Advent of the Robotic Monkeys

David Cohn 10.26.04

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If a monkey is hungry but has his arms pinned, there's not much he can do about it. Unless that monkey can control a nearby robotic arm with his brain.

And that's exactly what the monkey in Andrew Schwartz's neurobiology lab at the University of Pittsburgh can do, feeding himself using a prosthetic arm controlled solely by his thoughts.

If mastered, the technology could be used to help spinal cord injuries, amputees or stroke victims. "I still think prosthetics is at an early stage ... but this is a big step in the right direction," said Chance Spalding, a bioengineering graduate student who worked on the project.

The prosthetic limb, the size of a child's arm, has working shoulder and elbow joints and is equipped with a simple gripper to grasp and hold food. The monkey's arms are restrained at its sides and as the monkey thinks about bringing the food to his mouth, electrodes in the monkey's brain intercept the neuronal firings that are taking place in the motor cortex, a region of the brain responsible for voluntary movement.

The brain activity is fed to a computer where an algorithm developed by the University of Pittsburgh interprets the neuronal messages and sends them to the robotic arm. "We have learned to understand the patterns of firing rates and can decode them into movement, direction, velocity and speed," said Schwartz.

Schwartz expounded on the research Tuesday at the annual meeting of the Society for Neuroscience in San Diego.

The unique aspect of Schwartz's research is that he conducted what is known as "closed loop" brain experiments. In a "closed loop" experiment, the monkey is conscious of the robotic arm and is making an effort to control it. Monkeys in previous experiments did not understand that they were having an effect on the world at all. Duke University performed such prosthetic arm experiments as far back as 2000. In one case they even sent the electrode signals over the internet, allowing the monkey to move an arm 600 miles away at MIT.

"The open loop experiment was really very crude," said Schwartz. "The closed loop introduces us into a whole new field because the animal actually sees the arm and the consequence of what it is doing." For Schwartz's monkey the robotic arm is incorporated into its mental body representation, making it an extra limb.

"Getting the monkey to learn that he is controlling this robotic device was the hardest part. For him to figure out that it was under his control, and to decipher the mapping took a very long time," noted Spalding.

To achieve this state of computer-aided telekinesis, the monkey had to go through various stages of training in a virtual environment. First the monkey learned what the task was by using its arms, which were tracked in VR, to hit a blue ball.

Next the monkey had to repeat the task while its arms were restrained in a process called "brain control." The lessons at this stage were necessary as they provided a learning space for the monkey to adapt to using the robotic arm.

Because the prosthetic arm relies on a small percentage of the thousands of neurons that fire when the monkey intends to move its real arm, the monkey had to reform its natural thinking process in order to have steady control over the robotic arm.

In the virtual space the monkey learned through biofeedback how to modify the firing rates of the neurons that are being recorded and sent to the robotic arm for directions. By the end of its "brain control" lessons the monkey mastered this new form of movement and could control its phantom limb in virtual reality by knowing how to fire the few key neurons needed.

After graduating from these virtual lessons the monkey moved to the robot arm. While sitting on a high chair with its arms restrained at its side the monkey had to move the robotic arm, which was placed at its shoulder, from different locations to his mouth so he could eat.

"The initial movement to the mouth is pretty good, but when it gets to his mouth he is concentrating on the food and not on the arm movements so it gets a little clumsy," said Schwartz.

As for the future, the monkey still has more to learn. The researchers believe that the monkey can do more than just bring food to itself from various directions, but that it can also reach out for the food.

Even further down the road is a plan to give the monkey a more realistic arm. Schwartz wants to replace the simple one-movement gripper at the end of the current prosthetic arm, custom-built by Keshen Prosthetics in Shanghai, China, with a realistic hand containing finger movement.

"It is much more complicated, but we can take it in stages. We can grip first and then try to work individual fingers," said Schwartz.

While the professor thinks applications are far off, he is excited about the advancement that this experiment means for understanding the brain.

"Every time there is a technological advance, we can use it to better understand the goings-on in the brain," which leads to more scientific discoveries, said Schwartz.

John Donoghue of Cyberkinetics has already extended this research to humans. He has implanted electrodes into the motor cortex of a quadriplegic, allowing the patient to move a computer cursor to access e-mail or use other applications. "The human phase of this has moved forward tremendously," said Donoghue. Cyberkinetics will continue its pilot study by expanding the trial to four more patients.