Scientists restore movement to paralyzed limbs through artificial brain-muscle connections

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Researchers in a study funded by the National Institutes of Health have demonstrated for the first time that a direct artificial connection from the brain to muscles can restore voluntary movement in monkeys whose arms have been temporarily anesthetized. The results may have promising implications for the quarter of a million Americans affected by spinal cord injuries and thousands of others with paralyzing neurological diseases, although clinical applications are years away.

"This study demonstrates a novel approach to restoring movement through neuroprosthetic devices, one that would link a person's brain to the activation of individual muscles in a paralyzed limb to produce natural control and movements," said Joseph Pancrazio, Ph.D., a program director at the National Institute of Neurological Disorders and Stroke (NINDS).

The research was conducted by Eberhard E. Fetz, Ph.D., professor of physiology and biophysics at the University of Washington in Seattle and an NINDS Javits awardee; Chet T. Moritz, Ph.D., a post-doctoral fellow funded by NINDS; and Steve I. Perlmutter, Ph.D., research associate professor. The results appear in the online Oct. 15 issue of *Nature*. The study was performed at the Washington National Primate Research Center, which is funded by NIH's National Center for Research Resources.

In the study, the researchers trained monkeys to control the activity of single nerve cells in the motor cortex, an area of the brain that controls voluntary movements. Neuronal activity was detected using a type of brain-computer interface. In this case, electrodes implanted in the motor cortex were connected via external circuitry to a computer. The neural activity led to movements of a cursor, as monkeys played a target practice game.

After each monkey mastered control of the cursor, the researchers temporarily paralyzed the monkey's wrist muscles using a local anesthetic to block nerve conduction. Next, the researchers converted the activity in the monkey's brain to electrical stimulation delivered to the paralyzed wrist muscles. The monkeys continued to play the target practice game—only now cursor movements were driven by actual wrist movements—demonstrating that they had regained the ability to control the otherwise paralyzed wrist.

The group's approach is one of several lines of current neuroprosthetic research. Some investigators are using brain-computer interfaces to record signals from multiple neurons and convert those signals to control a robotic limb. Other researchers have delivered artificial stimulation directly to paralyzed arm muscles in order to drive arm movement—a technique called functional electrical stimulation (FES). The Fetz study is the first to combine a brain-computer interface with real-time control of FES.

"A robotic arm would be better for someone whose physical arm has been lost or if the muscles have atrophied, but if you have an arm whose muscles can be stimulated, a person can learn to reactivate them with this technology," says Dr. Fetz.

Until now, brain-computer interfaces were designed to decode the activity of neurons known to be associated with movement of specific body parts. Here, the researchers discovered that any motor cortex cell, regardless of whether it had been previously associated with wrist movement, was capable of stimulating muscle activity. This finding greatly expands the potential number of neurons that could control signals for brain-computer interfaces and also illustrates the flexibility of the motor cortex.

"The cells don't have to have a preordained role in the movement. We can create a direct link between the cell and the motor output that the user can learn to control and optimize over time," says Dr. Fetz.

Dr. Fetz and his colleagues found that the monkeys' control over neuronal activity—and the resulting control over stimulation of their wrist muscles—improved significantly with practice. Practice time was limited by the duration of the nerve block. Comparing the monkeys' performance during an initial two-minute practice and a two-minute peak performance period, the scientists found the monkeys successfully hit the target three times more frequently and with less error during the peak performance. In the future, greater control could be gained by using implanted circuits to create long-lasting artificial connections, allowing more time for learning and optimizing control, Dr. Fetz says.

The researchers also found that the monkeys could achieve independent control of both the wrist flexor and extensor muscles.

"An important next step will be to increase the number of direct connections between cortical cells and muscles to control coordinated activation of muscles," says Dr. Fetz.

If researchers are able to establish a connection between the motor cortex and sites in the spinal cord below the injury, people with spinal injuries may be able to achieve coordinated movements.

Clinical applications are still probably at least a decade away, according to Dr. Fetz. Better methods for recording cortical neurons and for controlling multiple muscles must be developed, along with implantable circuitry that could be used reliably and safely, he says.

Source: National Institute of Neurological Disorders and Stroke