# Toward a hybrid brain-machine interface for palliating motor handicap with Duchenne muscular dystrophy: A case report.

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# Towards a hybrid Brain-Machine Interface for palliating the motor handicap caused by Duchenne muscular dystrophy: a case report

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Dear Editor,

Given that the life expectancy of patients with Duchenne Muscular Dystrophy (DMD) has increased over recent years, motor handicap is experienced for longer and can also be more severe than in the past. Technical aids have been developed to enable patients with DMD to interact with the applications (an electrical wheelchair, a web browser, a video game, etc.) used in their daily life. Indeed, with the approaches reported in [1] patients with DMD can control these applications thanks to a variety of technologies including standard devices (the computer mouse, the joystick, the eye tracker, and voice recognition) and a novel device such as a Brain-Machine Interface

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(BMI). These devices are chosen as a function of the patient's residual muscular activity, and therefore must be replaced as the disease progresses. To avoid changing the patient's control paradigms, it would make more sense to offer a hybrid BMI (hBMI) that could adapt itself to the patient's level of motor handicap by using several signals - including at least one measurement of brain activity (for a review on hBMIs, see [2]).

We have started to develop an hBMI specifically for patients with DMD, so that the patient can control several different applications with a single interaction technique based on the online, real-time processing of electroencephalography (EEG), surface electromyography (EMG), and joystick signals. Next, signal processing will detect hand movement (either real or imagined) at different levels in the motor command chain. Two joysticks will be used as long as the patient is capable of activating them. Next, when disease progression leads to a reduction in motricity, the hBMI will take account of surface EMG signals and then only EEG signals to detect the same movements or the same movement intentions. Hence, patients will continue to use the same interaction technique - even when their motricity deteriorates. This will avoid having to switch to the use of a single joystick, which requires very accurate hand control. The prototype hBMI presented in this letter analyzes rough movements of both hands separately or simultaneously.

As a case study, we report the first results of our prototype hBMI usage by two patients with DMD during a virtual kart driving task. The primary objective of the present study was to assess the relevance of the interaction technique (described below) for controlling the patient's mobility kart using online-processed surface EMG signals. Although the reliability of surface

EMG processing and the efficacy of the interaction technique had already been confirmed in a group of healthy people [3], the technology had not previously been assessed in patients with DMD. In the present pilot study, surface EMG was preferred over others sensors because (i) joystick usage induced too much fatigue, and (ii) using EEG would have required a lengthy learning period. Indeed, the final version of our hBMI will be designed to select the most reliable signal as a function of the patient's motricity, and to switch smoothly from one signal to another as the disease progresses or the level of fatigue changes. Although EEG signals were not processed online during this experiment, they were recorded to allow subsequent offline analysis.

The interaction technique incorporated into our hBMI had been designed to enable the control of various applications. The user controls the trajectory of a moving object - either real or virtual – by using three independent commands, i.e. real or intended movement of the right hand, the left hand or both hands together. Right and left hand movements result respectively in left rotation and right rotation of the object, whereas the simultaneous movement of both hands moves the object forward. In order to help the user master the hBMI, we have developed several game-like applications: driving a vehicle in open and constrained environments, exploring a maze, and controlling a mouse-like cursor [4].

We studied two male patients with severe DMD (aged 20 and 28 years). Both are confined to a wheelchair but have residual motricity in their hands. This proof-of-concept study was made possible by collaboration between researchers from the CRIStAL laboratory, the Physical Medicine and Rehabilitation Unit at Lille University Medical Center, and the Centre Hélène Borel (all of which are located in Lille, France). Thanks to the use of portable, fully autonomous equipment, the experiments were carried out directly at the patients' place of residence over a period of about 90 minutes.

In Figure 1, the upper, left-hand panel shows a patient with DMD sitting in front of a computer screen that displays a virtual kart driving task. He is wearing an EEG cap (equipped with twelve active electrodes) placed on the scalp over the primary motor cortex at positions that allowed us to record signals that varied when the patient moved his hands. The upper, right-hand panel of Figure 1 shows two surface EMG electrodes specifically placed by a clinician on each hand, depending on the patient's residual motricity. A g.USBamp bioamplifier (gTec, Graz, Austria) was used to amplify and sample EEG and surface EMG signals. It took about 20 minutes to set up the EMG/EEG electrodes and to check the signal quality. The data were recorded and processed online using OpenVIBE software (INRIA Rennes, France) [5]. Typical surface EMG signals (Figure 1, the lower, left-hand panel) clearly showed bursts corresponding to hand movements.

The task consisted in completing two laps of a circuit with the kart shown in the lower, right-hand panel of Figure 1, by moving either the left hand or the right hand (depending on the intended trajectory). A time constraint (materialized by a "traffic light" graphic) obliged patients to control the kart by spacing out short-duration movements over time, which therefore induced less fatigue. When the traffic light was green, the user could send a command by moving his hands. After the command had been recognized by the system, the traffic light turned immediately red for a fixed resting time (set to 4 seconds here), during which the user could not send another command. To make it easier to control the kart, with short, spaced-out movements, we modified its kinematics by applying a dynamic transfer function for motion inertia [6]. Each lap time (in seconds) was used as a performance metric, and compared with those of ten healthy subjects performing the same task over two sessions. The two patients with DMD also performed two sessions.

Figure 2 shows the mean lap times for each session performed by the healthy participants and each patient. Although we did not perform a statistical analysis of these data, it appears as if the patients and healthy participants had similar lap times. Consideration of these results and an informal debriefing with the participants suggest that the interaction technique integrated into our hBMI is relevant for patients with DMD: a video game can be controlled by processing online surface EMG signals. Moreover, we observed a learning effect in both the patients and the healthy subjects, expecting performance improvement with training.

As mentioned above, the patients' EEG signals were not processed online but were recorded for offline processing. The usual approach for detecting actual or intended movements within EEG signals in motor-imagery-based BMIs consists in detecting event-related synchronizations (ERS) or desynchronizations (ERD) of rhythms in the $\mu$ and $\beta$ bands [7]. Detecting these brain patterns will allow the detection of hand movements when surface EMG signals are no longer reliable because of a deterioration in motricity. For example, the curves in Figure 3 show the average power levels of the EEG signals recorded at electrode C4 for patient#2 (after band-pass filtering in the 12-16 Hz of the low $\beta$ band) under two situations: when he was moving both hands simultaneously (red curves) vs. all other conditions (blue curves). A marked resynchronization of the $\beta$ rhythm after movement offset (1 s) is clearly visible.

With a view to confirming the conclusive results of this pilot study, we intend to study the same kart driving task in a larger number of patients with DMD. Furthermore, to assess the interaction technique with a wider range of applications, we shall ask patients to perform other video-game-based tasks (maze exploration and mouse-like cursor control) developed in our lab using Unity3D software. In order to assess all the components of our hBMI, we plan to process offline all the recorded EEG signals; this should enable us to identify neurophysiological patterns [2] of value for detecting real or intended hand movements as accurately as possible, and thus to develop an interface that matches the patient's level of motricity.

Conflicts of interest: none. No specific funding was received for the performance of this pilot study, since our groups receive recurrent grants from the French National Center for Scientific Research (CNRS) and the French Ministry of Higher Education through University of Lille.

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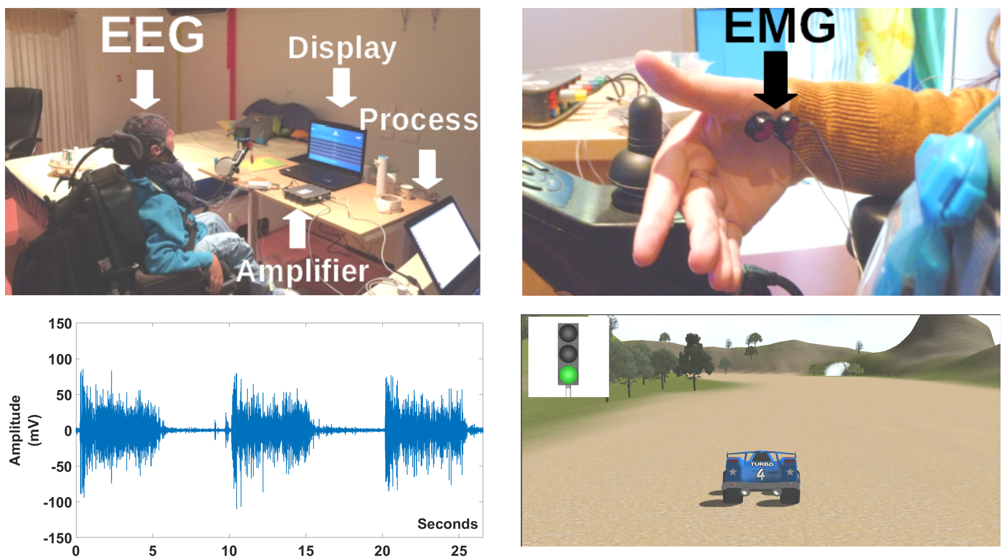


Figure 1: Upper panels: an overview of the hBMI experiment. Lower, left-hand panel: the bipolar surface EMG signal. Lower, right-hand panel: the kart driving task.

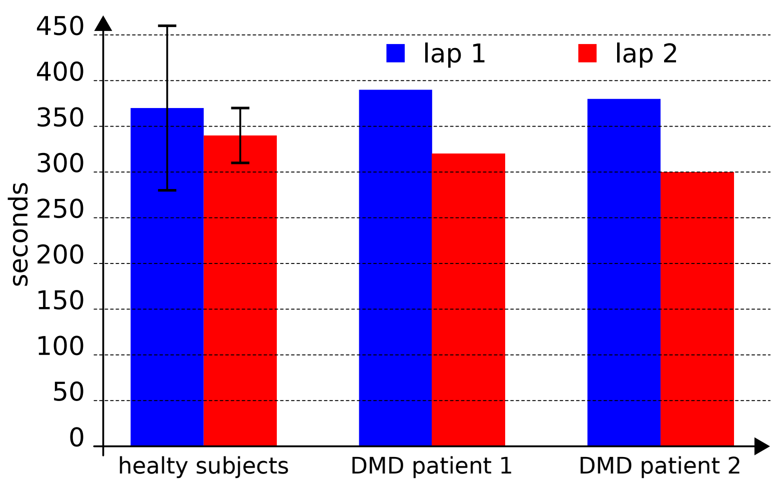


Figure 2: Lap times in seconds for healthy subjects and patients with DMD.

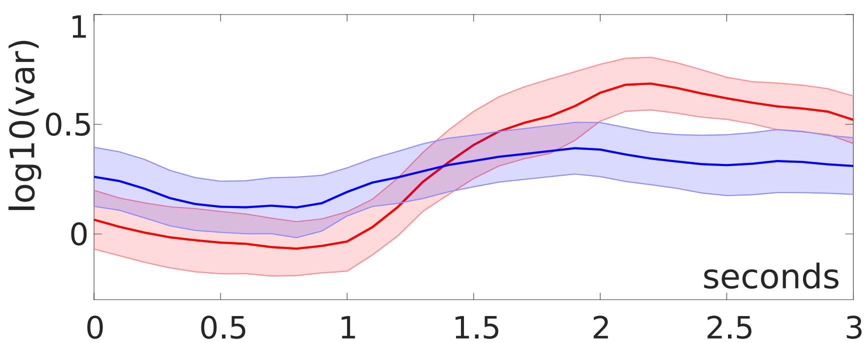


Figure 3: Offline processing of EEG signals.