How the brain learns new skills

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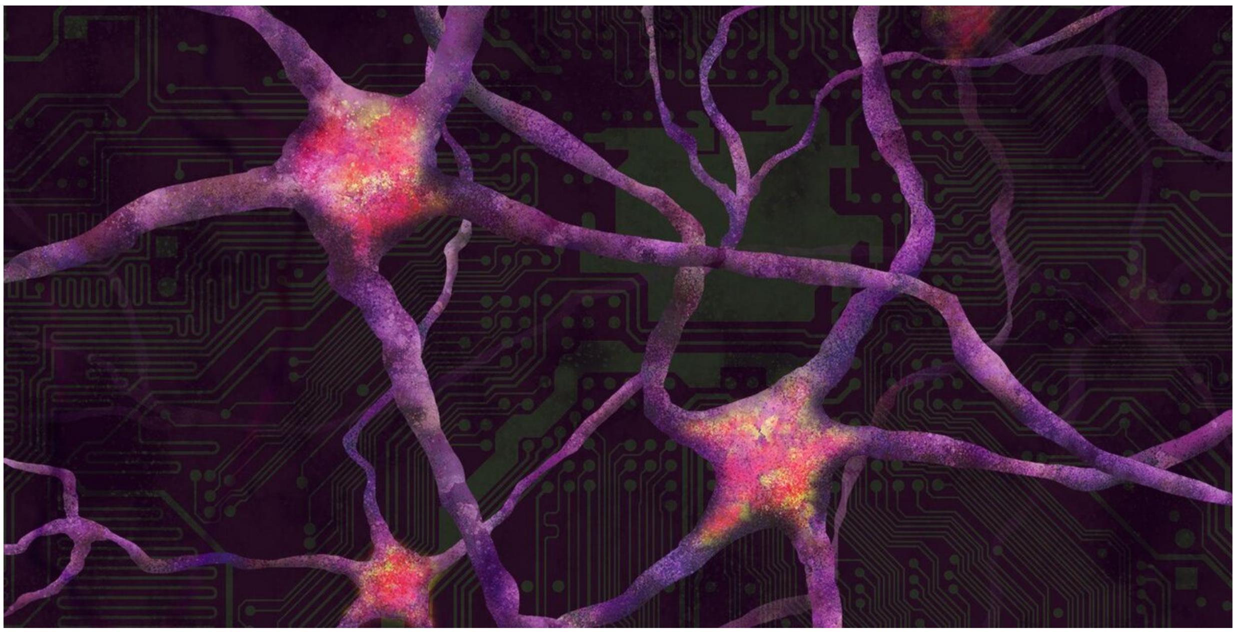

Credit: California Institute of Technology

The human brain is "plastic": it can adapt and rewire itself, often more easily when learning new things related to familiar skills. For example, it is probably easier for a professional tennis player to learn to play badminton than soccer.

Seeking to discover basic limits on the brain's plasticity, a new Caltech study discovered that learning is indeed easier when related to skills one already has because pre-existing neuronal structure constrains what one can learn. In other words, it is likely that the skills we already have developed restrict what we can learn easily in a short time.

"We want to understand how people learn and where in the brain this learning takes place. While this is still basic science, this research could one day potentially help people who have had a stroke or other brain trauma in their rehabilitation process," says Richard Andersen, the James G. Boswell Professor of Neuroscience, T&C Chen Brain-Machine Interface Center Leadership Chair, and director of the T&C Brain-Machine Interface Center of the Tianqiao and Chrissy Chen Institute for Neuroscience at Caltech. The research was conducted in Andersen's laboratory in collaboration with UCLA and Casa Colina Hospital and Centers for Healthcare in Pomona, California.

The study focused on a region of the brain called the anterior intraparietal cortex, or AIP. This region governs a person's intentions, particularly the intent to move. For example, when you reach out your hand to pick up an object, your AIP first encodes your intent to move and then sends signals down to the regions of the brain that control the movements of muscles, tendons, and the like.

Led by Caltech postdoctoral scholar Sofia Sakellaridi and scientific researcher Vassilios Christopoulos, the researchers partnered with a tetraplegic adult woman who had tiny electrodes surgically implanted in her AIP in order to control a brain-machine interface (BMI) system. The BMI measures neural activity in the region and can be programmed to translate this activity into instructions for a prosthetic device (for example, a computer). In this way, the study participant can control a cursor on a computer screen simply by thinking about moving it.

In the experiments, the participant was presented with a computer screen displaying a cursor. When a particular area on the screen lit up, she was asked to think about moving her paralyzed right wrist as if she were physically moving the cursor from its start position to the highlighted position. The BMI read her neural intention to move and moved the cursor accordingly.

The neurons in the participant's AIP fired in different patterns depending on what she was aiming to do. For instance, some neurons fired for intended upward movements and others fired for intended downward movements. The former are said to be "tuned for up" and the latter "tuned for down." The BMI was initially calibrated to move the cursor exactly as the participant intended. For example, if she thought about moving the cursor down, the downward-tuned neurons would increase their activity to translate the thought into that motion of the cursor.

Then, the researchers altered the mapping between neural activity and the cursor's movement—for example, if the participant thought about moving her wrist down, the cursor would go up. For some new mappings, the participant was able to adjust to the perturbation. In these cases, the researchers wanted to know how the adjustment happened. Did the individual neurons controlling the BMI learn to change their tuning for up and down? Or did the participant learn to think about moving up when instructed to move down?

The latter is an example of learning to use a new cognitive strategy. Many computer users have had experience with similar adaptive cognitive strategies, Christopoulos explains: "On an Apple mousepad, a user must move their fingers upward to scroll downward. On a Windows mouse, the direction is opposite. The 'skill' of moving one's hand is the same in both cases, but a person must adapt to the different mappings."

The researchers found that the participant was sometimes able to adapt to perturbations in the cursor's movement by altering her cognitive strategy. For example, she would say that she re-aimed the cursor movement in her mind to perform the task. However, the participant was not always able to solve the mapping perturbation by adopting a new cognitive strategy, and in those cases, the researchers found, her brain did not generate totally new patterns of neuronal activity. In other words, her adaptability—specifically, her ability to re-aim the cursor to certain locations in space—was constrained by the tuning of the particular set of neurons being recorded from. This suggests that the extent to which a person can learn a new skill is constrained by pre-existing neural wiring.

"This may not always be the case," says Sakellaridi, "As the experiments were conducted in one-hour blocks—thus representing short-term learning—it is likely that the AIP needs more training time to generate novel patterns of activity, for example, to learn new motor skills. Overall, our findings suggest that it may be that certain types of learning take much longer to alter the brain."

Next, the scientists plan to study different regions of the brain by working with people who have electrodes implanted into areas other than the AIP.

A paper describing the research, titled "Intrinsic Variable Learning for Brain-Machine Interface Control by Human Anterior Intraparietal Cortex," appeared online on March 7 in the journal *Neuron*.

More information: Sofia Sakellaridi et al. Intrinsic Variable Learning for Brain-Machine Interface Control by Human Anterior Intraparietal Cortex, *Neuron* (2019). DOI: 10.1016/j.neuron.2019.02.012

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