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Body suit may soon enable the paralyzed to walk

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In a busy lab at Duke University, Dr. Miguel Nicolelis is merging brain science with engineering in a bid to create something fantastical: a full-body prosthetic device that would allow those immobilized by injury to walk again.

On Wednesday, Nicolelis and an international group of collaborators declared that they had cleared a key hurdle on the path toward that goal, demonstrating they could bypass the body's complex network of nerve endings and supply the sensation of touch directly to the brains of monkeys.

Nicolelis and his collaborators - engineers, neuroscientists and physiologists from Brazil, Switzerland, Germany and the United States - are working toward an ambitious objective: On the opening day of the 2014 World Cup soccer tournament in Brazil, they hope to send a young quadriplegic striding out to midfield to open the games, suited up in the "prosthetic exoskeleton" they aim to build.

Nicolelis, a Brazilian-born physician and neuroscientist with a tinkerer's bent, calls that goal a "Brazilian moon shot." And as with moon shots of the past, his team has recruited a monkey - in fact, two female rhesus monkeys named Mango and Nectarine - to go first.

The latest experiment of the nonprofit consortium showed that electrical messages conveying sensation could be sent directly to the monkeys' brains - in enough detail that both animals could distinguish among three

identical circles by virtually "feeling" their differing textures.

Those sensations did not come from the animals' fingers, but from specially coded electrical currents delivered straight to each monkey's sensory cortex by four filaments the breadth of a hair.

Although no one really knows (and the monkeys are unlikely to tell us) whether one circle felt like sandpaper and another felt as smooth as glass, Mango and Nectarine quickly learned to discern one circle from another to complete a task and get their reward: a sip of juice.

The experiment was reported Wednesday in a letter published by the journal *Nature*.

For a person with spinal cord injury, sending such orchestrated bursts of electrical information to the brain could do more than allow a patient who has lost sensation to experience the pleasures of touch again. It could provide the necessary sensory feedback for the user of a prosthetic walker to navigate uneven terrain and steer clear of dangers such as hot or slippery surfaces.

The group's latest effort builds upon an earlier accomplishment, in 2003, in which monkeys learned to move a cursor to designated targets on a computer screen using thought alone.

In another experiment, first described in 2008, Nicolelis' team at Duke showed that monkeys could learn to initiate movement with their thought patterns and command a robotic device across the world in a Japanese robotics lab to walk in real time.

That development was a key step in creating a prosthetic device that could be controlled by a person incapable of voluntary movement below the neck. Now, by adding sensory feedback, the latest experiment

creates a loop of command and control that could make the complex act of walking possible.

Dr. Bruce Volpe, a professor of neurology at Weill Cornell Medical College who is not involved in the consortium - which its members have dubbed the Walk Again Project - praised the latest advance. He called it a "remarkable use of sensory information" that "opens novel ... possibilities" for patients who have lost movement and sensation to injury or illness.

Following injury or stroke, patients' recoveries are often hampered by the "noisy, unresponsive or absent sensory information" making its way to their brains, said Volpe, who studies and develops interactive robotic training devices for the rehabilitation of such patients.

"These data suggest new options for generating that missing and crucially informative sensory information," he said.

The Walk Again Project is one of many research efforts aimed at restoring movement and repairing tissue in those who have suffered grievous spinal cord injury. Although much of that work has focused on the use of stem cells to regenerate nerve and muscle fiber, advances in neuroscience have made the idea of "neural prosthetics" keenly attractive.

University of California, Los Angeles physiologist V. Reggie Edgerton, who was not involved in Nicolelis' work but has pioneered the use of electrical stimulation to initiate movement in paralyzed patients, said that the brain's innate flexibility - its ability to take in electrical signals and learn to attach meaning to them - makes approaches like that of the Walk Again Project highly promising.

Although the information conveyed to the monkeys' brains in Nicolelis'

lab was not fine-grained, the experiment demonstrated that "sensory feedback and brain control devices can be combined in real time and in a useful way," said Kip Ludwig, who directs the program on brain repair and plasticity at the National Institute of Neurological Disorders and Stroke, which has funded some of Nicolelis' work. "Before, they've always been separate.

"Ideally, the long-term goal would be a prosthetic that would send all the sensory information - touch, position, temperature - to the arm that goes into, say, drinking a cup of coffee," Ludwig added. "This is an important step, but there's a lot of work yet to be done."

In demonstrating the feasibility of their ideas on nonhuman primates first, Nicolelis said the team is starting with approaches that are fundamentally simple. He added that when the experiments move to a human, he or she will not only learn quickly how to initiate and repeat movements using thought alone, but the prosthetic should interface so seamlessly with the intelligent human brain that the patient will begin to see the prosthetic as a natural extension of him- or herself.

"We are trying to provide the patient a new body, and we believe the patient's brain will assimilate the new body as part of the sense of self of the patient," Nicolelis said. "It would be just like a car...only a little tighter."

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