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Brain-computer interface based on mutual learning helps tetraplegics to win Cybathlon avatar race

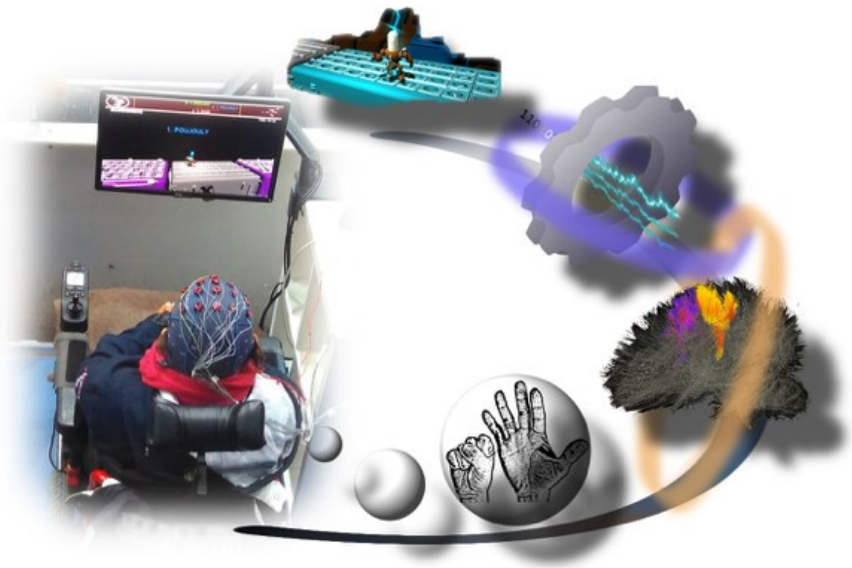
People using brain-computer interface are more efficient when both human and machine are allowed to learn. EPFL researchers trained two tetraplegic users to compete in the international Cybathlon BCI race. Both incrementally learned how to control the BCI, and obtained the best performances at the competition, confirming researchers' hypothesis that mutual learning plays a fundamental role in BCI training.

Brain-computer interfaces (BCIs) are seen as a potential means by which severely physically impaired individuals can regain control of their environment.

BCIs use the electrical activity in the brain to control an external device. They have seen growing use in people with severe motor disabilities, for communication (by controlling a keyboard), mobility (by controlling a powered wheelchair), and daily activities (by controlling a mechanical arm or other robotic devices). But establishing such an interface is not trivial.

In a study published in the open-access journal PLOS Biology, a group of researchers at the École Polytechnique Fédérale de Lausanne in Geneva (Campus Biotech), led by José del R. Millán - Defitech Foundation Chair in Brain-Machine Interface, School of Engineering, suggests that letting humans adapt to machines improves their performance on a brain-computer interface.

The scientists trained two tetraplegic subjects to compete in the Cybathlon BCI race, an international competition where competitors control an on-screen avatar with brain-computer interfaces. The results suggest that the most dramatic improvements in computer-augmented performance are likely to occur when both human and machine are allowed to learn.



In the Cybathlon's Brain Runners game pilots need to deliver the proper command in each color pad (cyan, magenta, yellow) in order to accelerate their own avatar.

How does it work?

With BCIs, the electrical activity is typically detected at one or more points of the surface of the skull, using non-invasive electroencephalographic electrodes, and fed to a computer program that, over time, could improve its responsiveness and accuracy through learning.

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As machine-learning algorithms have become both faster and more powerful, researchers have largely focused on increasing decoding performance by identifying optimal pattern recognition algorithms. It was suggested that the performance could be improved if the operator and the machine both engaged in learning their mutual task. However, direct evidences of such a learning mechanism were rare and fragmented.

Winning the gold medal

At EPFL, two tetraplegic adult men were trained with a BCI system designed to detect multiple brain wave patterns. Training took place over several months, culminating in an international competition, called the Cybathlon, in which they competed against ten other teams. Each participant controlled an on-screen avatar in a multi-part race, requiring mastery of separate commands for spinning, jumping, sliding, and walking without stumbling. The two subjects marked the best three times overall in the competition, one of them winning the gold medal and the other holding the tournament record.

A specific training

Electroencephalography recording of the subjects during their training showed that the brain wave patterns related to imagined movements (called sensorimotor rhythms), which have been adopted to control the avatar, became stronger over time, indicating that the subjects were learning how to better control the BCI during the training.

The authors believe they have maximized the chances for human learning by infrequent recalibration of the computer, leaving time for the human to better learn how to control the sensorimotor rhythms that would most efficiently evoke the desired avatar movement. Training in preparation of a competition may also contribute to faster learning, the authors propose.

“This study is one of the few to provide multi-faceted evidence on the efficacy of subject learning during BCI training,” the authors said. “Contrary to the popular trend of focusing on the machine learning aspects of BCI training, a comprehensive mutual learning methodology could strongly promote acquisition of BCI skills.”

Freely available article in PLOS Biology

The Cybathlon BCI race: Successful longitudinal mutual learning with two tetraplegic users, PLOS Biology

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NCCR Robotics

The Swiss National Center of Competence in Robotics (NCCR Robotics) is a federally funded programme bringing together robotics laboratories from EPFL, ETH Zurich, University of Zurich, IDSIA and UNIBE to work on wearable, rescue and educational robots.

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Images: Serafeim Perdikis and Robert Leeb

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