Brain-activated muscle stimulation restores monkeys' hand movement after paralysis

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An artificial connection between the brain and muscles can restore complex hand movements in monkeys following paralysis, according to a study funded by the National Institutes of Health.

In a report in the journal *Nature*, researchers describe how they combined two pieces of technology to create a neuroprosthesis – a device that replaces lost or impaired nervous system function. One piece is a multi-electrode array implanted directly into the brain which serves as a brain-computer interface (BCI). The array allows researchers to detect the activity of about 100 brain cells and decipher the signals that generate arm and hand movements. The second piece is a functional electrical stimulation (FES) device that delivers electrical current to the paralyzed muscles, causing them to contract. The brain array activates the FES device directly, bypassing the spinal cord to allow intentional, brain-controlled muscle contractions and restore movement.

The research team was led by Lee E. Miller, Ph.D., professor of physiology at Northwestern University's Feinberg School of Medicine in Chicago. Prior to testing the neuroprosthesis, Dr. Miller's group recorded the brain and muscle activity of two healthy monkeys as the animals performed a task requiring them to reach out, grasp a ball, and release it. The researchers then used the data from the brain-controlled FES device to determine the patterns of muscle activity predicted by the brain activity.

To test the device, the researchers gave monkeys an anesthetic to locally block nerve activity at the elbow, causing temporary paralysis of the hand. With the aid of the neuroprosthesis, both monkeys regained movement in the paralyzed hand, could pick up and move the ball in a nearly routine manner and complete the task as before.

Dr. Miller's research team also performed grip strength tests, and found that their system restored precision grasping ability. The device allowed voluntary and intentional adjustments in force and grip strength, which are keys to performing everyday tasks naturally and successfully.

This new research moves beyond earlier work from Dr. Miller's group showing that a similar neuroprosthesis restores monkeys' ability to flex or extend the wrist despite paralysis. "With these neural engineering methods, we can take some of the important basic physiology that we know about the brain, and use it to connect the brain directly to muscles," Dr. Miller said. "This connection from brain to muscles might someday be used to help patients paralyzed due to spinal cord injury perform activities of daily living and achieve greater independence."

In 2008, a team led by Eberhard Fetz, Ph.D. at the University of Washington in Seattle coupled the activity of single neurons to an FES device similar to the one used for Miller's study. Monkeys learned to activate individual neurons to control the FES device and move a joystick, and could adapt neurons previously unassociated with wrist movement to complete the task. (See "Scientists Restore Movement to Paralyzed Limbs through Artificial Brain-Muscle Connections") The investigators suggest that this process of learning and adaption plays an important role in how the BCI translates the brain's activity patterns into adaptive control of the FES device.

The unique design of the ball grasp-and-release task used with the animals in this study is a further contribution to advanced neuroprosthetic testing and development. Daofen Chen, Ph.D., a program director at NIH's National Institute of Neurological Disorders and Stroke (NINDS), described how researchers in the field are striving toward devices that will go beyond simple arm movements and allow fine hand and finger movements. "We've learned a lot from non-human primate studies focused on understanding neural control of arm and wrist movements," said Dr. Chen. "Dr. Miller's study builds on those efforts and focuses on the complex hand and finger movements needed to grasp an object."

FES devices are currently used for foot drop, a clinical condition seen in patients with stroke or partial spinal cord injury where weak or paralyzed muscles cause the toes to catch on the ground while walking, leading to trips and falls. FES can be activated with shoe sensors, or coordinated with walking movements, to stimulate muscles and lift the toes at the appropriate time during a step.

Other FES devices in current clinical use take advantage of the patient's residual muscle activity. For example, a prosthetic arm can use sensors built into the shoulder, sensing a shrugging motion that is used to stimulate muscles to open or close the hand. However, this is a less precise and less natural method of control, and it is not an option for patients with higher level spinal cord injuries and little or no shoulder and arm movement. For these patients, the creation of a brain-controlled FES device that connects brain activity directly to muscle stimulation would provide an opportunity to restore hand function.

The temporary nerve block used in the current study is a useful model of paralysis, but it does not replicate the chronic changes that occur after prolonged brain and spinal cord injuries, Dr. Miller cautioned. He said the next steps include testing this system in primate models of long-term paralysis, and studying how the brain changes as it continues to use this neuroprosthesis.

More information: Ethier C et al. "Restoration of grasp following paralysis through brain-controlled stimulation of muscles." *Nature*, published online April 18, 2012. DOI: 10.1038/nature10987

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