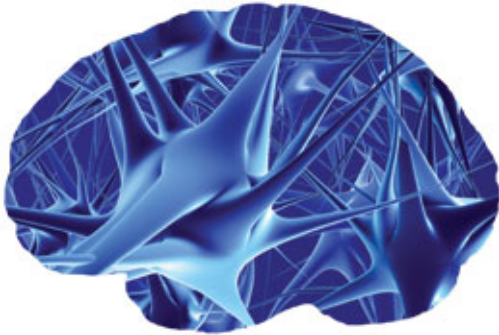


Reflections on Mirror Neurons

February 27, 2011



In 1992, a team at the University of Parma, Italy discovered what have been termed “mirror neurons” in macaque monkeys: cells that fire both when the monkey took an action (like holding a banana) and saw it performed (when a man held a banana). Giacomo Rizzolatti, the celebrated discoverer, will deliver the Keynote Address at the APS Convention in Washington DC, USA, on May 26, 2011, and report on his latest findings. To tide us over until then, here’s a report on the state of mirror neuron science.

Like monkeys, humans have mirror neurons that fire when we both perceive and take an action. Locating the tiny cells means attaching electrodes deep inside the brain. As this has hardly been practical in humans, studies have had to rely on imaging, which shows which areas of the brain “light up” in different circumstances. By last year, a meta-analysis of 139 imaging studies confirmed mirroring activity in parts of the human brain where, in monkeys, mirror neurons are known to reside. Because the lit-up areas contain millions of neurons, for humans most researchers speak of a “mirror system,” rather than mirror cells. Last year, single mirror neurons were recorded in humans for the first time, using in-depth electrodes, in 21 epileptic patients.

The cells showed up unexpectedly in an area known for memory, the medial temporal lobe, as well as in areas where they were expected. The discovery suggests that memory is embedded in our mirror system, says Marco Iacoboni (University of California, Los Angeles), a leading authority in the field and a co-author of the epilepsy study. Perhaps, he says, we form memory “traces” whenever we see or observe an action. “It’s a lovely idea,” says Rizzolatti, though he adds that it’s too early to say.

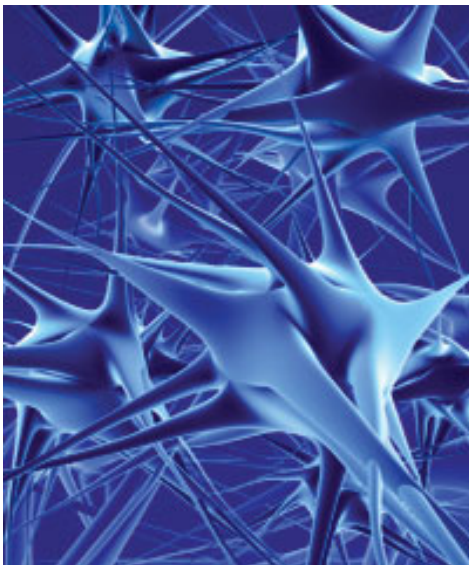
The mirroring system includes a mechanism that helps the brain record the difference between seeing and acting. In the epilepsy study, some neurons fired more during action and others fired more during observation. These same cells, Iacoboni proposes, help us distinguish between the self and others.

That’s an important issue, to say the least. We often confuse our own actions with those of other people. In a study published recently in *Psychological Science*, Gerald Echterhoff, University of Muenster, Germany, and his co-authors reported that people who had watched a video of someone else doing a simple action — shaking a bottle or shuffling a deck of cards — often mistakenly recalled two weeks later that they had done so themselves. The mistake occurred even when participants were warned that they could mix up other people’s actions with their own. Echterhoff and a co-author, Isabel Lindner, of the

University of Cologne, Germany, plan to conduct imaging studies to test if the phenomenon is related to mirroring.

Mirror neurons are present in infant monkeys. Three years ago, the first abstract appeared reporting that surface electrodes had recorded mirroring in monkeys one- to seven-days old as they watched humans stick out their tongues and smack their lips. Says Pier Francesco Ferrari, of the University of Parma, and co-author of an upcoming study, “This is the first evidence that infants have a mirror mechanism at birth that responds to facial gestures. Without any experience of stimulation, they are able to focus their attention on the most relevant stimuli and respond.” Sometimes the days-old monkeys even stuck out their tongues when they saw the human tongue, Ferrari says.

In monkeys, mirror neurons are present in the insula, an emotion center. Despite all the claims linking mirror neurons to empathy, Rizzolatti says he is only now reporting the discovery of a few mirror neurons in the insula in monkeys, “a reservoir for disgust and pain. Many other factors control how we react,” he says, “but mirror neurons are how we recognize an emotion in others neurally.”



Mimicry, linked to mirror neurons, makes monkeys bond. The idea that mimicry helps humans bond is well-accepted, but the first controlled experiment, with a monkey, came last year, Ferrari says. In that study, reported in *Science*, his team presented monkeys with a token and rewarded them with treats if they returned it. The monkeys had a choice of returning the token to either of two investigators, only one of whom was imitating the monkey. The monkeys consistently chose to return the token to the person who imitated them and spent more time near that investigator.

Mimicry in humans reflects social cues. The idea that we’re primed in one part of our brain to like those who mimic us doesn’t rule out other discriminations. Unconscious mimicry is deeply social and, as such, reflects prejudice, says Rick van Baaren of Radboud University in the Netherlands. In a 2009 overview of the science of mimicry published in the *Philosophical Transactions of The Royal Society*, he points out that people are more likely to mimic a member of the same ethnic group, less likely to mimic a stigmatized person who is obese or has a scar, and less likely to mimic members of a group we view with prejudice. In fact, humans tend to react badly when mimicked by someone from an “out group.”

The mirror systems of two people can move in tandem. Many researchers had proposed that the brains of

two people “resonate” with each other as they interact, with one person’s mirror system reflecting changes in the other. Last spring, *the Proceedings of the National Academy of Sciences* reported on the brain activity of people playing the game of charades. The observer and gesturer performing the charade did move neurologically in tandem, says co-author Christian Keysers, of the University Medical Center in Groningen, The Netherlands. Keysers says the discovery backs up the idea that mirroring plays a key role in the evolution of language. We’re exquisitely responsive to gestures, he says; “Nobody had ever shown that during gestural communication the observer’s mirror system tracks the moment to moment state of the gesturer’s motor system.”

Mirror neurons respond to sound. In monkeys, mirror neurons fire at sounds associated with an action, such as breaking a peanut or tearing paper. Mirroring has been discovered in birds hearing bird song, and in humans. Recent work, led by Emiliano Ricciardi at the University of Pisa, Italy, found that blind people, using their hearing, interpret the actions of others by recruiting the same human mirror system brain areas as sighted people.

Mirror neurons code intentions. Whether mirror neurons register the goal of an action or other higher-level systems must chip in to judge other people’s intentions has been the subject of much debate. The evidence is accumulating that mirror neurons “implement a fairly sophisticated and rather abstract coding of the actions of others,” says Iacoboni. One clue is that while a third of all mirror neurons fire for exactly the same action, either executed or observed, the larger number — about two thirds — fire for actions that achieve the same goal or those that are logically related — for example, first grasping and then bringing an object to the mouth. And these neurons make fine distinctions: When a monkey observed an experimenter grasping an object and pantomiming the same action, the neurons fired when the experimenter grasped the object but not during the pantomime. “In academia, there is a lot of politics and we are continuously trying to figure out the ‘real intentions’ of other people,” Iacoboni says. “The mirror system deals with relatively simple intentions: smiling at each other, or making eye contact with the other driver at an intersection.”

Mirroring increases with experience. In the first studies, monkeys mirrored when they saw a person grasping food but not if the person used a tool. That made sense because monkeys don’t use tools. In later research, monkeys did mirror humans using a tool; Iacoboni suggests that their brains had “learned,” adjusting to seeing researchers with tools. In humans, more mirroring activity occurs when dancers see other dancers perform routines they know well. Mirroring in blind people is more active in response to more familiar action sounds.

Stimulating the mirror system helps stroke victims. If mirroring develops as we learn, perhaps triggering mirroring can teach. Two studies with stroke victims, for example, have found that stimulating the mirror system helped them recover particular motor actions, says Ferdinand Binkofski at the University of Luebeck, Germany. When stroke victims received “action observation therapy,” in which they observed an action repeatedly, they regained more ability. Compared to a control group, the stroke victims also showed more mirroring in brain scans.

Children with autistic syndromes have mirroring defects. As early as 2001, researchers hypothesized that a deficit in the mirror neuron system could explain some of the problems of autistic patients. As of September, 2010 twenty published papers using brain imaging, magnetoencephalography, electroencephalography, and transcranial magnetic stimulation support this idea, and four failed to

support it, according to Iacoboni.

The hope is that basic science in the mirror system could lead to a better understanding of emotional difficulties. As Ferrari points out, some infant monkeys separated from their mothers show “symptoms like those in autistic kids. You see them rocking and avoiding your gaze.” Others develop normally. Ferrari and his colleagues plan to follow the infants they studied and measure whether strong mirror neuron activity in the first week of life indicates sociability later on. “We hope to create a picture of how brain activity interacts with the social environment to put some monkeys more at risk,” he says. “The obvious direction is to translate this to humans.”

Mirror neuron research continues to grow fast, across disciplines. Already the number of items produced by a PubMed search, for example, increased twenty-fold between 2000 and 2010, although that number only doubled for “Stroop and brain,” another popular topic. The ongoing technical challenge remains: Mirror neurons are not the majority of cells in the brain areas where they are located, so it is still difficult to pinpoint their role when those areas show spiking activity. Iacoboni suggests that mathematical modeling will help make more of this data useful. Such modeling allowed Keysers, for example, to establish the existence of resonance in the charades study. So what can we expect next? Most likely, Iacoboni, says, more work with depth electrodes in neurological patients and studies like Ferrari’s to test whether mirroring is a biomarker of sociality. A promising underexplored subject is the inhibitors that keep us from mimicking (but fail recovering addicts who relapse when they see others consume). Behind all this work will be a growing consensus that mirror neurons evolved in humans so we could learn from observation and communication. œ