Monkeys Think, Moving Artificial Arm as Own

By BENEDICT CAREY
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Two monkeys with tiny sensors in their brains have learned to control a mechanical arm with just their thoughts, using it to reach for and grab food and even to adjust for the size and stickiness of morsels when necessary, scientists reported on Wednesday.

Andrew Schwartz/University of Pittsburgh

A grid in the monkey's brain carried signals from 100 neurons for the mechanical arm to grab and carry snacks to the mouth.

The report, released online by the journal Nature, is the most striking demonstration to date of brain-machine interface technology. Scientists expect that technology will eventually allow people with spinal cord injuries and other paralyzing conditions to gain more control over their lives.

The findings suggest that brain-controlled prosthetics, while not practical, are at least technically within reach.

In previous studies, researchers showed that humans who had been paralyzed for years could learn to control a cursor on a computer screen with their brain waves and that nonhuman primates could use their thoughts to move a mechanical arm, a robotic hand or a robot on a treadmill.

The new experiment goes a step further. In it, the monkeys' brains seem to have adopted the mechanical appendage as their own, refining its movement as it interacted with real objects in real time. The monkeys had their own arms gently restrained while they learned to use the added one.

Experts not involved with the study said the findings were likely to accelerate interest in human testing, especially given the need to treat head and spinal injuries in veterans returning from Iraq and Afghanistan.

"This study really pulls together all the pieces from earlier work and provides a clear demonstration of what's possible," said Dr. William Heetderks , director of the extramural science program at the National Institute of Biomedical Imaging and Bioengineering. Dr. John P. Donoghue, director of the Institute of Brain Science at Brown University, said the new report was "important because it's the most comprehensive study showing how an animal interacts with complex objects, using only brain activity."

The researchers, from the University of Pittsburgh and Carnegie Mellon University, used monkeys partly because of their anatomical similarities to humans and partly because

they are quick learners.

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In the experiment, two macaques first used a joystick to gain a feel for the arm, which had shoulder joints, an elbow and a grasping claw with two mechanical fingers.

the scientists implanted a grid about the size of a large freckle. It sat on the motor cortex, over a patch of cells known to signal arm and hand movements. The grid held 100 tiny electrodes, each connecting to a single neuron, its wires running out of the brain and to a computer.

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"The reality of this is so remarkable. The potential impact, in terms of quality of life for amputees and patients with spinal cord damage, is awesome."

Ron, Chicago

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The computer was programmed to analyze the collective firing of these 100 motor neurons, translate that sum into an electronic command and send it instantaneously to the arm, which was mounted flush with the left shoulder.

The scientists used the computer to help the monkeys move the arm at first, essentially teaching them with biofeedback.

After several days, the monkeys needed no help. They sat stationary in a chair, repeatedly manipulating the arm with their brain to reach out and grab grapes, marshmallows and other nuggets dangled in front of them. The snacks reached the mouths about two-thirds of the time — an impressive rate, compared with earlier work.

The monkeys learned to hold the grip open on approaching the food, close it just enough to hold the food and gradually loosen the grip when feeding.

On several occasions, a monkey kept its claw open on the way back, with the food stuck to one finger. At other times, a monkey moved the arm to lick the fingers clean or to push a bit of food into its mouth while ignoring a newly presented morsel.

The animals were apparently freelancing, discovering new uses for the arm, showing “displays of embodiment that would never be seen in a virtual environment,” the researchers wrote.

“In the real world, things don’t work as expected,” said the senior author of the paper, Dr. Andrew Schwartz, a professor of neurobiology at the University of Pittsburgh. “The marshmallow sticks to your hand or the food slips, and you can’t program a computer to anticipate all of that.

“But the monkeys’ brains adjusted. They were licking the marshmallow off the prosthetic gripper, pushing food into their mouth, as if it were their own hand.”

The co-authors were Meel Velliste, Sagi Perel, M. Chance Spalding and Andrew Whitford.

Scientists have to clear several hurdles before this technology becomes practical, experts said. Implantable electrode grids do not generally last more than a period of months, for reasons that remain unclear.

The equipment to read and transmit the signal can be cumbersome and in need of

continual monitoring and recalibrating. And no one has yet demonstrated a workable wireless system that would eliminate the need for connections through the scalp.

Yet Dr. Schwartz's team, Dr. Donoghue's group and others are working on all of the problems, and the two macaques' rapid learning curve in taking ownership of a foreign limb gives scientists confidence that the main obstacles are technical and, thus, negotiable.

In an editorial accompanying the Nature study, Dr. John F. Kalaska, a neuroscientist at the University of Montreal, argued that after such bugs had been worked out, scientists might even discover areas of the cortex that allow more intimate, subtle control of prosthetic devices.

Such systems, Dr. Kalaska wrote, "would allow patients with severe motor deficits to interact and communicate with the world not only by the moment-to-moment control of the motion of robotic devices, but also in a more natural and intuitive manner that reflects their overall goals, needs and preferences."