Neural balls and strikes: Where categories live in the brain

January 15 2012

Hundreds of times during a baseball game, the home plate umpire must instantaneously categorize a fast-moving pitch as a ball or a strike. In new research from the University of Chicago, scientists have pinpointed an area in the brain where these kinds of visual categories are encoded.

While monkeys played a computer game in which they had to quickly determine the category of a moving visual stimulus, neural recordings revealed brain activity that encoded those categories. Surprisingly, a region of the brain known as the posterior parietal cortex demonstrated faster and stronger category-specific signals than the prefrontal cortex, an area that is typically associated with higher level cognitive functions.

"This is as close as we've come to the source of these abstract signals" said David Freedman, PhD, assistant professor of neurobiology at the University of Chicago. "One of the main points this study suggests is that the parietal cortex is more involved in the categorization process than we had expected."

Organizing the chaos of the surrounding world into categories is one of the brain's key functions. For instance, the brain can almost immediately classify a broad range of four-wheeled vehicles into the general category of "car," allowing a person to quickly take the appropriate action. Neuroscientists such as Freedman and his laboratory team are searching for the brain areas responsible for storing and assigning these categories.

"The number of decisions we make per minute is remarkable," Freedman said. "Understanding that process from a basic physiological perspective is bound to lead to ways to improve the process and to help people make better decisions. This is particularly important for patients suffering from neurological illnesses, brain injuries or mental illness that affect decision making."

Ten years ago, experiments by Freedman and his colleagues found neurons were encoding category signals in the prefrontal cortex (PFC), a region thought to control important mental tasks such as decision making, rule learning and short-term memory. But in subsequent experiments, Freedman found a region of the parietal cortex called the lateral intraparietal area (LIP), thought to be primarily involved in basic visual and spatial processing, also encoded category information.

For the new study, to be published in the journal *Nature Neuroscience*, Freedman and graduate student Sruthi Swaminathan conducted the first direct comparison of prefrontal cortex and parietal cortex during categorization tasks. Monkeys were taught a simple game in which they classified dots moving in different directions into one of two categories. The subjects were shown two sets of moving dots one second apart, then held or released a joystick based on whether the two stimuli belonged to the same category or different categories.

During the task, scientists recorded neural activity in PFC and LIP. Neurons in both areas changed their activity according to the learned categories; for example, increasing firing for one category and decreasing for the other. However, category-specific neurons in LIP exhibited stronger and faster (by about 70 milliseconds) changes in activity during the task than those recorded from PFC.

"The relative timing of signals in the two brain areas gives us an important clue about their roles in solving the categorization task. Since category information appeared earlier in parietal cortex than prefrontal cortex, it suggests that parietal cortex might be more involved in the visual categorization process, at least during this task," Freedman said.

More evidence for the primacy of parietal cortex was provided by an experiment where scientists threw their subjects a curveball. The monkeys were shown an ambiguous set of moving dots on the border between the two learned categories, then asked to compare them with a second set of non-ambiguous dots — a test with no correct answer. The subjects were required to make a decision about which category the ambiguous stimuli belonged to, and once again LIP neurons corresponded to that decision more closely than PFC.

"During the decision process, parietal cortex activity is not just correlated — it even predicts ahead of time what the monkey will tell you," Swaminathan said. "You can record neuronal activity in parietal cortex and, in many cases, predict with great reliability what the monkey will report."

In humans, the ambiguous stimuli would be similar to an umpire deciding whether a borderline pitch was a ball or a strike — a highly specialized real world example of the visual motion categorization task used in these experiments, Freedman said.

"In a lot of ways, that's the process we hope to understand, this umpire calling balls and strikes," he said. "It's an interesting learned behavior that's highly critical for an individual to perform with great reliability, and it's a spatial categorization with a sharp boundary, so we think it's the same process."

Next, Freedman's laboratory hopes to look at how the brain changes during the category-learning process, examining whether the category signals first arise in the parietal cortex or start in the prefrontal cortex before transferring to visual regions of the brain. The results may help scientists reverse engineer some of the brain's most important tasks in daily life.

"Making effective decisions and evaluating every situation that you're in moment by moment is critical for successful behavior," Freedman said. "We're really interested in what changes occur in the brain to allow you to recognize not just the features of a stimulus, but what it is and what it means."

More information: *Nature Neuroscience* Jan. 15 doi: 10.1038/nn.3016

Provided by University of Chicago Medical Center