

Cortical effects of BCI training measured with fNIRS

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Abstract. This study investigates the cortical training effects using a 2-class motor imagery (MI) based BCI. Twelve subjects were trained to use right hand or feet MI to control a cursor on a screen. The feedback was calculated by using features based on the EEG. To assess which areas are involved in the training, and how activity in these areas changes over time, three fNIRS measurements were applied before, in between and after the training. The statistical analysis of the measurement revealed that significant activity changes in the involved areas during the training can be found and that they occur accordingly to the task.

Keywords: BCI training, motor imagery (MI), fNIRS, cortical trainings effects

1. Introduction

The research work of the past decades showed that various parameters of brain activity, in particular EEG patterns, can be brought under voluntary control (e.g. [Birbaumer, 2006]). To contrive such intentional control of activity, it is essential to perform training sessions with feedback [McFarland 1998] [Pineda 2003]. As a result of feedback training, for example motor imagery (MI) based BCI training, and non-stationarity of the measured EEG signals, relevant EEG patterns usually change and require the adjustment of classifier and feedback [Neuper 2006] [Vidaurre2007]. To evaluate which areas are involved in such changes, and how the activity of these areas changes over time, the present study investigates cortical effects of BCI training with multichannel fNIRS measurements.

2. Material and Methods

2.1. Subjects and experimental procedure

The investigations were carried out on a group of 15 subjects (8 male, 7 female, all right-handed, aged 24 ± 2.3). Each subject participated in a series of ten experimental sessions: one screening, six feedback and three fNIRS sessions without feedback (min 3, max 6 days between the sessions; Fig 1A). Three participants did not complete the training and the data of two subjects were excluded from analysis due to bad data quality. After the screening, the subjects performed an initial fNIRS measurement followed by a first block of three feedback sessions and the second fNIRS session. The final fNIRS measurement was performed after the second block of feedback sessions. In the fNIRS sessions the participants had to imagine cue-guided right hand (RH) or feet (FE) MI in a fixed repetitive time scheme (Fig 1B). Between 20 to 60 RH/FE trials were collected during one fNIRS session. In the trainings sessions (each consisting of 160 RH and 160 FE trials) the subjects received an additional feedback in form of a cursor on a computer screen.

2.2. Data acquisition and processing

The EEG was recorded bipolarly from electrodes placed over C3, Cz and C4. For fNIRS recording a multichannel continuous wave system was used. The system measures the change of [oxy-Hb] and [deoxy-Hb] in mM mm and consists of 16 detectors and 17 emitters (3×11 grid, 52 Ch.). The grid was arranged above the motor cortex (Fig 1C). For the subsequent analysis only the [oxy-Hb] data of

channels covering functional involved areas were used. After removing baseline drifts, a common average reference spatial filter was used. Subsequent the task-related concentration changes referred to a 2 s baseline interval prior to the task were calculated. Afterwards the averages of three regions of interest (ROI; ROI₁ over C3; ROI₂ over Cz and ROI₃ over C4; Fig 1C) were computed. For statistical analysis the subjects were split into two equal groups (n=5) according to their mean classification accuracy of the EEG sessions (accuracy < or > 70%), afterwards a 2x2x3x3 analysis of variance (ANOVA) with the factors “GROUP” (good vs. worse performer), “CLASS” (hand vs. feet), “CHANNEL” (C3, Cz, C4) and “SESSION” (S1, S2 and S3) was performed.

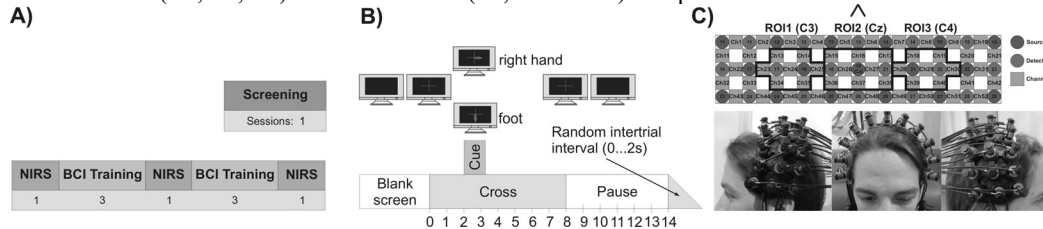


Figure 1. A) Experimental sessions B) Timing of the fNIRS paradigm C) Schematic illustration of the multi-channel array, array mounted on a subjects.

3. Results

The results of the ANOVA revealed a significant interaction “GROUP” x “CHANNEL” x “SESSION” ($F_{(4,32)} = 3.68, p < 0.05$). A Newman-Keuls post-test showed that for worse performer (<70% accuracy) significant differences between C3 and C4 during session one ($.0063 \pm 0.0039; -.0058 \pm 0.0044$) and two ($.0001 \pm 0.0062; -.0082 \pm 0.0048$) and between Cz and C4 during session two ($.0021 \pm 0.0042; -.0082 \pm 0.0048$) and three ($.0035 \pm 0.0032; -.0056 \pm 0.0044$) can be found. For the good performer (>70% accuracy) significant differences between C3 ($.0044 \pm 0.0077$) and Cz ($-.0048 \pm 0.0032$) can be found in session three.

4. Discussion

According to the group membership, significant differences in the course of the BCI training can be found. The subjects below 70% accuracy showed significant cortical activation differences between C3 and C4 (strong lateralization effect) as well as between Cz and C4, but no significant difference between C3 and Cz in the course of the training. These findings could be interpreted as a co-activation of C3 and Cz during both tasks, which may explain that these subjects performed worse in the EEG sessions (mean classification accuracies below 70%). In contrast the subjects above 70% showed no significant differences between C3 and C4 as well as between Cz and C4 in the course of the training, but according to the trainings task (hand vs. feet MI) significant differences between C3 and Cz at the end of the feedback training.

In summary, the study demonstrates that significant activity changes in functionally involved areas in the course of the training can be found and that these changes occur accordingly to the trainings task.

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