Picture credit: Eckert

From Aid
to Empowerment

Patients with paraplegia have partially regained feeling in their legs after a year's mobility training with an exoskeleton as part of the Walk Again Project. An artificial skin developed by Prof. Gordon Cheng played a key role here, enabling sensory feedback from the exoskeleton to the patient. Now, Cheng is teaming up with neurologists at TUM to explore how this type of training could help people with multiple sclerosis.

Link
www.ics.ei.tum.de

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Vom Hilfsmittel zum Heilmittel

Robotik und Neurologie können viel voneinander lernen. Davon ist Prof. Gordon Cheng fest überzeugt. Am Lehrstuhl für Kognitive Systeme an der TUM entwickelt er humanoide Roboter, die sich wie Menschen auf zwei Beinen fortbewegen. Ein Schwerpunkt seiner Arbeit ist dabei die Entwicklung einer mit Sensoren und Mikroprozessoren bestückten künstlichen Haut, die über sensorische Rückmeldung die Sicherheit der Maschinen verbessert. Sie kam auch zum Einsatz bei einer Studie, bei der querschnittgelähmte Menschen in einem dreistufigen Trainingsprogramm das Gehen mit einem Exoskelett lernten, und die überraschende Nebeneffekte zeigte. Nach einem Jahr des Trainings, das aus einer Kombination aus Neuro-Feedback und robotischen Hilfsmitteln bestand, hatten alle acht Teilnehmer nicht nur die bewusste Kontrolle über ihre Beine wiedergewonnen, sondern auch Teile ihres mit der Rückenmarksverletzung verlorenen Gefühls in den unteren Extremitäten. Anknüpfend an dieses Ergebnis richtet der Robotiker seine Forschung gemeinsam mit Prof. Bernhard Hemmer, dem Leiter der Neurologie am Klinikum rechts der Isar, künftig auch stärker auf die Erforschung von entzündlichen Erkrankungen des zentralen Nervensystems aus. „In den vergangenen acht Jahren war ich Teil eines internationalen Forschungsteams. Im Rahmen des „Walk Again Projects“ haben wir uns auf Wirbelsäulenverletzungen fokussiert und dabei festgestellt, dass das Gehirn genügend Plastizität hat, um bei entsprechendem Training Schädigungen des neuronalen Gewebes, auch bei Multipler Sklerose und anderen Erkrankungen, zu kompensieren“, ist Cheng überzeugt. Erste Tests mit Patienten bestätigen seine Vermutung. □

Training based on a combination of neurofeedback and robotic aids could benefit not only paraplegic patients but also those with other neurological conditions such as multiple sclerosis (MS). This technology was developed within the Walk Again Project, which made headlines in 2014 when paralyzed participant Juliano Pinto kicked off the soccer World Cup in Brazil at the opening ceremony. The 29-year-old was wearing a robotic body suit, controlling its leg movements with his thoughts.

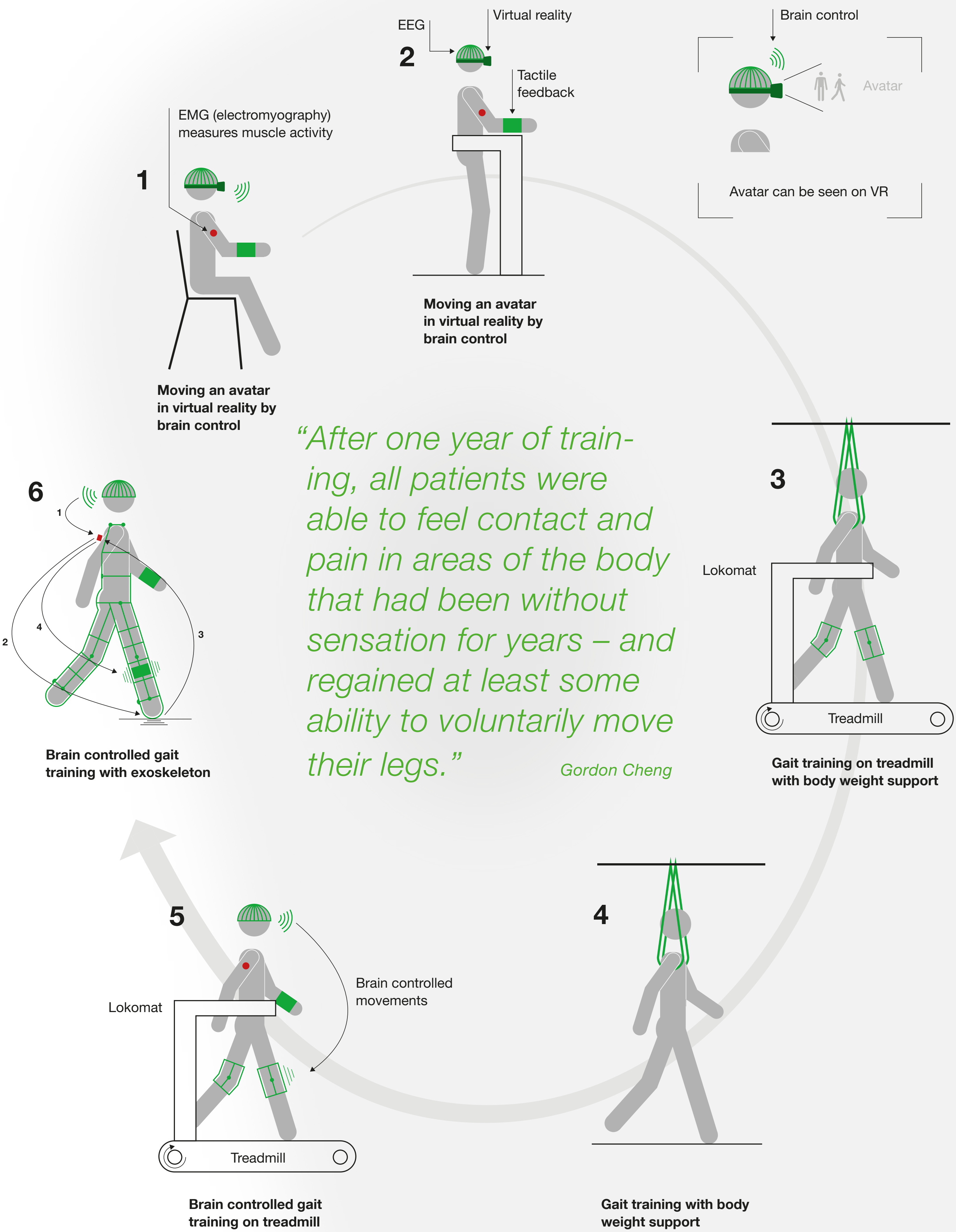
“When we started work, our aim was to develop equipment that would enable people with paraplegia to regain mobility by controlling prosthetic limbs or exoskeletons with their brains. We did not expect that training in this way over an extended period might itself have a therapeutic effect,” reveals Gordon Cheng, Director of TUM’s Institute for Cognitive Systems. His laboratory is responsible for the artificial skin fitted to the mind-controlled exoskeleton used in Juliano Pinto’s big debut in Rio two years ago. This robotic skin also played a decisive role in a clinical trial conducted within the Walk Again Project, the outcome of which was recently published. The electronic artificial skin uses sensors to detect pressure or touch, for instance, relaying these signals back to the person wearing the exoskeleton. Like the extraordinary World Cup participant, all of the eight people on what researchers refer to as the Walk Again Neurorehabilitation protocol were paralyzed from the hip down due to spinal cord injuries. “None of them could move or feel their legs,” confirms Cheng, describing their initial condition, which, in fact, improved dramatically over the course of the trial.

After six months of intensive training, the first signs of success were already clear. During this period, the participants not only learned to move the exoskeleton forward through brain activity, but also assimilated the robot’s legs and feet into their own body schema. “We were very surprised when they told us that they were actually experiencing the exo’s movements as their own steps,” Cheng recalls. Interpreting this man/machine merger, he explains: “Evidently, with the right training, we can trigger new connections in the brain, allowing us to reorganize our body schema to integrate new elements such as the exoskeleton.”

A year’s training to regain feeling in the legs

An even greater surprise for Cheng and his colleagues was that the participants’ medical condition also improved significantly – another side effect of training that emerged in subsequent months. “After one year, they were all able to feel contact and pain in areas of the body that had been without sensation for years – and regained at least some ability to voluntarily move their legs,” he reports, describing changes that astonished and delighted researchers and participants alike. “While training with the exoskeleton, one woman suddenly felt a burning sensation in her legs,” he recalls. “She started crying – not due to pain, but because she was so happy to be walking again after such a long time.” ▷

Graphics: ediundsepp (source: TUM)



"After one year of training, all patients were able to feel contact and pain in areas of the body that had been without sensation for years – and regained at least some ability to voluntarily move their legs." *Gordon Cheng*

Gordon Cheng developed the artificial skin in order to provide robots with tactile feedback.

Prof. Gordon Cheng

Gordon Cheng is a passionate robotic engineer who believes that in the future, robots and smart machines will better assist especially older and handicapped people in their daily lives.
Cheng studied information sciences at Wollongong University (Australia) and was awarded a doctorate in systems engineering in 2001 from the department of systems engineering of the Australian National University. He founded the department of humanoid robotics and computational neuroscience at the Institute for Advanced Telecommunications Research in Kyoto (Japan), where he was Department Head from 2003 to 2008. In addition, from 2007 to 2008 he was a project manager at the National Institute of Information and Communications Technology (Japan) and the Japan Science and Technology Agency, where he was responsible for the Computational Brain project (2004-2008). In 2010, Cheng founded the Chair for Cognitive Systems at TUM.

As far as Cheng and the team are concerned, there is just one plausible explanation: the training triggered plasticity in the brain. This refers to the brain's capacity to transfer specific tasks from a damaged region to a healthy one. "But I also think it rekindled neurons in the spinal cord. It's got to be both," is Cheng's interpretation of this unexpected therapeutic progress after just twelve months of training. "The combination of visual and tactile feedback is the key to the training's success," he states with conviction.
In the first stage of the program, the eight men and women learned to make an avatar walk by means of their own thoughts. To achieve this, they wore an electrode cap, which recorded their brain activity and conveyed it to a computer. Whenever it received the appropriate brain signals, this computer then set the virtual person in motion, with participants viewing it through virtual reality goggles. In stages two and three, the participants worked with the exoskeleton, taking their first steps on a treadmill before continuing their training on normal surfaces. In all three stages of training, they received sensory feedback from small motorized components in the sleeves of their clothing, which vibrated when the feet of the avatar or exoskeleton touched the ground. During training with the exoskeleton, this tactile feedback came from the artificial robot skin developed by Gordon Cheng and his team at TUM. This artificial skin was applied to the soles of the robotic exoskeleton's feet.

Picture credits: Eckert

Could MS patients benefit from robotics?

Building on these promising trial outcomes, Gordon Cheng now intends to apply his research to new treatment scenarios. “We have spent the last eight years focusing on spinal injuries and established that the brain has enough plasticity to compensate for neural tissue damage, given the right training. That could also apply to other conditions,” he explains. With this in mind, he has already been in touch with Prof. Bernhard Hemmer, Director of the Department of Neurology at TUM’s university hospital, Klinikum rechts der Isar. Hemmer specializes in neuroimmunology. His research focuses on inflammatory diseases of the central nervous system – in particular multiple sclerosis. This condition damages the protective sheath around nerves in the central nervous system and can trigger almost any kind of neurological symptom. “I learned a lot about this disease from him – and identified many similarities to paraplegia in the process,” recounts Cheng.

Symptoms such as sensory disturbances or impairment, muscle weakness and paralysis are all typical of MS. As Cheng discovered in his discussions with Prof. Hemmer’s patients, “Many of those affected lose their sense of touch and can no longer feel their feet hitting the ground.” As he also found out, they use their vision to compensate for this loss of sensation. “Assuming they are able to control their legs in the first place, these patients tend to move unsteadily and often stumble. When they close their eyes, many of them can no longer move at all.” Cheng is familiar with this problem from developing humanoid robots. Without tactile perception, these machines also struggle to stay steady on their feet. With artificial skin, though, they can even accomplish this on uneven terrain. “The issues facing robotics are also of interest to neurologists,” he is sure. He now believes that a combination of neurofeedback and assistive robotics could also have the potential to help restore MS-related impairments altogether.

At the same time, Cheng has continued optimizing his humanoid robots and fine-tuning the exoskeleton – the aim being to make it faster, lighter and, above all, less expensive. He has also made further advances with the artificial robot skin, maintaining the system’s sensitivity while shrinking its components and attaching it to a rubbery surface. This is flexible enough to cling to whatever it is applied to – whether a robot’s hand or foot or a human body, it adapts to ensure a perfect fit. This brings Gordon Cheng another step closer to the goal he has clearly in his sights: “I want to develop a body suit made of artificial skin to help people with neurological disorders get their life back to normal.” *Birgit Fenzel*

Cheng’s group developed this new EEG (electroencephalogram) device for measuring brain activitiy.

The artificial skin is made up of several hexagonally shaped unit cells, each featuring multiple sensor modalities.