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NEURAL REPAIR AND REHABILITATION

Neurally controlled robotic arm enables tetraplegic patient to drink coffee of her own volition

Two studies published in *Nature*, one in monkeys and one in humans, have demonstrated the striking ability of brain–machine interfaces to restore neural control of arm and hand movements following paralysis. The findings have implications for the millions of patients affected by spinal cord injury, brainstem stroke, amyotrophic lateral sclerosis and other neurological disorders that cause limb paralysis.

The work in humans, conducted by Leigh Hochberg and colleagues, forms part of an ongoing pilot study of the BrainGate neural interface system. "The job of the motor cortex is to control an external device, which usually just happens to be the person's own limb. The question is whether, after an insult that breaks the connection between the motor cortex and the spinal cord region controlling the limb, the powerful signals in the motor cortex can be harnessed to control an external device again," explains Hochberg.

The study involved two patients, 'S3' and 'T2', who were tetraplegic following brainstem stroke. A 96-channel microelectrode array was implanted into a small area of the motor cortex that sends impulses to control hand movements. Neural activity detected by this array was then decoded and used to generate a signal to move a remote, robotic arm.

Both patients were presented with foam spheres, and told to imagine themselves reaching for and grasping the spheres, in order to generate the motor cortical signal to control the robotic arm. Completion of the task involved manoeuvering the arm through 3D space within a narrow range of approach angles. Grasping of the target was achieved 46% of the time over 158 trials by patient S3, and 62% of the time over 45 trials by patient T2. "They thought about moving their arms and hands, and the robots moved that way," says Hochberg.

Next, the team tested the robotic arm in an activity of daily living. As documented in a striking movie that accompanies the article, patient S3 was able to reach for and grasp a bottle containing coffee on a table, bring the bottle towards her mouth and drink through a straw, before replacing the bottle on the table.

Using the investigational BrainGate neural interface system, a patient with tetraplegia serves herself coffee for the first time in 14 years. Reproduced from Hochberg, L. R. *et al. Nature* **485**, 372–375 (2012).

S3's microelectode array was implanted 5 years before this study, providing encouraging support for the long-term feasibility of such neural interfaces. Moreover, the patient has been tetraplegic for 14 years. "This finding shows that after all this time, the patient's motor cortex continues to produce neural activity associated with the intent to use her hand, which can be harnessed for the intuitive control of robotic limbs," says Hochberg.

In the other paper, by Lee Miller and colleagues, the researchers used injections of local anaesthetic to induce temporary paralysis in the arms of two rhesus monkeys that were trained to pick up weighted rubber balls and place them in an open container. Electrode arrays were implanted in the hand area of the motor cortex, and signals recorded from about 100 neurons were used to predict the intended activity of the paralysed muscles. Electrodes implanted in the hand and forearm muscles completed the circuit by translating the predicted muscle activity into stimulation of the same muscles. This system enabled the monkeys to successfully place a ball in a container during local anaesthesia in 80–90% of attempts. "This is the first time that a brain–machine interface has been used to reanimate paralysed limbs," says Miller.

Hochberg's team hopes to develop a system that will similarly link brain signals to the paralysed limb. "I'm encouraged by the possibility of neurorestoration through technologies that harness the rich information that can be recorded directly from ensembles of individual neurons," says Hochberg.

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Original articles Ethier, C. *et al.* Restoration of grasp following paralysis through brain-controlled stimulation of muscles. *Nature* **485**, 368–371 (2012) | Hochberg, L. R. *et al.* Reach and grasp by people with tetraplegia using a neurally controlled robotic arm. *Nature* **485**, 372–375 (2012)