NEURAL REPAIR AND REHABILITATION

Brain–machine interaction improves mobility

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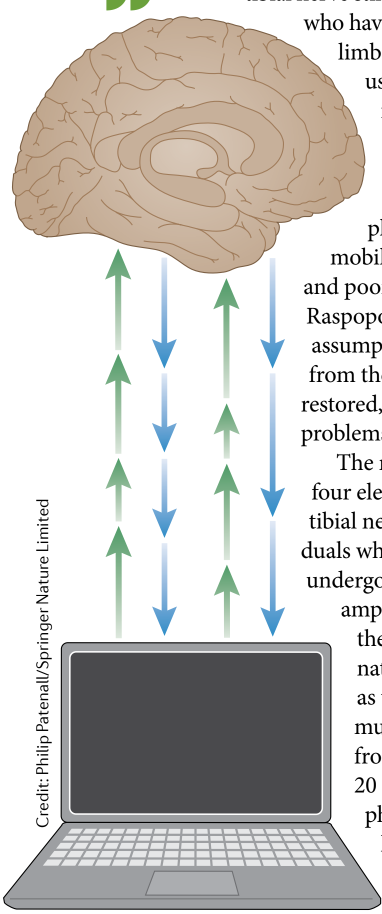

Credit: Philip Patenall/Springer Nature Limited

Communication between the brain and prosthetic devices can improve the mobility of individuals who have undergone leg amputation and those with tetraplegia, according to two new studies published in *Science Translational Medicine* and *Lancet Neurology*. The proof-of-concept studies pave the way for these new technologies to be used in the clinic.

In the first study, Stanisa Raspopovic and colleagues developed a leg neuroprosthesis that provides sensory feedback to the brain via tibial nerve stimulation. "Patients who have undergone lower limb amputation and are using a prosthesis suffer from problems related to missing sensory feedback, including low precision when placing the foot, low mobility, high fatigue, and poor balance," explains Raspopovic. "We made an assumption that, if feedback from the missing leg is restored, some of these problems could be solved."

The researchers implanted four electrodes into the distal tibial nerve of three individuals who had previously undergone transfemoral amputation. Stimulating the electrodes elicited natural sensations, such as touch, pressure and muscle contraction, from more than 20 positions over the phantom foot sole and lower leg.

Raspopovic and colleagues built a customized prosthesis with sensors in the insole and knee to drive stimulation of the tibial nerve electrodes. As patients walked, the sensors elicited sensations of touch at three different positions on the foot sole, and of contraction of the gastrocnemius muscle, which was interpreted by participants as knee flexion.

When receiving sensory feedback from the prosthesis, participants performed better in a test of stair climbing ability, were less likely to fall after treading on an obstacle and could place the prosthesis more accurately than when the sensory feedback was disabled. Participants could also pay more attention to an additional task when walking with sensory feedback enabled.

"These findings are, to the best of our knowledge, the first of their kind in individuals who have undergone above-knee, lower limb amputation," notes Raspopovic. However, the transcutaneous passage of the electrode cable meant that the trial period was limited to 3 months. "A longer investigation, with more patients and with in-home assessments, should be executed to provide more robust data," concludes Raspopovic.

In the second study, Alim Louis Benabid and colleagues developed a brain–computer interface system that allowed a robotic exoskeleton to be controlled by the brain activity of an individual with tetraplegia. The exoskeleton used in the study was fully motorized and wearable, and was designed to restore mobility by physically moving the limbs.

Benabid and colleagues implanted an epidural recording system that contained an array of electrodes over the sensorimotor cortices of an individual with tetraplegia. Data from the implants were sent via radio link to receivers in a helmet.

The researchers asked the participant to imagine performing a specific movement. The cortical activity data generated were decoded in real time by a computer in a backpack that interpreted the intended movement and communicated it to the exoskeleton.

This brain–computer interface system was used by the participant to mentally trigger 'on–off' events, such as initiation of a programme of walking behaviour in the exoskeleton. The participant could also use the system to drive an electric wheelchair and to control the exoskeleton to make continuous spatial movements of the arms and hands.

Although the exoskeleton does not yet enable independent walking — a ceiling suspension system was needed for the study — the findings are an important step forward. "The initial goals of our study were met, proving that brain–computer interface technologies can involve a high level of sophistication, such as the control of a whole body skeleton," say the researchers in the paper.

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ORIGINAL ARTICLES Petrini, F. M. et al. Enhancing functional abilities and cognitive interaction of the lower limb prosthesis. *Sci. Tansl Med.* **11**, eaav8939 (2019) | Benabid, A. L. et al. An exoskeleton controlled by an epidural wireless brain–machine interface in a tetraplegic patient: a proof-of-concept demonstration. *Lancet Neurol.* https://doi.org/10.1016/S1474-4422(19)30321-7 (2019)