КОГНИТИВНАЯ НАУКА В МОСКВЕ

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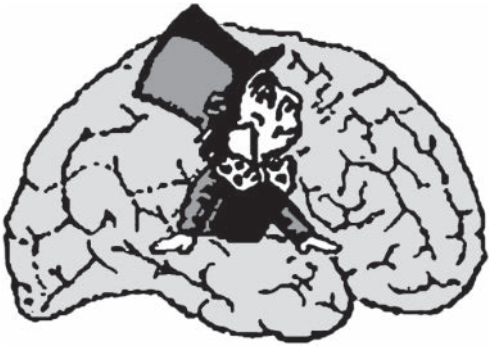

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SOFTWARE FOR FLEXIBLE EEG AND MEG NEUROFEEDBACK EXPERIMENTS: DESIGN, REAL-TIME PROCESSING AND DATA ANALYSIS

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Abstract. Our project (NFB Lab) focuses on the development of real-time software for EEG/MEG neurofeedback experiments based on classic and novel signal processing algorithms used to filter noise from the signal and to extract brain activity for use in feedback signal generation. The developed software has an interactive module to configure the filter pipeline based on spatial and temporal filters extracted from the data's spatial decompositions. There is also a possibility to implement a mock feedback condition and to perform training of the composite indices involving a combination of measurements derived from different frequency bands and brain areas.

Keywords: neurofeedback, software, signal processing, electroencephalography, magnetoencephalography

Introduction

Neurofeedback is a type of operant conditioning paradigm based on visualizing and learning to control a particular aspect of brain activity, typically measured non-invasively and with fine temporal resolution by means of electro- and magnetoencephalography (EEG, MEG) (Sitaram et al., 2017).

Nowadays, there are numerous software implementations supporting real-time EEG/MEG processing and implementing the neurofeedback paradigm. However, the majority of such programs are commercial and aimed at clinical applications which limits their flexibility. They are not suitable for research applications and do not allow researchers to flexibly configure signal processing tracts or feedback signal presentation parameters in search of increased learning efficiency.

Software description and method

Our project (NFB Lab) (Smetanin, 2016) focuses on the development of a real-time software for EEG/MEG neurofeedback experiments based on the classic and novel signal processing algorithms used to filter noise from the EEG signal and to derive the signals reflecting brain activity of interest to be then used

for feedback signal generation. The developed software includes three modules: an experiment designer (Fig. 1), a real-time acquisition and feedback generation module (Fig. 2) and an artifact cancellation and filter design module (Fig. 3).

The experiment designer module allows a researcher to describe the composition of an experiment, the derived signals, protocols and feedback presentation details. There is also a possibility to implement a mock feedback condition as well as to perform training of the composite indices involving a combination of measurements derived from different frequency bands and brain areas. The customized design is saved in an .xml file and can be loaded with the subsequent use of the program.

The real-time acquisition and feedback generation module displays the processed and raw real-time signals to the experimenter (Fig. 2a) and stimuli to the participant (Fig. 2b and fig 2c). NFB Lab uses Lab Stream Layer (Kothe, 2013) which makes our software compatible with most of the EEG amplifiers. The software also supports the FieldTrip buffer for data exchange and has been adapted to be used with a Neuromag MEG machine.

The filter design module is an interactive module for configuring the filter pipeline (see Fig. 3b) based on spatial and temporal filters extracted from the spatial decompositions of the data based on such methods as independent component analysis (ICA, see Fig. 3a) (Nikulin et al., 2011), spatio-spectral decomposition (SSD) (Bell, Sejnowski, 1995), and common spatial pattern (CSP) (Koles et al., 1990). Each type of analysis produces the decomposition of a raw signal into several components from which can be built spatial filters for the selection or rejection of corresponding components. ICA solves the blind source separation problem and can be used for to detect and reject eye related artifacts. SSD is used for extracting components with “peaky” spectral profiles. CSP allows one to select components with the highest ratio of signal power for two previously recorded states. For example, CSP performed on open eye and closed eye recordings can detect the spatial filters related to alpha activity.

Usage Examples

The developed software is being successfully used in neurofeedback experiments aimed at conditioning particular brain activity (sensorimotor rhythm, alpha rhythm) and also for identifying neurophysiological correlates of efficient learning in the neurofeedback paradigm.

Conclusion

Overall, NFB Lab serves as an effective, intuitive and easy to use real-time software for EEG/MEG neurofeedback experiments.

References

Bell A.J., Sejnowski T.J. An information-maximization approach to blind separation and blind deconvolution // Neural Computation. 1995. Vol. 7. P. 1129 – 1159. URL: http://fmriserver.ucsd.edu/ttliu/be280a_12/Bell_Sejnowski_1995.pdf.

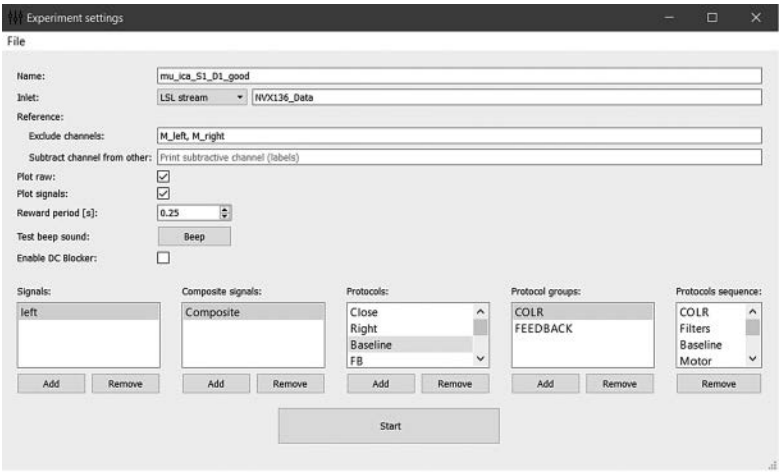

Figure 1. Experiment designer module

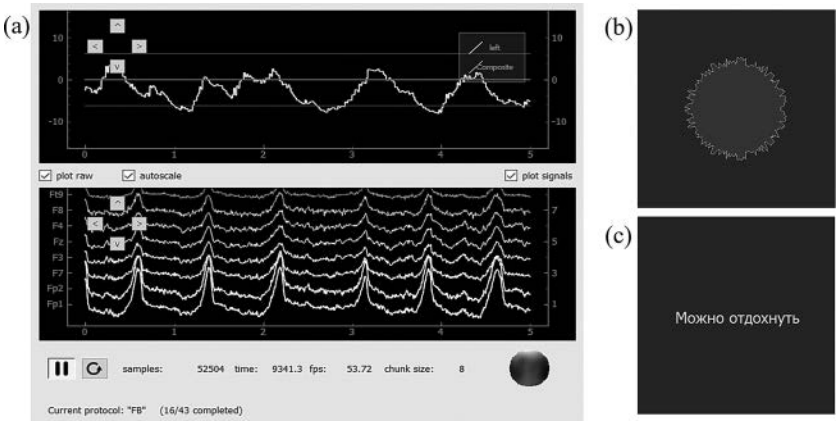

Figure 2. Real-time acquisition and feedback generation module: a) experimenter window, b) subject window (feedback presentation), c) subject window (rest)

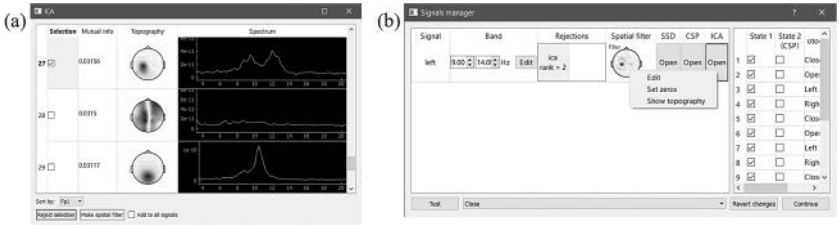

Figure 3. Filter design module: a) independent component analysis, b) filter pipeline

Koles Z.J., Lazar M.S., Zhou S.Z. Spatial patterns underlying population differences in the background EEG // Brain Topography. 1990. Vol. 2. No. 4. P. 275 – 284. doi:10.1007/BF01129656

Kothe C. Lab streaming layer. 2013.

Nikulin V.V., Noltec G., Curioa G. A novel method for reliable and fast extraction of neuronal EEG/MEG oscillations on the basis of spatio-spectral decomposition // NeuroImage. 2011. Vol. 55. No. 4. P. 1528 – 1535. doi:10.1016/j.neuroimage.2011.01.057

Sitaram R., Ros T., Stoeckel L., Haller S., Scharnowski F. Closed-loop brain training: the science of neurofeedback // Nature Reviews Neuroscience. 2017. Vol. 18. P. 86 – 100. doi:10.1038/nrn.2016.164

Smetanin N. Downward-lab. 2016. URL: http://lab.readthedocs.io/en/latest/.

Программное обеспечение для создания, проведения и обработки экспериментов в парадигме нейрообратной связи

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Аннотация. Настоящий проект (NFB Lab) посвящен разработке программного обеспечения (ПО) реального времени для проведения экспериментов в парадигме нейрообратной связи. В программе используются как классические, так и современные алгоритмы обработки сигналов, направленные на извлечение активности мозга, которая будет использоваться в качестве сигнала обратной связи. Разработанное ПО включает в себя интерактивный модуль, в котором алгоритмы декомпозиции многоканальных данных используются для создания набора пространственных и частотных фильтров. Кроме того существует возможность создания ложной обратной связи и обратной связи сложного сигнала, который является комбинацией простых сигналов соответствующих разным частотным полосам и областям мозга.

Ключевые слова: нейрообратная связь, програмное обеспечение, обработка сигналов, электроэнцефалография, магнитоэнцефалография