When the neuroprosthetics learn from the patient

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While it takes a long time to learn to control neuroprosthetics, Jose Millán research, published in *Nature Scientific Reports*, will enable the creation of a new generation of self-learning and easy-to-use devices.

Brain-Machine Interfaces (BMI) are a great hope for thousands of patients affected by the various motor impairments, notably paralysis. Patients fitted with such equipment can control artificial limbs through electrodes connected - directly or not invasively - to their brain. In an article published today in *Nature Scientific Reports*, Jose Millán, holder of the Defitech Chair in Brain-machine Interfaces, describes the application of an innovative technology that may allow the development of a new generation of non-invasive BMI.

Most BMI operate by interpreting variations in the electrical activity of the brain, generally through an electroencephalogram. To be effective, such a method requires significant training on the patient's side. They must be able to communicate the desired information (e.g, "extend left arm") by modulating their brain activity. The results are encouraging but come up against two obstacles. Patients must spend a lot of time to learn how to use their neuroprosthetics; despite this training, they are often not able to perform certain complex movements.

An "error signal"

When missing a step, the brain emits an electrical impulse signifying the failure of the action. This signal is called Error-related potential (ERP). Jose Millàn, whose seminal work in the field of BMI was noted by the journal *Science*, uses this signal to develop a new generation of neuroprosthetics. "With ERP the machine itself will learn to make the right moves." The EPFL professor calls this innovation "a paradigm shift."

The detection of this "error signal" allowed Jose Millàn's team to create a new generation of neuroprosthetics. They are capable of learning the proper movements based on ERP. For example, if we fail to grasp a glass of water placed in front of us, the neuroprosthetic will understand that the action was unsuccessful and the next movements will change accordingly until the desired result. The machine knows that the goal is reached when the action performed does not generate an ERP.

The paradigm shift lies in the use of these signals to relieve the subject from the tedious task of learning. This new approach could be the source of a new generation of intelligent prosthetics, able to learn a wide range of movements. Indeed, with the support of ERP, it is theoretically possible to learn and master quickly enough a multitude of motor movements, even complex ones.

25 minutes to train its decoder

The twelve subjects of the experiment were first asked to train their prosthetics to detect ERP. Equipped with an electrode headset, they observed the machine, programmed to fail in 20% of cases, performing 350 separate movements. The setting of the ERP detector lasted an average of 25 minutes. Once this first step was completed, the subjects performed three experiments to evaluate the effectiveness of this new approach. In the last one, they were asked to identify a specific target using a robotic arm placed two meters away. In all three experiments, the neuroprosthetic demonstrated interesting learning capabilities by continuously adapting its actions and increasing its precision.

Indeed, the artificial arm stores the correct movements and constitutes an increasingly wide database of appropriate motor actions. This capability could be particularly useful for people with neurodegenerative diseases, allowing them to compensate almost organically the loss of motor function. "We expect this new approach to become a key element of next-generation brain-machine interfaces that mimic natural motor control," says Jose Millán. "The prosthetic can function even if it does not have clear information about the target."

More information: "Teaching brain-machine interfaces as an alternative paradigm to neuroprosthetics control." *Scientific Reports* 5, Article number: 13893 (2015). DOI: 10.1038/srep13893

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