Mirrors in the mind: New studies elucidate how the brain reflects onto itself the actions of others

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In three new independent studies, researchers have deepened our understanding of the remarkable ability of some specialized areas of the brain to activate both in response to one's own actions and in response to sensory cues (such as sight) of the same actions perpetrated by another individual.

This ability is thought to be based in the activity of so-called mirror neurons, which have been hypothesized to contribute to skills such as empathy, socialized behavior, and language acquisition. The new findings contribute to our understanding of how conceptually related instances of language and action, and sound and action, are linked in the brain, and how the brain distinguishes actions perpetrated by "self" and by "other."

The studies are reported by three independent research groups: Lisa Aziz-Zadeh (now at USC) and colleagues at the University of Parma, Italy, UCLA; Christian Keysers and colleagues at the University of Groningen, The Netherlands and UC Berkeley; and Simone Schütz-Bosbach and colleagues at University College London, the Max Planck Institute for Human Cognitive and Brain Sciences in Germany, and the University of Rome. The papers appear in the September 19th issue of Current Biology, published by Cell Press.

Mirror neurons were first identified in the cortex of macaque monkeys:

A particular subset of these neurons fire when, for example, a monkey picks up a banana, and when the monkey observes a human picking up a banana in a similar way. Mirror-neuron activity appears to be highly specific, such that a somewhat different set of mirror neurons would fire if a banana were poked, for example, rather than picked up. There is also evidence that mirror neurons link actions not only with visual stimuli, but also with other types of sensory cues. Technical limitations have impeded identification of individual mirror neurons in humans, but brain-imaging studies support the existence of these neurons.

In the new work from Lisa Aziz-Zadeh and colleagues, researchers used a brain-imaging technique to investigate how literal phrases describing actions performed by the mouth, hand, or foot influenced cortical neurons that are activated by the sight of actions being performed by mouth, hand, or foot.

The researchers found a significant concordance between activation of certain cortical areas in response to linguistic descriptions and observed actions relating to the different body parts carrying out the actions. For example, when individuals read literal phrases such as "biting the peach" or "biting the banana," some brain areas activated that were also stimulated by videos of fruit being bitten. Similar findings were obtained for hand actions (for example, grasping a pen) and foot actions (for example, pressing a piano pedal). Together, the findings suggest that mirror neurons play a key role in the mental "re-enactment" of actions when linguistic descriptions of those actions are conceptually processed.

In the study reported by Christian Keysers, Valeria Gazzola, and colleagues, researchers investigated a different question: how mirror neurons might contribute to our understanding of auditory cues. Past work had shown that in monkeys, so-called auditory mirror neurons activate when monkeys perform certain actions and when they hear the same actions being performed. In the new work, the researchers report

new evidence for an auditory mirror system existing in humans as well.

When subjects were presented with sounds corresponding to mouth actions (such as crunching candy, kissing, or emptying a soda can with a straw) and hand actions (such as ripping a sheet of paper or opening a zipper), brain areas are activated that overlap with areas activated by the execution of those actions by the subjects themselves. Within this area, a subregion was preferentially activated when mouth actions were either heard or performed, and another subregion was preferentially activated when hand actions were heard or performed. In addition, the researchers found that most of this mirror system was also responsive to the sight of these actions being performed, suggesting that a particular area of the brain can respond similarly to execution of an action and its representation in different types of sensory cues.

Intriguingly, the researchers also found that of the subjects taking part in the experiment, those that scored higher on tests for empathy activated the system more strongly than those who scored lower on the empathy evaluation. While the relationship between motor mirror systems and empathy skills is far from clear, these findings are consistent with the existence of a link between the two.

Though mirror neurons appear to relate--and, potentially, equate--the actions of oneself with those of another, we are in fact highly adept at distinguishing our own actions from those of someone else. The basis for this distinction is explored in the study reported by Simone Schütz-Bosbach, Patrick Haggard, and colleagues, who used an established method--the so-called rubber-hand illusion--for experimentally manipulating the sense of body ownership. This approach was useful because without such illusion, it is difficult to identify meaningful differences in how the brain responds to actions performed by oneself or others--the two scenarios involve significant differences in, for example, visual viewpoint and familiarity, and other sensory inputs.

Past work had used the rubber-hand illusion to show that when a rubber hand is seen being stroked at the same time that the viewer's own (unseen) hand is synchronously stroked, the viewer feels that the rubber hand becomes part of his or her body.

In the new work, the researchers used this illusion--though in this case, the rubber hand was replaced by a real hand of an experimenter--to control whether a subject experienced that an experimenter's hand was the subject's own or not. This allowed the researchers to investigate whether finger movements made by the experimenter's hand were able to facilitate the subject's own finger movements--this facilitation was measured by the ability of benign stimulation of a particular brain region to promote motor signals (corresponding to those finger movements) in the subject's own hand.

The researchers found that such facilitation did occur, but, curiously, it occurred when the illusion was not effective, and subjects felt that the experimenter's hand was not their own. Observing actions interpreted as one's own tended to suppress motor facilitation. Taken together, the findings indicate that the observation of others facilitates the motor system. The authors point out that the findings also suggest that the neural mechanisms that underlie action observation are intrinsically "social"--that the neural mechanisms map the actions of others onto one's own body, rather than initially treating all observed action (whether perpetrated by one's self or by others) as essentially neutral in ownership. These findings inform our understanding of the motor system's role in social cognition, and support previous suggestions that the motor system may have strongly influenced developments in human social evolution.

Source: Cell Press