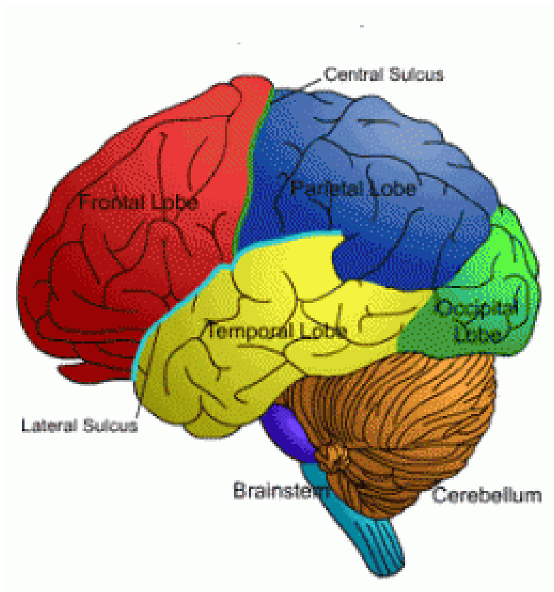
Scientists pinpoint brain's area for numeral recognition

April 16 2013



Brain diagram. Credit: dwp.gov.uk

Scientists at the Stanford University School of Medicine have determined the precise anatomical coordinates of a brain "hot spot," measuring only about one-fifth of an inch across, that is preferentially activated when people view the ordinary numerals we learn early on in elementary school, like "6" or "38."

Activity in this spot relative to neighboring sites drops off substantially when people are presented with numbers that are spelled out ("one" instead of "1"), homophones ("won" instead of "1") or "false fonts," in which a numeral or letter has been altered.

"This is the first-ever study to show the existence of a cluster of nerve cells in the human brain that specializes in processing numerals," said Josef Parvizi, MD, PhD, associate professor of neurology and neurological sciences and director of Stanford's Human Intracranial Cognitive Electrophysiology Program. "In this small nerve-cell population, we saw a much bigger response to numerals than to very similar-looking, similar-sounding and similar-meaning symbols.

"It's a dramatic demonstration of our brain circuitry's capacity to change in response to education," he added. "No one is born with the innate ability to recognize numerals."

The finding pries open the door to further discoveries delineating the flow of math-focused information processing in the brain. It also could have direct clinical ramifications for patients with dyslexia for numbers and with dyscalculia: the inability to process numerical information.

The cluster Parvizi's group identified consists of perhaps 1 to 2 million nerve cells in the inferior temporal gyrus, a superficial region of the outer cortex on the brain. The inferior temporal gyrus is already generally known to be involved in the processing of visual information.

The new study, which will be published April 17 in the *Journal of Neuroscience*, builds on an earlier one in which volunteers had been challenged with math questions. "We had accumulated lots of data from that study about what parts of the brain become active when a person is focusing on arithmetic problems, but we were mostly looking elsewhere and hadn't paid much attention to this area within the inferior temporal gyrus," said Parvizi, who is senior author of the study.

Not, that is, until fourth-year medical student Jennifer Shum, who also is doing research in Parvizi's lab, noticed that, among some subjects in the first study, a spot in the inferior temporal gyrus seemed to be substantially activated by math exercises. Charged with verifying that this observation was consistent from one patient to the next, Shum, the study's lead author, reported that this was indeed the case. So, Parvizi's team designed a new study to look into it further.

The new study relied on epileptic volunteers who, as a first step toward possible surgery to relieve unremitting seizures that weren't responding to therapeutic drugs, had a small section of their skulls removed and electrodes applied directly to the brain's surface. The procedure, which doesn't destroy any brain tissue or disrupt the brain's function, had been undertaken so that the patients could be monitored for several days to help attending neurologists find the exact location of their seizures' origination points. While these patients are bedridden in the hospital for as much as a week of such monitoring, they are fully conscious, in no pain and, frankly, a bit bored.

Over time, Parvizi identified seven epilepsy patients with electrode coverage in or near the inferior temporal gyrus and got these patients' consent to undergo about an hour's worth of tests in which they would be shown images presented for very short intervals on a laptop computer screen, while activity in their brain regions covered by electrodes was recorded. Each electrode picked up activity from an area corresponding to about a half-million nerve cells (a drop in the bucket in comparison to the brain's roughly 100 billion nerve cells).

To make sure that any numeral-responsive brain areas identified were really responding to numerals—and not just generic lines, angles and curves—these tests were carefully calibrated to distinguish brain responses to visual presentations of the classic numerals taught in Western schools, such as 3 or 50, as opposed to squiggly lines, letters of the alphabet, number-denoting words such as "three" or "fifty," and symbols that in fact were also numerals but—because they were drawn from the Thai, Tibetan and Devanagari languages—were extremely unlikely to be recognized as such by this particular group of volunteers.

In the first test, subjects were shown series of single numerals and letters—along with false fonts, in which the component parts of numerals or letters had been scrambled but defining curves and angles were retained, and the foreign-number symbols just described. A second test, controlling for meaning and sound, included numerals and their spelled-out versions (for instance, "1" and "one," or "3" and "three") and other words with the same sound or a similar one ("won" and "tree," respectively).

All of our brains are shaped slightly differently. But in almost the identical spot within each study subject's brain, the investigators observed a significantly larger response to numerals than to similar-shaped stimuli, such as letters or scrambled letters and numerals, or to words that either meant the same as the numerals or sounded like them.

Interestingly, said Parvizi, that numeral-processing nerve-cell cluster is parked within a larger group of neurons that is activated by visual symbols that have lines with angles and curves. "These neuronal populations showed a preference for numerals compared with words that denote or sound like those numerals," he said. "But in many cases, these sites actually responded strongly to scrambled letters or scrambled numerals. Still, within this larger pool of generic neurons, the 'visual numeral area' preferred real numerals to the false fonts and to same-meaning or similar-sounding words."

It seems, Parvizi said, that "evolution has designed this brain region to detect visual stimuli such as lines intersecting at various angles—the kind of intersections a monkey has to make sense of quickly when swinging from branch to branch in a dense jungle." The adaptation of one part of this region in service of numeracy is a beautiful intersection of culture and neurobiology, he said.

Having nailed down a specifically numeral-oriented spot in the brain, Parvizi's lab is looking to use it in tracing the pathways described by the brain's number-processing circuitry. "Neurons that fire together wire together," said Shum. "We want to see how this particular area connects with and communicates with other parts of the brain."

Provided by Stanford University Medical Center