Multitasking is no problem for these brain cells: Individual brain cells can ID both cars and cats

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In previous studies showed that when monkeys are trained to categorize animals by distinguishing cats from dogs, some neurons in the prefrontal cortex become tuned to the concept of “cat” while others respond to the idea of “dog.” This new study trained the monkeys to perform two different categorization tasks — distinguishing cats from dogs and sedans from sports cars.

(PhysOrg.com) -- Researchers at MIT's Picower Institute for Learning and Memory found that single brain cells, if confronted with a difficult task, can identify objects as dissimilar as sports cars and dogs.

In humans and other primates, the prefrontal cortex is the seat of high-level functions such as learning, decision making, and planning. Neuroscientists have long wondered whether neurons in that part of the

brain are specialized for one type of task or if they are “generalists” — that is, able to participate in many functions. A new study from MIT’s Picower Institute for Learning and Memory comes down in favor of the generalist theory.

MIT professor Earl Miller and others in his lab showed that when they trained monkeys to perform two different categorization tasks, about half of the neurons involved could switch between the two. The findings, reported in the June 10 issue of the journal *Neuron*, suggest that neurons of the prefrontal cortex have a much greater ability to adapt to different cognitive demands than neurons in other parts of the brain. These results support ideas about the malleability of neurons — nervous-system cells that process and transmit information — that Miller first proposed a decade ago.

Miller, the Picower Professor of Neuroscience in MIT’s Department of Brain and Cognitive Sciences, says he’s not surprised by the findings. “We have a lot of mental flexibility,” he says. “We can change our topic of conversation, we can change what we’re thinking about. Some part of the brain has to have that flexibility on a neural level.”

Listening to single neurons

Most neuroscientists who study brain activity in monkeys train the animals on only one task, so until now it had been impossible to reveal whether single neurons in the prefrontal cortex could be involved in more than one job.

In previous studies, Miller has shown that when monkeys are trained to categorize animals by distinguishing cats from dogs, some neurons in the prefrontal cortex become tuned to the concept of “cat” while others respond to the idea of “dog.”

This time, Miller, postdoctoral fellow Jason Cromer, and research scientist Jefferson Roy trained the monkeys to perform two different categorization tasks — distinguishing cats from dogs and sedans from sports cars. They recorded activity from about 500 neurons in the monkeys' prefrontal cortex as the animals switched back and forth between the tasks.

Although they found that some neurons were more attuned to car images and others to animal images, they also identified many neurons that were active during both tasks. In fact, these "multitasking" neurons were best at making correct identifications in both categories.

The findings suggest that neurons in the prefrontal cortex have a unique ability to adapt to different tasks, says Miller. In other parts of the brain, earlier research has shown, most neurons are highly specialized. Neurons in the visual cortex, for example, are programmed to respond to very specific inputs, such as a vertical line or a certain color. Some have even been shown to fire only in response to one particular face.

"Our results suggest that the prefrontal cortex is different from the sensory cortex and the motor cortex. It's highly plastic," says Miller. "That's important, because it means the human brain has the capacity to absorb a lot of information."

The Neuron study focused on two categorization tasks, but Miller hopes to run another study in which the monkeys learn a third task involving some other cognitive function. That could give another hint about how much information our brains can handle, says David Freedman, an assistant professor of neurobiology at the University of Chicago.

"We're very good at learning dozens, hundreds, or even thousands of categories," he says. "You wonder if there is some limit, or would these neurons be as flexible as we are as observers?"

Freedman says he would also be interested to see whether the same prefrontal-cortex neurons can multitask between activities that involve different kinds of sensory inputs — for example, a visual task and an auditory task.

Overstimulation

Meanwhile, Miller has a study under way that he believes could demonstrate a biological basis for the impaired categorization ability often seen in people with autism. Autistic children often have a hard time understanding that two slightly different objects — for example, a red toothbrush and a blue toothbrush — both belong to the same category.

Miller theorizes that an evolutionarily older part of the brain, known as the basal ganglia, gathers information about new objects, and the prefrontal cortex learns how to categorize them. “The basal ganglia learn the pieces of the puzzle, and the prefrontal cortex puts the pieces together,” he says.

In his current study, Miller is monitoring brain activity in monkeys as they learn a categorization task. He expects to find a sharp peak in prefrontal-cortex activity at the moment when the monkeys learn that certain objects belong to the same category.

Eventually, he hopes to show that in autism, the balance between those two brain regions is thrown off: there is either too much activity in the basal ganglia or not enough in the prefrontal cortex.

More information: "Representation of Multiple, Independent Categories in the Primate Prefrontal Cortex," Jason A. Cromer, Jefferson E. Roy, and Earl K. Miller. Neuron. 10 June 2010.

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