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Engineer studies advances in recovery of paralyzed patients

BY ETIENNE BENSON


Engineer Krishna Shenoy inspects a lab space yet to be painted or furnished. The lab is being built for his research in neural prosthetics. Photo: L.A. Cicero

Reaching out to touch a dot on a computer screen may seem simple, but it requires a complex chain of signals that link together the eye, brain and arm. Damage to any part of that chain, such as a spinal injury, stroke or neurodegenerative disease, can make even the simplest tasks impossible.

In a new study, Stanford engineer Krishna Shenoy and a group of researchers at Caltech have shown that at least some links in that chain can be dramatically bypassed. The study is a significant advance in the growing field of neural prosthetics -- implanted devices that eventually may help severely paralyzed patients regain some of their lost functions. The results of the study were presented by Daniella Meeker, a Caltech graduate student, at the annual meeting of the Society for Neuroscience in San Diego on Nov. 11.

Planned movements

Shenoy, Meeker and their colleagues showed that electrical signals from the parietal reach region (PRR), the part of the brain responsible for planning arm movements, can be used to control the movement of a cursor on a computer screen. Using signals from an electrode implanted in the PRR of a monkey, the researchers were able to mimic the animal's arm movements with the movements of a cursor called a prosthetic icon. Eventually, the monkey was able to control the icon by thought alone.

Previous studies have shown that the brain cells responsible for moving an arm also can be used to control robotic arms, computer cursors or other devices. But this study is the first to show that the cells responsible for planning those movements can do the same.

"The key difference between our approach and the approach of several other groups around the country is that we're looking at neural activity that is present before, or even without, real arm movement," says Shenoy, an assistant professor of electrical engineering at Stanford.

The advantage of using planning cells is that they encode a simpler set of parameters than motor cells do. Whereas motor cells generate complex signals that control the three-dimensional path of an arm as it moves toward its target, planning cells encode primarily two parameters: where and when to move. Systems based on planning cells may be able to use fewer brain cells, and thus simpler electronics, than those based on motor cells. Planning cells also are less likely than motor cells to atrophy or change function over the course of prolonged paralysis.

Direct neural control

The PRR study was conducted at Caltech using a rhesus monkey, which was trained and tested by Meeker. A monkey was chosen because, unlike rats and other laboratory animals, monkeys share with humans the ability to perform high-level cognitive tasks, such as planning.

The monkey was trained to reach toward the left or right side of a computer screen, depending on where a target dot had flashed several seconds before. During the delay between the appearance of the dot and the monkey's reach, brain cells in the PRR that signaled the monkey's intention to move were highly active. An implanted electrode transmitted signals from neurons in the PRR to a bank of electronics that determined whether the monkey intended to reach to the right or left. A computer then automatically used the interpreted signals to move the cursor in the appropriate direction.

The monkey eventually learned that it could successfully complete the task whether it moved its arm or not, as long as the cursor moved in the proper direction. Since the cursor was controlled directly by the monkey's PRR, the animal could receive its reward -- a sip of fruit juice -- just by thinking about reaching toward the correct spot.

Because only a single electrode was implanted in the PRR, the system was limited to indicating whether the monkey intended to move left or right, but a more sophisticated system could calculate exactly where and when the monkey intended to move, says Shenoy.

Such a system could help severely paralyzed people communicate by "reaching" toward keys on a virtual keyboard to spell out messages. Determining how quickly and accurately a person using the system could work -- a crucial factor in whether it eventually finds real-world applications -- is one of the major goals of Shenoy's research.

Major challenges

Shenoy came to Stanford this fall after completing a postdoctoral fellowship at Caltech in the laboratory of neurophysiologist Richard Andersen, the study's senior author. At Stanford, he is affiliated with the Neurosciences Program and Bio-X -- a campus-wide interdisciplinary research initiative in bioengineering, biomedicine and biosciences. His collaborators include electrical engineering Professor Teresa Meng, who is helping Shenoy design a low-power neural prosthetic system that someday might be small enough to wear on a belt.

Despite recent advances, the current system is still a long way from helping people who are paralyzed, observes Shenoy. Three major challenges remain: developing a better understanding of the brain, especially its ability to adapt to injury and other changes; designing electrodes that can function in the brain for extended periods of time; and engineering an overall system that is reliable, efficient and compact. But Shenoy is confident those challenges eventually will be overcome.

"Given a great enough need, given the right circumstances, I think there's a strong driving force to help people right away," he concludes.