Keywords: Brain–computer interface; Communication; Disorder of consciousness; Coma

Introduction.-- The reestablishment of communication is one of the main goals for patients with disorders of consciousness (DOC). It is now established that many DOC patients retain the ability to process stimuli of varying complexity even in the absence of behavioral response. Motor impairment, fatigue, attention disorders might contribute to the difficulty of communication and could be substituted by a brain computer interface (BCI) device.

Methods.-- Review of the current literature of BCI applications for communication purposes (following commands, yes-no code, spelling simple words) in DOC patients using functional magnetic resonance imaging (fMRI) or electroencephalography (EEG). Results are critically analyzed in a clinical perspective.

Results.-- One fMRI study assessed the ability to generate willful responses during two mental-imagery tasks (Monti et al., 2010). Only one of the 54 DOC patients included was able to use this technique to answer yes or no to questions during fMRI. Two studies investigated a BCI device based on the EEG signal in DOC patients. Cruse et al. (2011) recorded sensori-motor brain activity generated by two motor imagery tasks in 16 VS patients. Three patients demonstrated the ability to modulate their brain activity. In another study, a P3 auditory BCI paradigm was developed (Lulé et al., 2013). None of the 16 DOC patients could demonstrate a functional communication using this device. In one MCS patient, it was possible to detect offline commands.

Discussion–Conclusion.-- The use of fMRI appears limited from a clinical point of view given the exclusion criteria associated with paramagnetic effects of MRI, the low rate of responders and the lack of portability. The EEG seems more feasible with possible BCI applications at the patient’s bedside but concerns a minority of DOC patients. The global inconsistency of current results can be explained by several factors: lack of awareness of DOC patients, lack of sensitivity of the technique, atypical pattern of brain activity. The challenge is to select the best candidates, to improve the efficiency, portability and cost of these techniques.

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Improving non-invasive BCI for possible clinical application: Example of the “P300-speller”

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A well-known neurophysiological marker that can easily be captured with electroencephalography (EEG) is the so-called P300: a positive signal deflection occurring at about 300 ms after the relevant stimulus. This brain response is particularly salient when the target stimulus is rare among a series of distracting stimuli, whatever the type of sensory input. Therefore, it has been proposed and extensively studied as a possible feature for direct brain-computer communication. The most advanced non-invasive BCI application based on this principle is the P300-speller. However, it is still a matter of debate whether this application will prove relevant to any population of patients.

In a series of theoretical and empirical studies, we have been using this P300-based paradigm to push forward the performance of non-invasive BCI. We will summarize the proposed improvements and obtained results. Importantly, they could be generalized to many kinds of BCI, beyond this particular application. Moreover, they relate to most of the key components of a closed-loop BCI, namely:

– simplifying the hardware and time for set-up in the aim of routine use in patients;
– improving the accuracy of the system by trying to detect and correct for errors automatically;
– optimizing the computer’s speed-accuracy trade-off by endowing it with adaptive behavior.

Most of those evaluations have been realized in healthy subjects. We will conclude on the ensuing perspectives for clinical applications.

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