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Cortical Effects of User Learning in a Motor-Imagery BCI Training

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Abstract. The aim of this work was to investigate cortical effects of user learning in a BCI training. 15 participants absolved six sessions of a two-class BCI training (right hand vs. feet motor imagery), whereby the classifier gained from an initial screening session was not adapted. Good performers showed distinct patterns right from the beginning and no changes due to the training could be observed. In bad performers a cortical effect of BCI training was found. A significant difference in brain activity pattern between right hand and feet motor imagery developed in the course of the training..

Keywords: BCI, user training, motor imagery, cortical effects , learning

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1. Introduction

Research in the field of brain-computer interfaces (BCI) proved that it is possible to control certain patterns of brain activity (e.g. [Birbaumer 2006]). To imagine a movement activates the same regions of the brain as actual movement. Both lead to a desyncronization (ERD) within the μ-rhythm of the EEG over the sensorimotor cortex [Pfurtscheller and Neuper, 1997]. BCI training leads to changes in these activation patterns [Neuper et al., 2006]. But usually BCI training is an adaptive process where both, system and user, adjust to each other [Pfurtscheller and Neuper, 2001], so the reported changes can not only be related to learning effects of the user. The aim of the present study was to investigate this learning effect. Due to the reinforcement by the feedback provided we expect an increase in the differentiability of the brain patterns in the course of training.

2. Material and Methods

EEG was recorded from 3 bipolar Ag/AgCl electrodes mounted over the sensorimotor cortex (C3, Cz, C4) in a sample of 15 participants (8 male, 7 female, all right-handed, aged 24±2.3). The participants completed 10 sessions (see Fig. 1A) within 45 days. The interval between 2 sessions was at least 3 days and not more than one week. In a first screening session the participants performed motor imagery either of the right hand (RH) or both feet (FE) according to an arrow, presented on a screen in front of them, pointing to the right or down. Based on this data, 2-3 bandpower features were selected to train an LDA-classifier. This classifier was used to distinguish between the two different classes (RH vs. FE) by generating an output of positive or negative classlabels with a continuous distance value that was proportional to the probability of the actual classification belonging to one class. The classifier provided feedback for the trainings sessions. Feedback (see Fig. 1B) had the form of a fluid cloud which could change color (RH/positive classlabel = green, FE/negative classlabel = blue), intensity (continuous distance value) and direction (RH = right, FE = down; integrated classifier output). The benefits of this feedback are the various possibilities to display performance. Each training session consisted of 160 RH and 160 FE trials in randomized order. For the timing of a trial see Fig. 1C. In addition to the BCI training sessions 3 NIRS measurements were conducted but this analysis is not within the scope of this paper. 3 participants did not complete the training and were discarded.

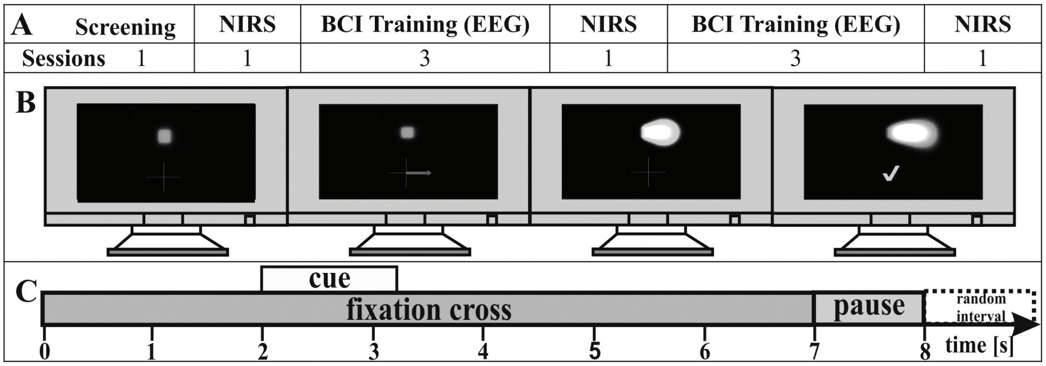

Figure 1. *A Description of sessions. B Paradigma for training sessions. C Timing of a trial.*

To investigate the effects of BCI training on ERD, time-frequency maps for every session and channel were calculated and ERD values were statistically analysed. The sample was divided in participants with high (mean accuracy >70%; n = 6) and low accuracy (mean accuracy <70%; n = 6) and an ANOVA for repeated measures with the between-subject factor "accuracy" (high vs. low) and the within subject factors "session" (1-6), "channel" (C3, Cz, C4) and "class" (RH vs. FE) was conducted for alpha (8-10 Hz, 10-12 Hz) and beta frequency bands (12-16 Hz, 16-20 Hz, 20-24 Hz, 24-30 Hz). In case of significant effects a Newman-Keuls posttest was conducted.

3. Results

The statistical analysis resulted in a significant interaction "accuracy x channel x class" for frequency bands between 8-10 Hz ($F_{(2,20)} = 4.05$; $p < .05$) and 16-30 Hz ($F_{(2,20)} = 10.29;6.20;4.61$; $p < .05$) showing that only participants with high accuracy show significant differences between channels and classes. For RH ERD is stronger over C3 compared to Cz and C4 and for FE ERD is stronger over Cz compared to C3 and C4. In participants with low accuracy there are no significant differences between channels and classes. In addition a significant interaction "accuracy x class x session" was found in 24-30Hz ($F_{(2,20)} = 4.61$; $p < .05$). Participants with high accuracies have a stronger ERD for RH (M = -24.09; SD = 11.72) compared to FE (M = -11.81; SD = 12.35) over all sessions, whereas in participants with low accuracies this difference is only found in session 3 (RH: -8.80 ± 13.63; FE: 6.97 ± 20.30) and in session 6 (RH: -16.03 ± 10.91; FE: -5.38 ± 9.21), which were the last sessions of the two BCI-training blocks interrupted by a NIRS session.

4. Discussion

Cortical effects of BCI training could only be found in participants with low accuracies, who showed significant differences between RH and FE only after some sessions of training and only in 24-30 Hz. Participants with high accuracies showed pronounced distinct patterns from the very beginning, which possibly points to some kind of ceiling effect and could explain why no significant effect of training was found. Concluding, this study could show that BCI-training leads to changes in cortical activation patterns but only if the user is forced to learn, due to low accuracies.

Acknowledgements

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References

Birbaumer N, Weber C, Neuper C, Buch E, Haapen K, Cohen L. Physiological regulation of thinking: brain-computer interface (BCI) research. *Progress in Brain Research*, 159: 369-391, 2006.

Neuper C, Müller-Putz GR, Scherer R, Pfurtscheller G.Motor imagery and EEG-based control of spelling devices and neuroprostheses. *Progress in Brain Research*, 159: 393-409,2006.

Pfurtscheller G, Neuper C. Motor imagery activates primary sensorimotor area in humans. *Neuroscience Letters*, 239: 65-68, 1997.

Pfurtscheller G, Neuper C. Motor imagery and direct brain-computer communication. *Proceedings of the IEEE,* 89: 1123-1134, 2001.