Operant conditioning vs. application of strategies in a neurofeedback based SMR BCI

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Introduction

Many Brain–Computer Interfaces (BCI) rely on neurofeedback for the regulation of sensorimotor rhythms (SMR) of the EEG. According to Lacroix’s Two-Process Theory of neurofeedback learning, subjects either identify efferent programmes already in their behavioural repertoire which allow them to achieve control over the targeted physiological signal. If so, subjects use the provided feedback to refine these strategies. If no strategy is available afferent processes underlie the acquisition of autonomous control to construct a new behavioural programme by means of operant conditioning (1).

In the current study, we aimed at investigating how learning to control an SMR-based BCI differs as a function of the process – efferent vs. afferent - by which such control is instantiated.

Methods

Nineteen healthy BCI novices were randomly assigned to an “efferent” group (EG) and an “afferent” group (AG). EEG subjects were instructed to kinesthetically imagine the movement of their right hand. The AG was instructed to focus their attention on the feedback signal and observe how its trajectory changes in relation to different thoughts. In both groups subjects were required to move a cursor into one of two targets. A decrease of the power in the alpha band over EEG channel C3 moved the cursor to the bottom target, and an increase of power to the top target. The EEG was recorded with a 16 channel EEG amplifier. Correct response rate (CRR) in % served as measure of performance.

Results

Initial and final performances were 61.9/67.36% in the EG and 50.9/62.8% in the AG. A 2 (session) × 2 (group) repeated measures ANOVA revealed that performance was significantly better in the last session when compared with the first session (F[1,17] = 8.7, p < .01), but the group differences and interaction were not significant. Both groups learned significantly during the course of 10 sessions (linear trend EG: F[1,18] = 9.7, p < .05; AG: F[1,18] = 139.5; p < .001; power trends also significant). Learning was more pronounced in the afferent group (F[1,17] = 397.3, p < .001).

Discussion and Conclusion

As expected, both groups learned and the increase in learning rate was greater in the afferent group. Although, on a descriptive level, the efferent group performed better in the first session compared to the afferent group, this difference failed to reach significance. End performances were not significantly different between the groups. The high variance in performance and the low overall performance which is atypical for SMR-BCIs may have been due to not determining the best motor imagery and the best electrode for each subject. However, a screening session to identify which motor imagery works best for each subject at which electrode could not be performed in this study, as it would have revealed the motor imagery strategy to all subjects. In further analysis it has been shown that the low performers in the Efferent group actually had a very strong focal point between CP5 and P3, very close to the location of measurement which is where their right hand was represented. Should a screening session had taken place, the initial, and, probably, final performance would have been significantly higher (as the right hand representation location seemed to be PC3 and not the measured C3).

On the other hand, the Afferent group showed great improvement in some subjects, and absolutely none in others. Further analysis revealed that while the learners have managed to pinpoint the electrode location, the low non-learners had a very scattered activity pattern. We conclude that motor imagery is not necessary to regulate the SMR amplitude and cautiously, that providing a strategy only improves the initial performance, which might be important to sustain motivation for BCI training.

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