Journal Club

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Mirror Neurons and the Lateralization of Human Language

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Review of Aziz-Zadeh et al. (http://www.jneurosci.org/cgi/content/full/26/11/2964)

In the premotor cortex of the macaque there are neurons whose firing rates increase when the monkey makes goal directed movements and when the monkey observes similar movements being made by others. These cells are named "mirror neurons." It has been suggested that by mapping observation of movements onto cells involved in the production of similar movements, mirror neurons help individuals understand and imitate motor goals (Gallese et al., 1996). Several studies have used functional imaging techniques to determine whether mirror neurons exist in humans. Neural activation in response to both movement production and observation has been described in Brodmann area 44 (BA44), located in the pars opercularis of the inferior frontal gyrus (Iacoboni et al., 2005). In the left hemisphere, BA44 contains Broca's area, a brain region that has been the focus of intense study because of its role in language processing and speech production. The close anatomical proximity of mirror neurons to Broca's area has led some to speculate that mirror neurons may have played a role in the lateralization of human language. If true, the human mirror neuron system might also be left lateralized.

In their *Journal of Neuroscience* article, Aziz-Zadeh et al. (2006) used functional magnetic resonance imaging to determine the extent to which the human mirror neuron system is lateralized. Blood oxygen level-dependent (BOLD) neural activity was recorded in each of four experimental conditions. In each condition, subjects saw movies of left and right hands (each hand was presented independently) with the index finger extended between two targets. In the static observation condition, subjects observed a stationary hand. In the action observation condition, subjects watched as the index finger moved toward one of the targets. In the execution condition, the observed hand was stationary, but the subjects moved their own index finger when instructed by an abstract cue. In the imitation condition, the observed index finger moved toward one of the targets and subjects did the same [Aziz-Zadeh et al., 2006, their Fig. 1 (http://www.jneurosci.org/cgi/content/full/26/11/2964/FIG1)]. Responses were made with the same hand as was observed. Images of left hands were presented to the left visual field so that sensory input was confined to the right hemisphere and vice versa for images of right hands. By controlling the hemisphere involved in visual processing and movement production, the authors were able to determine whether mirror neurons were lateralized.

The authors found that observation, execution, and imitation of finger movements resulted in reliable increases in BOLD activity within the pars opercularis. Neural activation increased linearly from observation to execution to imitation conditions, consistent with the properties of mirror neurons. Both left and right visual-field stimuli resulted in bilateral activation of mirror neurons [Aziz-Zadeh et al., 2006, their Fig. 2 (http://www.jneurosci.org/cgi/content/full/26/11/2964/FIG2)]. Stronger activation was seen in mirror neurons ipsilateral to the stimuli: left visual-field stimuli led to stronger activations in the left hemisphere whereas right hemisphere mirror neurons responded to right visual-field stimuli. These findings suggest that cells in the pars opercularis of both the left and right hemisphere demonstrate mirror-neuron like properties and, hence, that mirror neuron activity is not lateralized.

The carefully controlled studies of Aziz-Zadeh et al. (2006) confirm previous findings identifying mirror neurons in the pars opercularis, but also report a novel finding that mirror neuron activation is not lateralized to the left hemisphere. The authors conclude that because mirror neurons in the pars opercularis show bilateral activation they were not precursors to the development of lateralized language function in humans. However, functional imaging studies that shed light on the current organization of the human brain do not necessarily provide insights into the origins of that organization.

The idea that mirror neurons play a role in human language is an intriguing one that to date is based only on the presence of mirror neurons in Broca's area. The close proximity of these two systems may be indicative of functional linkage or it may be a coincidence. Broca's area is classically known as a language area but it is also active during actions such as swallowing (Mosier et al., 1999). The functional role of mirror neurons in Broca's area is, thus, unclear.

Through the action of mirror neurons, subjects can learn new movements simply by observing others (Stefan et al., 2005).

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This suggests that mirror neurons help humans acquire novel patterns of movement control. In a study that used a robot to perturb the path of the jaw, the nervous system corrected altered patterns of movement when the perturbations were applied during speech (Tremblay et al., 2004). Thus, speaking involves specific motor goals that the nervous system works to achieve. Together, these results suggest that precise control of movements during speech can be learned through observation. If true, this may indicate that mirror neurons in Broca's area aid in the acquisition of novel movement patterns required for speech.

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