DESCRIPTION FOR THE GENERAL PUBLIC (IN ENGLISH)

Electroencephalogram (EEG) is noninvasive, relatively easy and cheap method for monitoring brain activity. In human it was for the first time recorded in a year 1929 by a German neurologist Hans Berger. Soon, the spectrogram of normal healthy EEG was described and main frequencies were associated with basic brain states. First, slower waves were ascribed to sleep (delta, theta) and relax (alpha) in opposition to faster (beta and gamma) oscillation observed in awake, active brain states. Following decades of investigations resulted in association of the EEG bands with multiple higher cognitive functions such as inhibition during cognitive tasks and memory processes (alpha), working memory (theta and gamma), motor execution (beta) and attention (beta and gamma).

However, these functional ascription of the different EEG frequency bands to various behavioral and cognitive functions are still debated because we do not have direct proofs of their production by the relevant brain structures. EEG is recorded with the electrodes located on a surface of a head. Due to the long range of electric fields, each EEG electrode records a mixture of signals generated by multiple neuronal groups scattered within the brain volume. Standard analytical methods easily decompose EEG signal into its basic components (e.g. frequencies of oscillations), but the question regarding the location of the brain structures generating particular components remains largely unresolved. If we want to really understand how brain works and how it realizes our most sophisticated cognitive abilities, we urgently need to deepen the understanding of the relation between EEG signal recorded from the scalp and brain structures contributing to its activity.

In our project we plan to run a set of experiments during which volunteers will be ask to perform computer based tasks (like simple games) requiring cognitive effort (e.g. attention, reasoning). We will record their brains activity with multichannel EEG and in parallel we will perform fMRI scans. fMRI stands for functional magnetic resonance imaging – a method that has advantages complementary to EEG – in particular it has very good spatial resolution. fMRI proved to be effective in indicating (with a millimeter precision) the spots of active brain tissue. In our experiment we will use fMRI data to locate the structures activated by cognitive tasks, and with sophisticated mathematical analysis we will look in recorded EEG signals for spatio-temporal patterns characteristic for these structures.

Most of research in this area were focused on searching for sources of the individual frequency bands. It is however unlikely that a brain structure would produce simple signal composed of one frequency. We would rather expect that brain areas should produce more complicated but characteristic (defined by particular morphology and set of connections) spatio-temporal maps of electrical activations. Such maps should appear like a fingerprint within EEG record each time a structure was activated.

Apart from the undertaking this neurophysiological challenge, the study will also advance the field of neuroinformatics by proposing, developing and testing novel approaches of mathematical signal analysis. Different computational algorithms were proposed previously to detect the link between the in-brain active sources and EEG waves, but none of them can offer unambiguous conclusions. False assumptions of dipoles localization, volume conductions or improper signal separation fabricate spurious landscape of the detected generators and deceive our interpretation of the brain activity. We propose novel mathematical solution based on minimum-variance pseudo-unbiased reduced-rank estimator achieves provably smaller error if sources are closely positioned, especially if the background activity is high, that is where most of currently used methods fail.

Outcome of our project will advance the understanding on how the brain activity is represented in the EEG signal and will equip specialists with novel analytical tools allowing for its efficient use in research dedicated to physiology, psychopathology and therapy of cognitive function such as attention.