Stanford ENGINEERING

Did something jostle my arm? My neurons need a moment

Revealing the mechanism that allows the brain to pause between this particular stimulus and response will help researchers develop prosthetic arms controlled by thought.

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By Glen Martin

Understanding the brain's response when the arm is jostled will help develop a thought-controlled prosthetic arm. | Photo by Sergey Stavisky

It happens all the time. You're carrying a full cup through a crowded room when someone unexpectedly jostles your arm. In a split second, your arm starts making the nuanced adjustments necessary to prevent a spill. No problem, right?

But as neuroscientists try to understand how the brain accomplishes this, they've noticed a mystery. The motor cortex, which helps control movement, registers the sensation of jostling almost immediately. But it pauses before ordering the muscles to react. Understanding why and how this occurs is critical to designing a system to allow a person with paralysis to use their brain to control a prosthetic arm.

Now a team led by electrical engineer and neuroscientist Krishna Shenoy, director of Stanford's Neural Prosthetic Systems Lab, has solved the mystery of this brief pause between stimulus and response.

Writing in the journal *Neuron* , his team explains how cells in the motor cortex use this tiny interval of time to determine the appropriate muscular response.

“The brain has a mechanism to keep us from prematurely reacting when we are jostled,” Shenoy said. “Now that we understand it we can design an electronic interface between the motor cortex and a prosthetic arm that works as nature intended.”

This discovery has practical implications. Neuroengineers previously worried that when the brain is directly connected to a prosthesis, its earliest responses to perturbations would leak out and cause the arm to move erratically every time the user encountered something unexpected.

Brain-computer interface

The current findings build on Shenoy’s long-term collaboration with Stanford neurosurgeon Jaimie Henderson. They are already doing clinical trials of a technology that allows people with paralysis to use their brains to “type” commands onto a virtual keyboard displayed on a computer screen.

Sergey Stavisky, a postdoctoral fellow in the Department of Neurosurgery and first author of the *Neuron* paper, explained how thought-controlled typing has worked in those clinical trials.

Several people with paralysis have been surgically implanted with one or more tiny silicon chips just beneath the skull. This chip is part of a system called a brain-computer interface, or BCI. Electrical leads on the chip pick up signals from neurons in the motor cortex that reveal what movement the person wants to make.

Developing a brain-controlled prosthetic limb is even more complicated. But some of the technology developed for the thought-controlled keypad has enabled the Stanford team to get a leg up on the arm challenge. In the new pre-clinical experiments they describe in *Neuron* , the Stanford researchers used the BCI to reverse-engineer the mechanism that enables the motor cortex to pause between stimulus – like when the arm is jostled – and response.

The experiments confirmed that during this delay the motor cortex, while recognizing the need to react, ever so briefly suppresses that urge while deciding what orders to send to the muscles.

“It’s like having a scratch pad where you can first prepare a rough draft that no one else will see,” Stavisky said.

This understanding is crucial to developing brain-controlled prosthetic arms. Shenoy said other researchers have already developed a prosthetic arm controlled by the brain, but they have not yet seen what happens when it encounters an unexpected perturbation.

“This problem has been worrisome,” Shenoy said. “We knew that if we couldn’t separate out the different neural patterns, we’d have trouble designing a brain-controlled prosthetic that works like a biological arm.”

Shenoy said Stanford researchers want to design brain-controlled artificial limbs that don’t overcompensate or overreact. The knowledge gained from the *Neuron* paper will feed into early-stage efforts to develop human clinical trials of prosthetic arms controlled through BCIs.

“Understanding how the brain responds when the arm is unexpectedly perturbed will be critical to making these efforts successful,” Shenoy said.

Co-authors of the Neuron paper, “Motor Cortical Visuomotor Feedback Activity Is Initially Isolated from Downstream Targets in Output-Null Neural State Space Dimensions,”are Jonathan Kao, currently assistant professor at the University of California, Los Angeles, Department of Electrical Engineering, and Stephen Ryu, adjunct professor atStanford’s Department of Electrical Engineering. This work was supported by the National Science Foundation, the Christopher and Dana Reeve Foundation, the Burroughs Wellcome Fund, the DARPA REPAIR initiative and the National Institutes of Health.

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