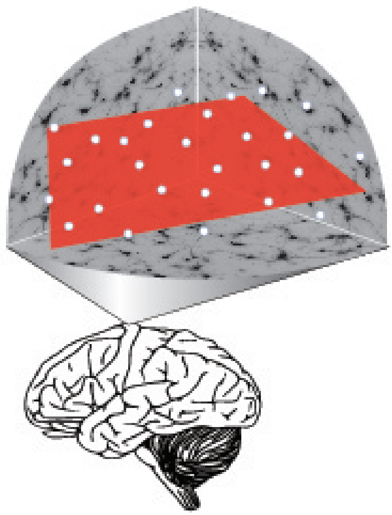
Flexing the brain: Scientists discover why learning tasks can be difficult

27 August 2014



Scientists mapped neural activity patterns (white dots) in a learning brain. They found that learning occurs faster when it only requires existing patterns of activity (red box) than when it needs to use patterns outside of the red box. Credit: Batista lab, University of Pittsburgh

Learning a new skill is easier when it is related to an ability we already have. For example, a trained pianist can learn a new melody easier than learning how to hit a tennis serve.

Scientists from the Center for the Neural Basis of Cognition (CNBC) – a joint program between Carnegie Mellon University and the University of Pittsburgh – have discovered a fundamental constraint in the brain that may explain why this happens. Published as the cover story in the August 28, 2014, issue of *Nature*, they found for the first time that there are limitations on how adaptable the brain is during learning and that these restrictions are a key determinant for whether a new skill will be easy or difficult to learn. Understanding the ways in which the brain's activity can be "flexed" during learning could eventually be used to develop better treatments for stroke and other brain injuries.

Lead author Patrick T. Sadtler, a Ph.D. candidate in Pitt's Department of Bioengineering, compared the study's findings to cooking.

"Suppose you have flour, sugar, baking soda, eggs, salt and milk. You can combine them to make different items—bread, pancakes and cookies—but it would be difficult to make hamburger patties with the existing ingredients," Sadtler said. "We found that the brain works in a similar way during learning. We found that subjects were able to more readily recombine familiar activity patterns in new ways relative to creating entirely novel patterns."

For the study, the research team trained animals to use a brain-computer interface (BCI), similar to ones that have shown recent promise in clinical trials for assisting quadriplegics and amputees.

"This evolving technology is a powerful tool for brain research," said Daofen Chen, program director at the National Institute of Neurological Disorders and Stroke (NINDS), part of the National Institutes of Health (NIH), which supported this research. "It helps scientists study the dynamics of brain circuits that may explain the neural basis of learning."

The researchers recorded neural activity in the subject's motor cortex and directed the recordings into a computer, which translated the activity into movement of a cursor on the computer screen. This technique allowed the team to specify the activity patterns that would move the cursor. The test subjects' goal was to move the cursor to targets on the screen, which required them to generate the patterns of neural activity that the experimenters had requested. If the subjects could move the cursor well, that meant that they had learned to generate the neural activity pattern that the researchers had specified.

The results showed that the subjects learned to generate some neural activity patterns more easily than others, since they only sometimes achieved accurate cursor movements. The harder-to-learn patterns were different from any of the pre-existing patterns, whereas the easier-to-learn patterns were combinations of pre-existing brain patterns. Because the existing brain patterns likely reflect how the neurons are interconnected, the results suggest that the connectivity among neurons shapes learning.

"We wanted to study how the brain changes its activity when you learn, and also how its activity cannot change. Cognitive flexibility has a limit—and we wanted to find out what that limit looks like in terms of neurons," said Aaron P. Batista, assistant professor of bioengineering at Pitt.

Byron M. Yu, assistant professor of electrical and computer engineering and biomedical engineering at Carnegie Mellon, believes this work demonstrates the utility of BCI for basic scientific studies that will eventually impact people's lives.

"These findings could be the basis for novel rehabilitation procedures for the many neural disorders that are characterized by improper neural activity," Yu said. "Restoring function might require a person to generate a new pattern of neural activity. We could use techniques similar to what were used in this study to coach patients to generate proper neural activity."

More information: Neural constraints on learning, *Nature*, DOI: 10.1038/nature13665

Provided by Carnegie Mellon University