Brain Mapping As a Tool To Improve a Physiologically Driven-Feature Selection for Non-Invasive BCI Applications

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Abstract. In the present study, we illustrate how advanced methodologies for the reconstruction of brain sources based on scalp EEG recordings could be of value in improving feature extraction in the field of non-invasive BCI applications. The EEG spectral information extracted offline at cortical and sub-cortical levels and related to three mental imagery tasks performed by 14 subjects during a screening session, allowed the selection of individual spatial/spectral feature sets reliably encoding the physiological substrates of each imagery task. Such features were then used in a online BCI application based on mental imagery proving the feasibility of the present approach.

Keywords: high resolution EEG, source reconstruction, Linear Inverse Problem, sLORETA, statistical mapping, mental imagery tasks

1. Introduction

In the present study we applied a set of advanced EEG brain mapping techniques to increase the spatial resolution of scalp signals in order to improve the feature extraction procedures for non-invasive Brain Computer Interface (BCI) applications. The rationale was to identify the neurophysiological substrates of imagery tasks which are or can be possible candidates to operate BCI systems, with the ultimate aim of addressing a physiologically driven feature selection. As such this approach could not only maximize classification performances but it could also allow the use of the BCI output as a measure of the subject's involvement in the executed task and thereby, to boost the BCI use beyond serving as a new class of assistive technology devices.

2. Materials and Methods

2.1. Experimental Design and Data Acquisition

Fourteen healthy right-handed volunteers (age: 28.5 ± 6.4 years, 6 females) participated to the study. During the EEG (61-channel commercial system; sampling rate of 200 Hz) screening session, subjects were asked to perform three imagery tasks, playing Tennis (T), Spatial Navigation in a familiar environment (N) and bilateral hand grasping (G), or to relax (R). A total of 6 runs (24 trials each run; single trial duration of 15 s; inter-trial interval equal to 2 s) were acquired for each task randomly ordered. The same imagery tasks of the screening were performed during a BCI session where 6 out the 14 involved subjects were asked to control a screen cursor horizontal movement (real-time feedback provided by means of BCI2000 platform). Each BCI session consisted of 4 runs: 2 runs were based on T/N contrast and 2 on G/N contrast, respectively.

2.2. Data Analysis

After pre-processing of the scalp EEG potentials, cortical and sub-cortical patches of relevant activity were reconstructed by means of Weighted Minimum Norm Linear Inverse Estimation [Babiloni et al., 2001] and sLORETA [Pascual-Marqui, 2002]. The obtained waveforms were averaged within each considered EEG frequency band (theta, alpha, beta and gamma). A statistical contrast between task and rest (baseline) conditions was performed (significance level = 5%) and corrected by means of False Discovery Rate to prevent the occurrence of type I errors. Statistical maps were generated for each subject, task and frequency band.

3. Results

Scalp, cortical and subcortical statistical maps relative to the screening session of a representative subject are reported in Figure1 for the three imagery tasks. The cortical and sub-cortical maps revealed 3 distinct patterns of

EEG significant activity for each imagery tasks, reported in Fig. 1: the left sensorimotor and parietal areas in Beta band for Tennis imagery, the bilateral sensorimotor motor areas in Beta band for Grasping imagery and the left parieto-occipital area corresponding to the para-hippocampal gyrus at sub-cortical level for Navigation task in Alpha Band. Such electrical activations were common to all the investigated subjects.

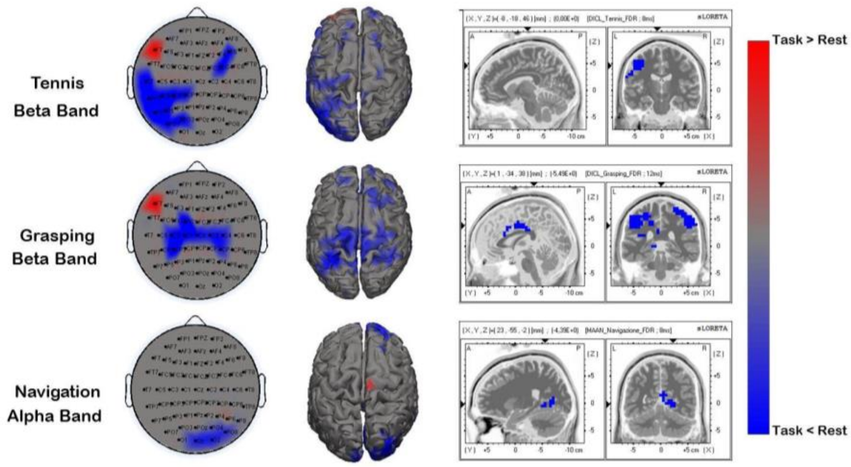

Figure 1. *Statistical maps obtained for a representative subject, for the three mental imagery tasks contrasted with the rest condition. The significant "activations" were represented at scalp (first row), cortical (second row) and sub-cortical (third row) level.*

On the basis of the screening results, the following spatial/frequency control features were selected for the online BCI session: CP3/beta for T, CP3/CP4/beta band for G and PO4/alpha band for N. Similar results were obtained in 3 out of the 14 investigated subjects who showed an online accuracy of 65% (± 1%), 65% (± 10%) and 75% (± 7%) for T/N contrast and of 70% (± 7%), 87.5% (± 10%) and 60% (± 3%) for G/N contrast, respectively.

4. Discussion

These preliminary findings indicate that is feasible to adopt such approach and prompted us to increase the number of observations in order to consolidate the translation of advanced methods for brain source reconstruction into non-invasive BCI applications. Particularly, we target to those applications in which the BCI classification output may function as a real-time objective assessment of the subject's ability to elicit a given activation pattern related to specific cognitive tasks. The relevance resides in detecting mental states in healthy subjects (Wang et al., 2012) or in those clinical conditions characterized by the absence of any behavioral signs of communications like, the disorders of consciousness (Monti et al., 2010).

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