Mind over matter: Study shows we consciously exert control over individual neurons

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UCLA-Caltech collaboration demonstrates how we focus our thoughts

By Mark Wheeler

Every day our brains are flooded by stimulation — sounds, sights and smells. At the same time, we are constantly engaged in an inner dialogue, ruminating about the past, musing about the future. Somehow the brain filters all this input instantly, selecting some things for long- or short-term storage, discarding others and focusing in on what's most important at any given instant.

How this competition is resolved across multiple sensory and cognitive regions in the brain is not known; nor is it clear how internal thoughts and attention decide what wins in this continual contest of stimulation.

Now a collaboration between UCLA scientists and colleagues from the California Institute of Technology has shown that humans can actually regulate the activity of specific neurons in the brain, increasing the firing rate of some while decreasing the rate of others. And study subjects were able to do so by manipulating an image on a computer screen using only their thoughts.

Reporting in the Oct. 28 issue of the journal Nature, UCLA professor of neurosurgery Itzhak Fried and Caltech neuroscientist Christof Koch, along with colleagues, recorded the activity of single neurons in patients implanted with intracranial electrodes (for clinical reasons) and demonstrated that humans regulate the activity of their neurons to intentionally alter the outcome of all this stimulation.

Such pioneering intracranial recordings from neurosurgical patients have been carried out at UCLA under the direction of Fried for nearly two decades now, with the goal of unraveling the underpinning of cognition at the cellular level in humans.

In 2005, Fried, Koch and colleagues found that individual neurons are able to recognize people, landmarks and objects (thus identifying in one a patient a so-called "Halle Berry neuron" that consistently fired when viewing the actress' picture). The finding suggested a consistent and explicit

code that plays a role in transforming complex visual representations into long-term and more abstract memories.

Then, two years ago, in a paper in the journal Science, Fried and other colleagues showed that the act of remembering something from the past — a short sequence from television's "The Simpsons," for example — can bring to life the same individual brain cells that had responded the first time the episode had been seen.

Now Fried and Koch, along with lead author and Caltech postdoctoral fellow Moran Cerf, have found that individuals can exert conscious control over the firing of these single neurons, thus choosing what to focus on. The researchers demonstrated this by having individuals manipulate the behavior of an image on a computer screen by thought alone.

The work, said Fried, who directs the UCLA Epilepsy Surgery Program, is another step forward in "understanding how the brain transforms external reality into mental objects. What these findings show is that thought alone can shape and override the reality of the visual input."

The study was conducted on 12 patients who were being treated at Ronald Reagan UCLA Medical Center for intractable epilepsy. The patients had been implanted with intracranial depth electrodes to identify seizure foci for potential surgical treatment. Electrode location was based solely on clinical criteria. The researchers, with the patients' consent, "piggybacked" their research, using the same electrodes to record the activity of individual neurons in parts of the medial temporal lobe (MTL), a brain region that plays a major role in memory and emotion.

Prior to recording the activity of the neurons, each patient was interviewed to learn about their interests. Some liked the Boston Red Sox, some the TV show "House," others Marilyn Monroe or the band Guns N' Roses. Eventually, for each patient, the researchers settled on four images, each of which caused a particular neuron to fire. (The individual neurons studied by Fried and his colleagues are considered representative of groups of neurons that respond similarly to a particular image or stimulus.)

The four strongly responding neurons, representing the four different images, were selected for further investigation. By thinking about the individual images that were displayed on a laptop computer — the picture of Marilyn Monroe, for instance — the patients triggered the activity of their corresponding neurons, which could be translated into the movement of a cursor on a computer screen, thus creating, in Cerf's words, a "mini brain-computer interface."

"The goal was to get patients to control things with their minds," Cerf said. "At the same time, we wanted to take it one step further than just brain–machine interfaces and tap into the competition for attention between thoughts that race through our minds."

So the team asked patients to think of one of their four images. As they did so, causing the related neuron to fire, the image appeared on the screen. Other images were then placed on the screen by the researchers as a distraction to the patient. The patient was told to focus on his or her particular image, which caused that image to brighten on the screen and the others to fade. Overall, the patients achieved a 70 percent success rate in brightening their target image.

More importantly, the research showed that the individuals were controlling the firing rate of their neurons in the MTL. For example, when shown images of Marilyn Monroe, the object of one of the subjects' focus, and the actor Josh Brolin, the "distractor," the patient was able to excite the set of neurons responding to Monroe while at the same time suppressing the population of neurons representing Brolin. Other neurons in the MTL that represented other concepts or familiar persons were not affected.

The results show that "individuals can rapidly, consciously and voluntarily control neurons deep inside their head," said Koch, Caltech's Lois and Victor Troendle Professor of Cognitive and Behavioral Biology and a professor of computation and neural systems.

"Looking at these results," Fried said, "people may ask, 'Do we control our neurons or do our neurons control us,' while the ultimate reductionist's answer may be, 'We are our neurons.' "

Other study authors included Nikhil Thiruvengadam, Florian Mormann, Alexander Kraskov and Rodrigo Quian Quiorga.

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The UCLA Department of Neurosurgery provides the finest and most comprehensive patient care through innovative clinical programs in minimally invasive brain and spinal surgery; neuroendoscopy; neuro-oncology for both adult and pediatric brain tumors; cerebrovascular surgery; stereotactic radiosurgery for brain and spinal disorders; surgery for movement disorders such as Parkinson's disease; and epilepsy surgery.