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Event-related changes detection in sensorimotor rhythm

Abstract

Brain activities initiate motion in the human body. In our research we try to detect brain electrical activities and generate control signals for robotic devices like prosthetic legs. Human legs are associated with a small representation area in the sensorimotor (SMR) cortex, which is located deep inside the inter hemispheric fissure. It is difficult to observe any electroencephalographic activity related to the legs. Detection of sensorimotor signals, based on leg imagery, could potentially be useful in medical applications, i.e. for systems that are using brain-computer interface for lower limbs assistance. We investigate reactivity of sensorimotor rhythm i.e., mu rhythm, as a result of given tasks, such as, motor execution (ME) and motor imagery (MI) of the leg. Resulting SMR was analyzed, for each task state and evaluated in terms of event-related de synchronization and event-related synchronization patterns. Higher power concentration was observed in the foot representation and peripheral areas, during both ME and MI tasks. No contralateral dominance was detected during left or right discrimination tasks. Results provide a foundation for leg imagery based, interfacing and control signals creation. This could be used for locomotion functions' restoration in a lower limb wearable rehabilitation system. Spinal cord injury patients could, also, be potential users of this type of biomechanical systems.

Keywords: electroencephalography, brain-computer interface, motor execution, motor imagery, event-related desynchronization, event-related synchronization

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Abbreviations: EEG, Electroencephalography; BCI, brain-computer interface; ME, motor execution; MI, motor imagery; ERD, event-related desynchronization; ERS, event-related synchronization, SMR, sensorimotor rhythms

Introduction

Human walking gait is disrupted by the spinal cord injury (SCI) or amputation.[1] Gait rehabilitation involves improvement of the motor control functions by the activation of neuro-plasticity. It can be achieved by deciphering and translation of brain signals that correspond to the execution, or action imagery, of the affected limb, into output commands. BCI could be used to build new communication channel between the brain and output devices. EEG features, generated against motor execution or imagery tasks, comprise of sensorimotor rhythms generated in the primary and sensory motor cortex. SMR are usually concentrated in the *mu* (8-11Hz) or *beta* (12-32Hz) frequency bands.[2] SMR changes against each task are unique and can be exploited using feature extraction and classifications. This report highlights the changes in *mu* rhythm against the ME and MI of leg movement. The *mu* rhythm changes are quantified in terms of event-related desynchronization and event-related synchronization. ERD is associated with the proportional power decrease in concentration, while ERS with the proportional power increase in the signal. SMR ERD is linked with MI, as well as, with actual movement.[3] Studies on tasks related to lower limbs are presented here.[4,5] Investigations are required of SMR on leg tasks, both for ME and MI, to be used as control signals in BCI applications. The limbs somatotopy, in the sensory and motor cortices, enables cortical localization of ERD patterns. Lower limbs area representation is located deep within the interhemispheric fissure of the sensorimotor cortex, which makes it hard to detect ERD patterns.[6]

Materials and methods

Study involved three healthy participants, 25-27 years old. Ethics approval was granted by the University ethics committee. Experiments were based on the Graz BCI protocol for ME/MI tasks and consisted of 6 runs, 3 for each task. Standard 10-20 Electro-cap was used to acquire brain signals from the motor cortex. EEG system includes 20 channels sampled at 256Hz with 24-bit resolution. Statistical EEGLAB package (http://www.sccn.ucsd.edu/eeglab/) was used to process and analyse data. Acquired signals were band pass filtered between 8 to 11Hz which is the required frequency bandwidth range of *mu* rhythm followed by epoching of the trials (10seconds in length). Extracted and analyzed trials included period of 3seconds prior to cue onset used as reference period. This was followed by artifact removal method, the independent component analysis (ICA).[7] Quantification of *mu* ERD/ERS patterns was done following method proposed by Kalcher et al.[8] Proportional power decrease or increase, compared to the reference interval, is usually in the period of several seconds before the event onset. A 3 second interval, prior to visual cue onset, was selected as reference.

Results and discussion

Experiments involved execution and imagination of left and right legs movements. Topographical scalp maps of participant 1 during imagery and execution of left leg movement are presented in Figure 1. Color bar indicates the spectral power concentration over the scalp for all channels in the *mu* frequency range. Power spectral density is represented in logarithmic scale. For participant 1 it was observed that a high spectral power concentration was in the central regions. The left leg ME enhanced the *mu* rhythm concentrated in the foot area representation. This was visible at both 8 and 11Hz frequencies.

Similarly with MI task, the ERD was centrally localized and edged towards right parietal region, which could be an indication of contralateral dominance at 8 and 11Hz frequencies. However, this was not the case with remaining participants. After experiments with all participants, we have collected large amount of data that we analyze and try to decipher.

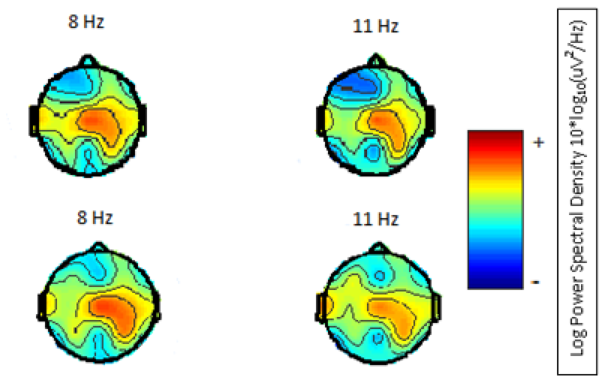

Figure 1 Participant 1 topographical scalp maps during left leg ME and MI sessions, at 8Hz and 11Hz.

Conclusion

The ME and MI signals elicited against leg movement tasks can prove to be potential control signals in the BCI application for assistive technologies, useful for SCI patients or amputees with intact brain functions. The spectral topographic plot suggested the central cortical areas to be high in power concentration during leg imagery and execution tasks. Motor execution tasks activate same cortical areas as imagery tasks. In all cases, at the beginning of the visual cue onset a desynchronization in the leg *mu* area was visible followed by a dominant ERS at the end of the trial. These results are in coherence with the established results from the spectral power distribution maps. Further study is needed for a comprehensive mapping of our thoughts to robotics control signals, but obtained results are promising.

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Conflict of interest

The author declares there is no conflict of interest.

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