Non Invasive EEG-Based Brain Computer Interface for Communication and Control

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Abstract—The aim of this paper is to analyze whether the use of the cortical activity estimated from non invasive EEG recordings could be useful to detect mental states related to the imagination of limb movements. Estimation of cortical activity was performed on high resolution EEG data related to the imagination of limb movements gathered in five normal healthy subjects by using realistic head models. Cortical activity was estimated in Region of Interest associated with the subject’s Brodmann areas by using depth-weighted minimum norm solutions. Comparisons between surface recorded EEG and the estimated cortical activity were performed. The estimated cortical activity related to the mental imagery of limbs in the five subjects is located mainly over the contralateral primary motor area. The unbalance between brain activity estimated in contralateral and ipsilateral motor cortical areas relative to the finger movement imagination is greater than those obtained in the scalp EEG recordings. Results suggest that the use of the estimated cortical activity for the motor imagery of upper limbs could be potentially superior with respect to the use of surface EEG recordings.

I. INTRODUCTION

Recently, it has been suggested that with the use of the modern high resolution EEG technologies [1] it could be possible to estimate the cortical activity associated to the mental imagery of the upper limbs movements in humans [2]. The scientific question at the base of the present work is whether the estimated cortical activity related to the mental imagery of the upper limbs returns more useful features with respect to those obtained by using scalp EEG recordings. To address this issue, we performed high resolution EEG recordings during the imagination of upper limb movements in a group of five healthy subjects. Comparisons between the waveforms from scalp electrodes and those from the estimated cortical activity in particular Region of Interest (ROIs) were then performed. These comparisons returned information about the usefulness of the use of cortical activity for the recognition of mental states with respect to the use of the scalp recorded data.

II. METHODS

Five healthy subjects participated voluntarily in experiments, in which they were asked to perform the imagination of right finger movements when they perform the protrusion of their lips. EEG was recorded by using a high resolution EEG cap with 64 electrodes disposed accordingly to an extension of the 10-20 international system. Subjects were asked to imagine the movement of their right middle finger during the simultaneous protrusion of their lips. This provided the necessary EMG trigger to synchronize the average of the recorded movements. For all subjects analyzed in this study, sequential EMG images were acquired and realistic head models were generated. A cortical surface reconstruction was accomplished for each subject’s head with a tessellation of about 10,000 triangles on average. The estimation of cortical activity during the mental imagery task was performed in each subject by using the depth-weighted minimum norm algorithm [3]. Such estimation returns a current density estimate for each of the five thousand dipoles constituting the modeled cortical source space. This rather large amount of data can be synthesized by computing the ensemble average of all the dipoles magnitudes belonging to the same cortical ROI. Each ROI was defined on each subject’s cortical model adopted in accordance with its Brodmann areas (BAs). In the present study, the activity in the primary left and right motor area, related to B.A. 4 for the lips as well as hand regions have been taken into account. Each artifacts-free single trials was then subjected to the linear inverse procedure, and the time varying cortical distributions associated was estimated. The collapsing procedure explained above was then applied to retrieve the cortical waveforms related to each particular ROI analyzed.

III. RESULTS

Figure 1 shows the event related potentials gathered from the scalp electrodes C3 and C4 (right bottom) and the event related mean current densities obtained from the bilateral MI-hand and MI-lips (right top and middle, respectively) areas for a representative subject (Subjet 5). Estimated current density underlying motor imagery is characterized...
by a negative slope peaking around 100ms before the EMG onset (0 Time) over the left M1 hand-ROI (namely contralateral to the imagined hand movements); no relevant activity was present over the right M1-hand ROI. As for the estimated current density underlying lip pursing, the negative slope involved bilaterally the M1-lips ROI. Scalp potential related to the task displayed a higher peak amplitude over C3 electrode lead with respect to C4. Analysis of the time varying current density distributions over the cortical mantle showed the presence of a bilateral negative (i.e. inward directed) activity on the supplementary motor area.

The values of the measured current density in the different BAs examined at the peak of the motor potential for all the subjects employed in this study were then measured. Furthermore, the estimated cortical current density values in the primary motor areas related to the lips movements are rather symmetrical. A statistical analysis of this unbalancing for the gathered scalp potentials as well as for the estimated cortical activity between left and right primary motor areas of the right and left hemispheres with respect to those gathered from scalp electrodes. It is also worth to note that this unbalancing of the estimated cortical activity between left and right primary motor areas related to the finger movement imagination was not found in the primary motor areas related to the actual performed lip movements.

There is a large trend in the modern neuroscience field to move toward invasive electrodes implants for the recording of cortical activity in both animals and humans for the realization of an efficient BCI device [4]. In this paper we have presented evidences that suggest an alternative methodology for the estimation of such cortical activity in a non invasive way, by using the possibilities offered by an accurate modeling of the principal head structures involved in the transmission of the cortical potential from the brain surface to the scalp electrodes.

### IV. DISCUSSION

The data reported here suggest that it is possible to retrieve the cortical activity related to the mental imagery by using sophisticated high resolution EEG techniques, obtained by solving the linear inverse problem with the use of realistic head models. The relevant finding is that the group analysis of the cortical waveforms associated to the mental imagery suggested the presence of a more pronounced unbalance between the cortical activity estimated in the primary motor areas of the right and left hemispheres with respect to those gathered from scalp electrodes. It is also worth to note that this unbalancing of the estimated cortical activity between left and right primary motor areas related to the finger movement imagination was not found in the primary motor areas related to the actual performed lip movements.

There is a large trend in the modern neuroscience field to move toward invasive electrodes implants for the recording of cortical activity in both animals and humans for the realization of an efficient BCI device [4]. In this paper we have presented evidences that suggest an alternative methodology for the estimation of such cortical activity in a non invasive way, by using the possibilities offered by an accurate modeling of the principal head structures involved in the transmission of the cortical potential from the brain surface to the scalp electrodes.

### REFERENCES


