The MIT-Manus, developed at the Massachusetts Institute of Technology, helps patients to improve movement in their arm after a stroke.

REHABILITATION

Machine recovery

Interactive devices are helping people who have had a stroke to regain their motor function.

BY MOHEB COSTANDI

Etienne Burdet leans over a glass table, places his elbow in a spring-loaded support clamped to its edge and uses both hands to cut a virtual tomato into thin slices. The tomato is one of several manipulable objects displayed on a touchscreen fitted with force and motion sensors, motors and light-emitting diodes, all of which are connected by Bluetooth to an Android tablet. Burdet finishes slicing the tomato and moves on to unscrewing the lid of a virtual jar.

Burdet, who directs the Human Robotics Group at Imperial College London, is demonstrating a prototype of the iTable, a device that helps people who have had strokes and other neurological injuries to regain use of their hands. Each task draws on reaching, grasping and coordination skills. Sensors detect and analyse the user's movements, then relay the information back to the tablet[1].

"Strictly speaking, this isn't a robot," Burdet says — it does not have moving parts that are powered by electric motors, or perform tasks automatically. "It's an interactive object that tells the patient what to do and how to do it." The iTable is a 'haptic' device — patients interact with it using their sense of touch — but unlike other such devices, the user interface and visual display are one and the same. The patients interact directly with the virtual objects rather than watching them on a separate monitor, "so whatever they learn is directly transferable to the real world", Burdet says.

Rehab devices are in huge demand. Stroke is the world's leading cause of severe disability. In the United Kingdom alone, more than 150,000 people have a stroke in any one year, and about 1.1 million people are living with the consequences, more than half of whom need help to carry out their everyday activities. And because the world's population is ageing, the number of people who have strokes will only increase.

RISE OF THE MACHINES

Stroke usually causes paralysis or weakness on one side of the body, but the injuries can often be treated through intensive training that involves repetitive movements of the affected limbs. The process is time consuming and laborious for both patient and therapist. "The more intense the practice, the better the outcome," says Diane Playford, a consultant neurologist at University College London. Evidence from rats[2] suggests that each movement needs to be repeated between 400 and 600 times a day to recover function.

"We're essentially trying to re-educate the brain," says James Patton, a bioengineer at the Rehabilitation Institute of Chicago in Illinois, "and that means that patients have to do a lot of homework."

In the United Kingdom, people who have a stroke typically spend only a few days in a hospital stroke unit. Most of their recovery happens after discharge: they need to do up to two hours of exercises a day for many months to regain use of their limbs. Many people lack the patience. And a shortage of therapists and caregivers, at least in Europe, exacerbates the situation. Researchers hope that combining robotics with conventional physiotherapy might help people to stick to their daily exercise regimes.

Machines are already invaluable in rehabilitation — they measure patients' progress with great accuracy and are widely used to compare the outcomes and identify the people most likely to benefit from therapies. Some researchers think that machines will transform the way in which treatment is delivered. As the cost of technology drops, that of manual labour rises; researchers hope that robots will not only lend help to deliver the intensive therapy needed for stroke recovery, but also do it more cost-effectively.

"It's a very exciting time," says Hermano Igo Krebs, a mechanical engineer at the Massachusetts Institute of Technology (MIT) in Cambridge. In 1998, Krebs, along with his colleague Neville Hogan, founded Interactive Motion Technologies to commercialize MIT-Manus, an interactive arm device they had developed. The company has sold about 250 devices to clinics around the world. "I believe that robots will change the rehab landscape within the next five years," says Krebs.

Research interest in rehabilitation devices has grown over the past 20 years. A survey published in January[3] lists more than 120 devices for arm rehabilitation alone, ranging from passive braces for the shoulder to complex exoskeletons that actively assist users in performing certain movements.

David Reinkensmeyer, an engineer at the University of California, Irvine, has been involved in the development of more than a dozen devices, several of which emerged from the Machines Assisting Recovery from Stroke centre at the Rehabilitation Institute of Chicago, which he co-directs with Patton. "In neurological rehabilitation, it's critical that the patient exerts as much effort as possible," he says. "An active robot can actually discourage patients from being active."

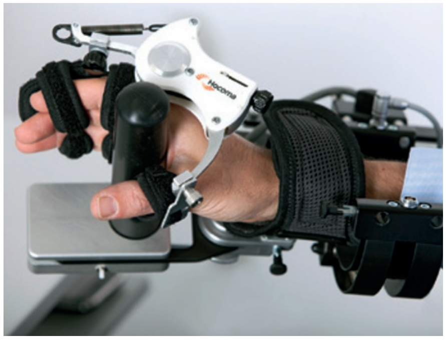
SPRING INTO ACTION

That is the idea behind the ArmeoSpring, an arm exoskeleton that Reinkensmeyer developed with Tariq Rahman, an engineer at the University of Delaware in Newark. The device "has springs that relieve the weight of the paralysed or weak arm", says Reinkensmeyer. "It's a mechanically passive device that demands activity from the patient — it won't move unless the person is active." The ArmeoSpring has been commercialized by Hocoma in Volketswil, Switzerland, which has sold more than 500 units to hospitals around the world and makes a similar device for the hand, the ManovoSpring.

One way to get people moving is to make the task fun and engaging. Reinkensmeyer's latest invention is the Finger-individuating Grasp Exercise Robot (FINGER), a hand exoskeleton containing two motorized rod-and-lever mechanisms, one each for the index and middle fingers. The system, co-developed with Eric Wolbrecht of the University of Idaho in Moscow, helps users to move their fingers individually in a natural curling motion. The device captures their movements and monitors their effort and progress while they play a computer game similar to Guitar Hero, in which players use a guitar-shaped controller to simulate playing the real instrument[4].

Other researchers are developing low-cost, home-based systems that use virtual-reality and gaming technology to make exercise routines more enjoyable, and relay information to therapists who can then monitor patients' progress remotely.

The Limbs Alive project, founded in 2010 by neuroscientist Janet Eyre and occupational therapist Janice Pearse in partnership with Newcastle University, UK, brought together game developers and mathematicians to produce Circus Challenge, a set of games that can be played on televisions, desktop computers, laptops and tablets. Players use motion-sensitive controllers to take charge of various circus performers, using increasingly complex arm and hand movements as they progress through the game.



HOCOMA

The ManovoSpring trains users in grasping skills.

The controllers that move the on-screen avatars capture the speed, accuracy and smoothness of players' movements, allowing therapists to perform validated clinical assessments, which would otherwise take a whole day to do, in less than 20 minutes of game play, says Eyre.

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Few devices have been tested in randomized clinical trials. Of those that are commercially available, the MIT-Manus has been assessed the most thoroughly, in several large, multi-centre trials and in more than 800 patients. The results have shown that robot-assisted therapy works about as well as conventional therapy, but can modestly improve outcomes when delivered at the same time[5–7]. On the basis of such results, the American Stroke Association now endorses the use of robotics for stroke rehabilitation.

Playford, who runs the rehabilitation unit at the National Hospital for Neurology and Neurosurgery in London, has come up with similar preliminary findings. She is testing the HapticKnob, a simple robot developed in Burdet's lab that trains patients in the movements needed to turn a doorknob[8]. "If you use robots as an adjunct to usual practice you get slightly better results," Playford says, "but if you use them instead there's no difference."

The real improvements may lie not in effectiveness but in economic efficiency. A 2011 study[9] of the MIT-Manus showed that a 36-week course of robot-assisted therapy cost several thousand dollars less than the same duration of conventional therapy, even when the cost of the devices was taken into account.

To answer the economics question more definitively, UK researchers have begun a four-year, multi-centre trial to evaluate the cost-effectiveness of robot-assisted rehabilitation in the National Health Service. The study is led by neurologist Helen Rodgers of Newcastle University, and is the largest of its kind, with plans to enrol up to 800 patients. Another large trial, led by Olivier Rémy-Néris, a psychiatrist at the University of Western Brittany in Brest, is evaluating the ArmeoSpring at 21 hospitals in France.

MONEY MAGNETS

At present, cost remains the biggest barrier to the widespread use of rehab robots. "Most commercially available robots are still very expensive," says Playford. "They take time to set up and need an expert, so at this stage it probably isn't cheaper to have a robot in most settings." Ultimately, Playford says, cost savings will come only when portable robots are available that are inexpensive to make and can be delivered to people's homes for a course of therapy. In line with that thinking, Burdet's team is now focusing on developing cheap, compact machines. Most of the creations coming out of his lab are either passive, sensor-based devices such as the iTable, or simple robots such as the HapticKnob.

Krebs, for his part, sees a time when both large and small robots are an integral part of the therapeutic mix. "Large machines are more suitable for clinics, which could have different machines to train different movements," he says. "Then you might move to simpler devices that go to the home, based on the individual's needs."

Krebs predicts that home-based machines will soon become commonplace. He and his team are therefore developing devices for use in what they call social spaces, or virtual environments in which rehab exercises are built into multiplayer games. In the not-too-distant future, then, patients may motivate each other to do their daily exercises by virtually beating each other up, even though they are thousands of kilometres apart. ■

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