Our blender brains enable us to simultaneously provide support and avoid emotional paralysis.

“The best response to another’s distress may not be distress, but efforts to soothe that distress,” says Jean Decety, University of Chicago, who discusses the subject in the April 2006 Current Directions in Psychological Science. “Empathy has a sharing component, but also self-other distinctions and the capacity to regulate one’s own emotions and feelings.”

In one study, writes Decety, researchers showed subjects a video of patients feeling pain as a result of medical treatment. Some subjects imagined themselves in the patient’s position, whereas others merely considered the patient’s feelings. Patients who put themselves in the painful shoes showed stronger neural responses in regions of the brain involved in experiencing real pain.

“If we were to consciously feel what [others] feel all the time, we would be in permanent emotional turmoil, leaving no room for our own emotions,” report Frédérique de Vignemont and Tania Singer in a recent Trends in Cognitive Science. When subjects playing a game witness a fair opponent in pain, neural regions controlling empathy are activated, the researchers found. But that’s not always the case when subjects, particularly males, see a deceptive opponent in pain. The way that relationships qualify empathy might explain why some people appear to lack compassion. Experiencing empathy for someone considered an enemy, after all, may not be a beneficial behavioral characteristic.

More primitive motivations, such as hunger, might also govern the mirror system. In a study that appeared in Cerebral Cortex, Decety, Meltzoff, and Yawei Cheng showed two groups of subjects a video of a person grasping food. Some of the subjects had fasted for at least 12 hours before the viewing; others had a meal before the session. Using functional imaging, the researchers found greater activity in the mirror systems of the hungry subjects. When a blender brain is running on empty it reacts strongly to the site of fresh fruit; when it’s filled to the brim with a smoothie, it’s less interested.

“There is a functional link between motivation and the motor system that will be used to achieve a goal,” Decety says. “When you want something badly, our perception-action system is readily tuned to perceive and act upon the aspects in the environment that will satisfy our internal state.”

What remains unclear about mirror system regulation is the order in which it occurs. Empathic response might occur automatically, only to be modified later; it might also be the outcome of a split-second neurological appraisal.

Cracks in the Mirror System

The evolutionary benefits of an efficient and well-regulated perception-action system that swings into action shortly after birth are numerous. A glimpse into another person’s emotions might help predict that person’s behavior. Understanding the face of pain from an early age could keep us from touching a hot stove. At a greater social level, a personal insight into the experiences of others could aid cooperation.

But as the functions of a healthy mirror system become clearer, some researchers have turned attention to what happens when the system falters. Many have discovered a connection between dysfunctional mirror regions and social disorders — namely, autism.

“At this point, it seems that autism is the field in which [the mirror system] will have the most immediate impact,” says Iacoboni.

To investigate this connection, Iacoboni and his colleagues studied the neurological activity of 20 child subjects, half of whom had autism. The subjects saw 80 pictures of faces expressing anger, fear, happiness, sadness, or nothing in particular. The researchers asked some subjects to merely view the faces and others to imitate them.

In the group of autistic children asked to imitate the faces, the researchers found no activity in brain regions associated with mirror neurons they report in a 2006 issue of Nature Neuroscience — the first report to demonstrate a difference in mirror activity between a control group and autistic children. The more severe the condition, says Iacoboni, the less active the mirror-neuron system seems to be.

Others believe it's too early to know the role mirror regions play in social impairments. So many theories have connected autism and brain dysfunction that the only responsible way to approach any new one, however promising, is with caution, says Decety.

"People tend to overgeneralize when there's some exciting finding," says Knoblich. Mirror neurons play a clear and important role in social cognition, he says, but the scope of that role — and how it is influenced by other processes, such as language — remains to be seen. "There's a lot of hype around the mirror system, but I don't think it's arrived yet in psychology enough."