

McGovern Institute Researchers Discover Brain Patterns for Visual Objects

New approach bridges the gap between neuronal activity and human brain imaging

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Cambridge, MA — February 21, 2006 — One way to open up the black box of the brain is to use non-invasive fMRI brain images that highlight the regions involved in a certain activity, such as recognizing a familiar face. Another method, used in animals but not usually in people, probes that brain region with electrodes, which record the spikes of neural activity in response to specific images. But do a burst of spikes and a bright spot on an fMRI scan mean the same thing, and what do they tell us about how our neurons distinguish among very similar objects?

Neuroscientists in the labs of Tomaso Poggio and James DiCarlo at the McGovern Institute at MIT have developed an approach that may bridge the gap between the electrode and fMRI studies of high-level vision. The study, which appeared in the February 2nd issue of *Neuron*, focused on the inferior temporal cortex (IT), where different neurons are known to recognize or "prefer" specific types of objects, such as faces, fruits, or vehicles.

Typically, electrode studies of the IT region measure the number of electrical spikes emitted from each neuron in response to a visual object. The McGovern Institute team also measured the local field potential (LFP), a more diffuse but very rich signal that contains a different type of information than the spikes do. Spikes essentially tell us what a neuron says: a quick outburst in response to a specific image. LFPs tell us what the neuron itself hears: the steady buzz from the surrounding neighborhood, or the conglomerate input from other neurons, glial cells, and feedback from its own cell body.

"We've shown that LFPs are only weakly correlated with very nearby spike activity, but better correlated with average spike activity over larger spatial regions," explained second author Chou Hung, the post-doctoral associate in the DiCarlo Lab who trained two macaque monkeys to look at a large array of images and then recorded from individual neurons at several hundred IT sites. "Because fMRIs have been previously shown to be correlated with LFPs, our finding is an important piece of the puzzle of what may underlie the fMRI signal, and it encourages further use of fMRI to understand the spatial organization of object representation in IT."

Surprisingly, the recordings showed that the LFP contains information about the object's identity, according to the analysis of first author Gabriel Kreiman, a post-doctoral scientist in the Poggio Lab. Because LFPs already show object selectivity, this provides clues and constraints on how the IT neurons achieve their remarkable object selectivity.

Moreover, analyzing LFP signals over a mini-neighborhood (several millimeters) and

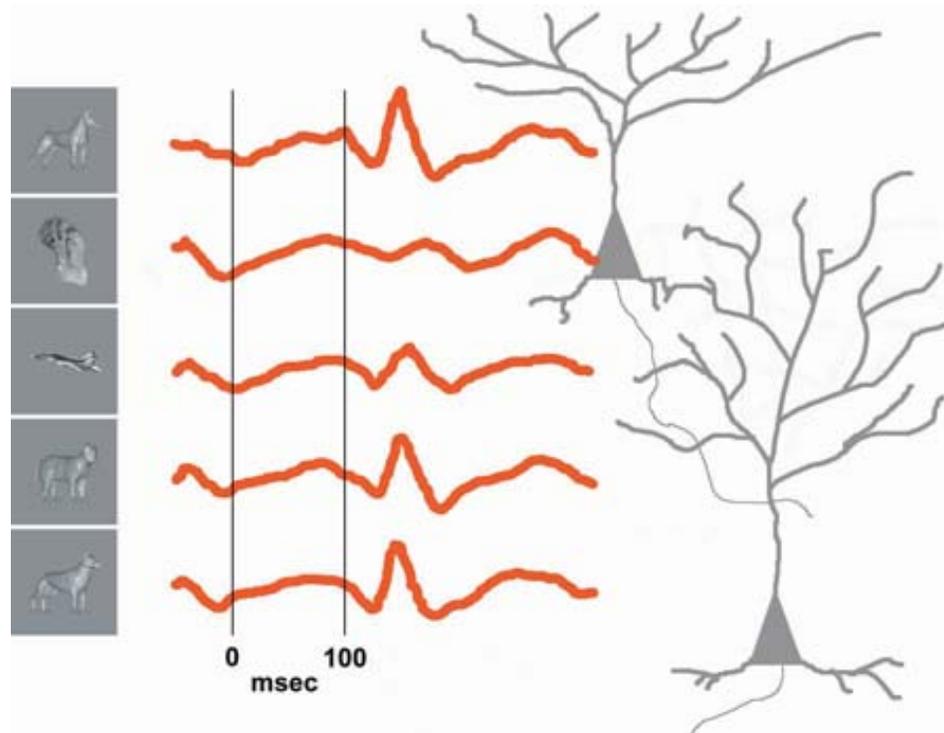

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over a longer time span (several hundred milliseconds - much longer than a single spike) identified geographic clusters of like-minded neurons, such as those that "prefer" an apple over a pear. fMRI studies also pinpoint such preferences, such as a region that brightens up more to faces (or face-like objects) than to any other type of image. Reading the LFP signal can dissect the face region into smaller, more specialized enclaves than fMRI can, such as a minute cluster that responds more strongly to a monkey face than a human's.

"The LFP data suggest the possibility of a larger-scale of organization in this part of the brain, perhaps created by input organization," DiCarlo said. "The results are interesting because they improve our understanding of the organization of this important brain area, they will lead to greater understanding of what fMRI is measuring in humans, and they suggest that LFPs are useful for brain machine interfaces in high-level vision."

The researchers still think spikes contain the most valuable information for decoding how the brain recognizes objects and faces. But LFP analysis could help define the spatial pattern created in the brain by each object. That's one type of information needed to build seeing robots, accurate surveillance systems, or visual prosthetics that can recreate visual images in the brain of a blind person.

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Local Field Potential (LFP) signals for 5 different objects

Visual stimuli (example images of dog, hand, airplane, cat, and a different dog) are shown, and neural signals in the monkey inferotemporal (IT) cortex appear 100 msec later. Local field potential signals (LFPs, in red) are emitted by the web of input activity, mostly from the neurons' dendrites (the gray, tree-like branches). The researchers also recorded the neurons' output activity in the form of spikes (not shown) produced at the cell bodies (triangles). The signals vary in strength for different objects. Comparing the input (LFP) and output (spiking) signals can help to understand how object shapes are processed in the brain.

Drawing by Chou Hung and Gabriel Kreiman, McGovern Institute for Brain Research at MIT

About the McGovern Institute at MIT

The McGovern Institute at MIT is a research and teaching institute committed to advancing human understanding and communications. Led by a team of world-renowned, multi-disciplinary scientists, The McGovern Institute was established in February 2000 by Lore Harp McGovern and Patrick McGovern to meet one of the great challenges of modern science - the development of a deep understanding of thought and emotion in terms of their realization in the human brain. Additional information is available at: <http://web.mit.edu/mcgovern>

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