MedicalXpress

How the brain assigns objects to categories

July 28 2011

New research from MIT neuroscientists suggests how the brain learns which category an object belongs to — for example, fruits or animals. Image: Christine Daniloff

The human brain is adept at recognizing similar items and placing them into categories — for example, dog versus cat, or chair versus table. In a new study, MIT neuroscientists have identified the brain activity that appears to control this skill.

The findings, published in the July 27 issue of the journal *Neuron*, suggest a potential explanation for why autistic children focus intently on details, but often seem unable to group things into broad categories, says Earl Miller, the Picower Professor of Neuroscience and senior author of the paper.

"We think what may happen in autism is the system may get out of balance … and as a result, the details overwhelm the category. Then you have a brain that's not only too good at memorizing details, it can't help but memorize the details," says Miller, a principal investigator at the Picower Institute for Learning and Memory at MIT.

Miller and Picower postdoc Evan Antzoulatos focused their study on two brain regions, the prefrontal cortex and the striatum, which is part of a larger structure known as the basal ganglia. Both regions are known to be important for learning.

Until a few years ago, it was believed that the prefrontal cortex learns information quickly, then sends what it learns to the basal ganglia, which helps form habits, such as the ability to play a musical instrument. However, in 2005, Miller and colleagues showed that when monkeys learn simple tasks, their basal ganglia are more active early in the process, followed by a slower activation in the prefrontal cortex.

In other words, the striatum quickly learns the individual puzzle pieces, and the prefrontal cortex puts them together, Miller says. He and Antzoulatos theorized that the same pattern would be evident during category learning.

For the new *Neuron* study, Antzoulatos trained monkeys to assign patterns of dots into one of two categories. At first, the animals would see only two examples, or "exemplars," from each category — a small enough number that they could memorize the category to which each

belonged, without having to learn the general category traits. After the animals learned the first two exemplars, the number would be doubled. Eventually, the number of exemplars became so great that it was impossible to memorize them, and the monkeys' brains would start picking up on general traits that characterize each category.

As they did so, brain activity shifted from the striatum, a more primitive brain region, to the prefrontal cortex, which is responsible for high-level functions such as planning and decision making.

"What happens during category learning is the more primitive, faster basal ganglia can memorize the exemplars, but then it sends what it learns up to the prefrontal cortex. And the prefrontal cortex figures out what's common among all the exemplars, among all the individuals, and extracts the essence," Miller says.

Gregory Ashby, a professor of psychology at the University of California at Santa Barbara, says the new study represents the "clearest picture yet" of the striatum's involvement in category learning. "We've known for quite a while that the striatum plays an important role in category learning, but it was not at all clear exactly what that role was," he says.

In future studies, the MIT researchers hope to test their theory that autism results from an imbalance between the striatum and prefrontal cortex by interfering with the normal balance between the two brain regions and observing the results.

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Provided by Massachusetts Institute of Technology