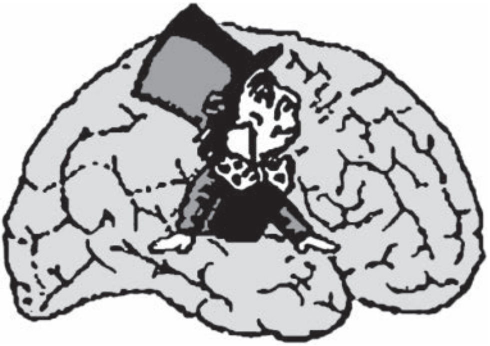
КОГНИТИВНАЯ НАУКА В МОСКВЕ

НОВЫЕ ИССЛЕДОВАНИЯ



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NEUROPHYSIOLOGICAL CORRELATES OF EFFICIENT LEARNING IN THE NEUROFEEDBACK PARADIGM

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Abstract. A group of brain structures responsible for operant conditioning is widely recognized as belonging to the reward system (Kamiya, 2011), and neurofeedback training is considered to be a reinforcement learning paradigm (Zander et al., 2009). Depending on the ergonomic parameters of the feedback signal, the efficiency of learning and the intensity of plastic changes will vary. Can we identify the correlates of efficient learning in the EEG recording and use them to tune the ergonomic parameters of the feedback? We exposed our study participants to real and mock feedback and contrasted the EEG during these two conditions to find the neuronal sources explaining the difference between the two states. We found statistically significant differences in the activity of brain structures previously implicated in the operant conditioning process.

Keywords: alpha waves, reinforcement learning, feedback signal, mock feedback, ergonomic parameters optimization

Introduction

Neurofeedback is a reinforcement learning process and its efficiency critically depends on the extent to which the feedback signal is matched to a particular patient. Feedback signal latency, color, shape, pitch, timbre are some of the ergonomic parameters that may strongly affect the efficiency of learning and the intensity of plastic changes. Finding the proper ergonomic settings for each individual patient has the potential to boost the efficacy of the neurofeedback therapy and to further advance its usefulness in treating various neurological deceases.

Method

Study participants were trained either with real feedback on their alpha waves' instantaneous power (extracted from a P4 electrode) or with mock-feedback. During the training they were instructed to sit as still as possible and were continuously presented with visual feedback in the form of a circle with an uneven border. The task was to make the circle border as smooth as possible by attempting to up-regulate their P4 alpha power. Mock feedback was derived from the EEG data recorded from the same participant during one of the previous trials and was thus unrelated to the current value of the alpha power.

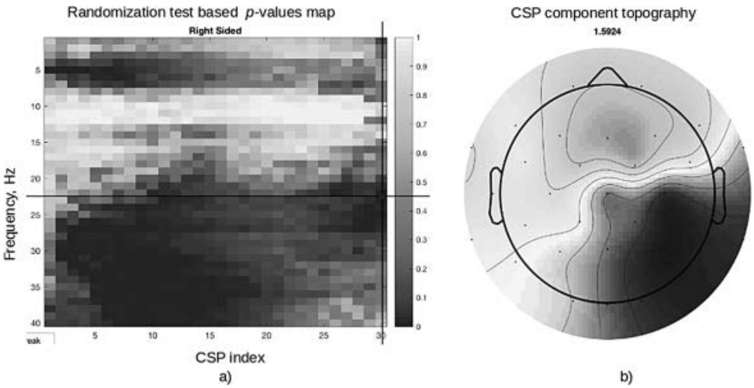

Figure 1. a) *p*-values and b) the topography of the CSP component for the most illustrative participant. We observe statistically significant differences for components with the greatest eigenvalue in beta frequency band 22 Hz, corresponding to the activation in frontal brain areas which may coincide with the ACC.

Each session consisted of 8 experimental trials each lasting 45 seconds, and mock versus real feedback condition trials were randomized. Note that in this paradigm we did not aim at training alpha but rather attempted to catch the low-level difference between the consistent and inconsistent feedback as it is perceived by the brain. This explains the use of short trials (45 second duration) to minimize the chances of the participant consciously disentangling and realizing the presence the two types of feedback (real vs. mock).

For each participant we recorded EEG data for mock and real feedback conditions at a 500 Hz sampling rate. The data were then filtered with a band-pass FIR-filter in 40 different frequency bands ranging from 2 – 40 Hz with 2 Hz bandwidth. The data from the two conditions (real and mock feedback) were contrasted using the CSP technique.

In order to establish the significance of the observed differences, we performed a non-parametric randomization test to obtain the *p*-values of the null hypothesis of no significant changes between the real and mock feedback conditions.

Results

We found statistically significant components in the beta band, with frontal localization which may correspond to the anterior cingulate cortex (ACC), whose activity contrasts the real feedback and mock feedback conditions. Fig. 1 shows the *p*-values and the topography of the CSP component for the most illustrative participant.

Discussion and Conclusions

Since the ACC is one of the key nodes of the reward network, our results agree with previous studies aimed at studying brain activation during the RL process.

It remains to be seen whether or not the activity in the reward network nodes can be used as a gauge to tune the efficacy of the NFB by adjusting the ergonomic parameters of the feedback signal.

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Нейрофизиологические корреляты эффективного обучения в парадигме нейронной обратной связи

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Аннотация. Широко известно, что группа структур в мозге, отвечающих за оперантное обусловливание, является частью системы вознаграждения, в то время как нейронная обратная связь рассматривается как процесс обучения с подкреплением. В зависимости от эргономических параметров сигнала обратной связи эффективность обучения и интенсивность пластических изменений в мозге может различаться. Можем ли мы определить корреляты эффективного обучения во время записи ЭЭГ и использовать их для того, чтобы настроить эргономические параметры обратной связи? Мы предъявляли испытуемым реальный и ложный сигнал обратной связи и сравнили ЭЭГ, записанную во время этих двух разных условий. Мы обнаружили статистически значимое различие в активации мозговых структур, причастных к процессу оперантного обусловливания.

Ключевые слова: альфа-ритм, обучение с подкреплением, сигнал обратной связи, ложная обратная связь, оптимизация эргономических параметров