Dynamics of similarity of brain cortical areas revealed from MEG data with seizures using mutual information function

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***Abstract**. Epilepsy is a serious and fairly widespread neurological disease — according to the classification of the International League against Epilepsy (ILAE). Epilepsy as a network phenomenon suggests that the mechanisms responsible for the discharge occurrence are mostly result of interactions between neurons of different types, which form a pathological neural circuit, with this circuit being unique for each individual. Modern concepts for medicine personalization for diagnostics and treatment require understanding how much results obtained when studying animals match the human epileptogenesis. The purpose of the current study is to determine the evolution of non-directional connectivity underlying the spike-and-wave discharges (SWDS) of patient with childhood absence epilepsy (CAE) recorded with MEG.*

Epilepsy affects 1-2% of people in the world [1], and manifests itself via pathological synchronous activity of a large number of brain neurons — discharges, which can be accompanied by other clinical manifestations. In the significant number of cases epileptic discharges lead to other pathological activities, including spreading depression [2]. Absence epilepsy is the most common forms in children and adolescents. This form is defined by daily absences lasting 4–30 seconds, but most often less than 10 seconds. If not treated it mute into some severe convulsive forms in many cases.

The main results on the analysis of connectivity in the brain were obtained for absences in animal models (rats of WAG/Rij and GAERS lines) since surgical interventions and recording of signals from thalamus which plays a fundamental role in the formation of absences are mostly not possible in humans. When working with human patients, the best data are magnetoencephalogram (MEG) recordings, since the skull practically does not distort the magnetic field unlike the electric one, and there is a more detailed resolution on the cerebral cortex and important in case of connectivity analysis, the reference signal which is important for EEG does not play a role [3]. The present work is aimed at determining the evolution of non-directional connectivity of patient MEG signals. We were provided with magnetic encephalograms of 5 patients containing 122 channels from various regions of the patient's cerebral cortex. In these recordings we managed to identify 14 epileptic seizures lasting more than 4 seconds.

Mutual information is a well known not directed measure popular in computational neuroscience [4]. Here we used an algorithm for calculating mutual information (MI) [5] based on the accounts of nearby neighbors. Using this algorithm, mutual information was estimated and plotted for several 1 s duration time epochs starting from three s before the seizure and considering first four seconds of each seizure. Intrahemispheric and interhemispheric couplings were considered. Intrahemispheric connections are good because they are quite well studied in rats, and in the current study, we have shown that in humans, the distribution pattern of the discharge on magnetoencephalogram is repeated. Interhemispheric connections on genetic animal models have been studied less frequently due to the fact that it is believed that absence epilepsy is a primary generalized form in humans and animals.

On the resulting graphs of the values of the function of mutual information, we observe a clear rise in connectivity in the majority of seizures (11 out of 14 discharges) in intrahemispheric connections in the right hemisphere at the time of discharge onset (0th second). For interhemispheric connections reaches values equal to less than half of all digits.

A t-test (Student's t-test) was carried out for the mean, which allows to compare the average values of two samples and, based on the test results, and to draw a conclusion about whether they differ from each other statistically or no. The samples of values of the following time points were compared: t = -3 and t = 0. It appears that the mean of the two sets of values are different, which confirms the presence of the dynamics of the absence discharge.

Based on the statistical analysis of the dependencies presented in the graphs, it was shown that connectivity changes not only during the transition from normal activity to epileptiform, but also during discharge: there was an increase in MI during the prectal period, and then a decrease by 2-4 seconds of the attack. At the start of the attack, the MI value reaches its maximum, which was also found in a study in rats of the WAG/Rij line [6]. This process differs by time for different discharges and by amplitude.

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