Auto – and Cross – Correlation Patterns in the Diagnosis of Obsessive-Compulsive Disorder using Electroencephalogram Analysis

Alexander Elenev
Institute of Physics
Kazan Federal University
Kazan, Russia
a.elenev6345@gmail.com

Sergey Demin
Institute of Physics
Kazan Federal University
Kazan, Russia
serge_demin@mail.ru

Oleg Panischev
Institute of Physics
Kazan Federal University
Kazan, Russia
opanischev@gmail.com

ID-161

ITNT - 2023

Kazan Federal University

Annotation

In this paper, auto- and cross-correlation patterns in the diagnosis of obsessive-compulsive disorder (OCD) by means of electroencephalogram (EEG) analysis are considered. The author's method was used for the analysis: the memory function formalism. On the basis of electroencephalograms from 30 subjects, 15 of whom suffer from OCD-symptoms, 15 are healthy people, the parameter of non-Markov for autocorrelation study was studied. As part of the cross-correlation study, cross-Markov parameter was studied, and the distances of strong manifestation of this effect for the group of healthy people and patients with OCD were determined.

Introduction

One of the current problems of modern clinical medicine is the search for objective diagnostic criteria for various diseases, as well as the assessment of the patient's current state.

The application of methods of modern statistical physics makes it possible to obtain more detailed and detailed information on the dynamics and interaction of EEG signals, i.e., to study the behavior of electrical activity not only of individual areas, but also of their interaction.

We use auto – and cross – correlation methods based on the memory function formalism (MFF) [1], which allows to find dynamic, spectral, and stochastic characteristics of the studied signals. In the present work, we refine our previous results and search for the most significant electrodes and the interaction of these areas with other [2].

The main features of the analysis of auto- and cross-correlations

In this paper, we develop an original method for determining the distinctive parameters of electroencephalogram (EEG) signals of people with OCD and healthy people using method MFF. There are 2 analysis: auto- and cross-correlations. Within the framework of the memory function formalism, let us represent the signal under study as a set of values of some random variable X:

$$X = \{x(T), x(T+\tau), x(T+2\tau), \dots, x(T+(N-1)\tau)\},$$

Here: T – initial moment of time, $(N-1)\tau$ – total time of signal registration, τ – time step of discretization.

The mean value of X can be found as:

$$\langle X\rangle = \frac{1}{N}\sum_{j=0}^{N-1} x_j, \qquad x_j = x(T+j\tau).$$

The deviation and dispersion X are obtained using the following expressions:

$$\delta x_j = x_j - \langle X\rangle, \qquad \sigma^2 = \frac{1}{N}\sum_{j=0}^{N-1}\delta x_j^2.$$

Initial time correlation function (TCF):

$$a(t) = \frac{1}{(N-m)\sigma^2}\sum_{j=0}^{N-m-1}\delta x_j \delta x_{j+m}.$$

For this function, using the technique of projective operators, we obtain a kinetic equation of non-Markov type:

$$\frac{\Delta a(t)}{\Delta t} = \lambda_1 a(t) - \tau\Lambda_1\sum_{j=0}^{m-1} M_1(j\tau)a(t-j\tau).$$

Here,

$$M_1(j\tau) = \frac{\langle \mathbf{A}_k^0(0)\hat{L}_{12}\{1+i\tau\hat{L}_{22}\}^j\hat{L}_{21}\mathbf{A}_k^0(0)\rangle}{\langle|\mathbf{A}_k^0(0)|^2\rangle},$$

first-order memory function, which includes the state vectors of the system. The memory function formalism method introduces power spectra of memory functions $M_i(t)$. For example, for the initial TCF $a(t) = M_0(t)$,

$$\mu_0(\nu) = \left|\tau\sum_{j=0}^{N-1} a(jt)\cos 2\pi\nu j\tau\right|^2,$$

and the first point of the non-Markov [3] parameter

$$\varepsilon_1(\nu) = \left\{\frac{\mu_0(\nu)}{\mu_1(\nu)}\right\}^{\frac{1}{2}}.$$

For the cross-correlation analysis, all parameters are the same with the addition of the second variable Y.

Experimental data

Two groups of people were taken as subjects. One group, consisting of 15 people who had strong OCD symptoms. The second group, also consisting of 15 people, is a control group – people who have no or very weakly expressed OCD. Sixty-four channels of EEG were recorded continuously with active scalp electrodes according to the extended international "10-20%" electrode placement system (Fig. 1). The sampling rate was 512 Hz.

Electroencephalograms were taken under the influence of expression stimuli. Stimuli were four positive and four negative sentences written in the first person, with a blank space for name insertion, e.g. "I hope that _____ wins the lottery soon", and "I hope that _____ becomes seriously ill soon." The order of presentation of the sentence stimuli was randomized across participants. Each trial began with the presentation of a sentence stimulus on screen. Participants then closed their eyes before repeating the sentence aloud, inserting a name from their list of family and friends.

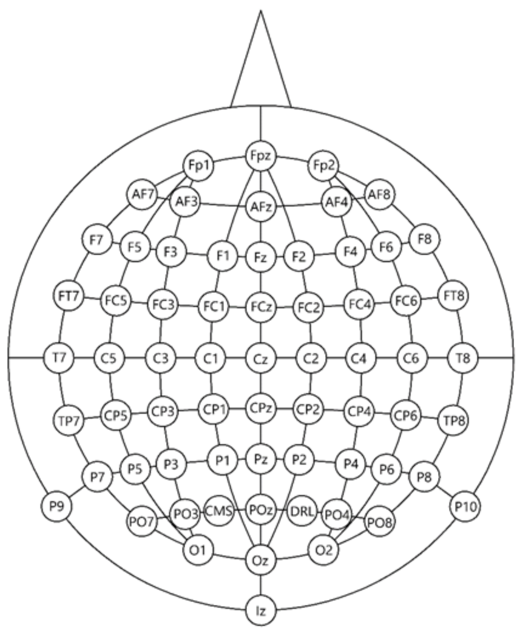

Fig. 1. Electrode placement according to the international "10-20%" system.

Results

Using the MFF, non-Markov parameters were found for each electrode of each subject, and then the values were averaged over each group for specific electrodes. These were electrode F_7 and F_{pz} (Fig. 2).

Frequency dependences of non-Markov parameters and memory parameters for signals from these electrodes were obtained (Fig. 3).

Next, as part of the cortical region interaction analysis, the values of the non-Markov parameter for all sensor combinations were obtained, and the results were averaged over each group. Power spectra of the cross – correlation function were plotted for the combinations that showed the greatest differences in values (Fig. 4).

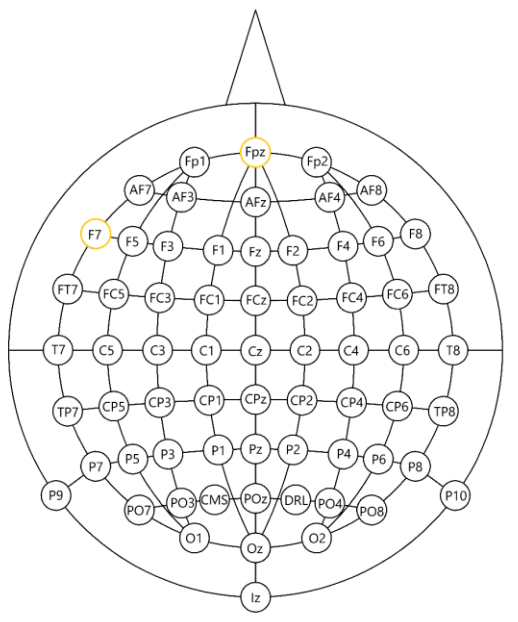

Fig. 2. Schematic arrangement of the most informative for the parameter of non-Markov electrodes

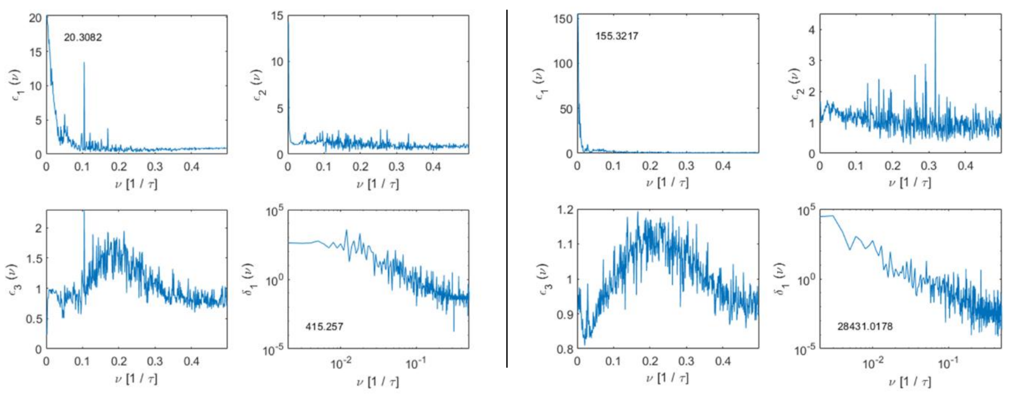

Fig. 3. Frequency dependences of the non-Markov parameter and the memory parameter. Left – for healthy people, right – for people with obsessive-compulsive disorder symptoms.

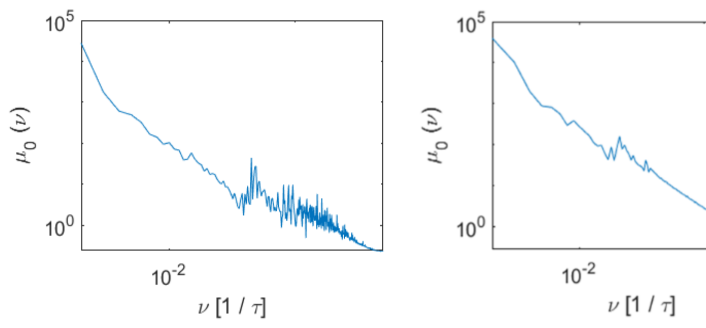

Fig. 4. Power spectra of the initial time correlation function for healthy people (left) and for people with obsessive-compulsive disorder (right).

Fig. 5 shows the sensor combinations for the highest values of the cross-Markov parameter for healthy subjects and patients with OCD.

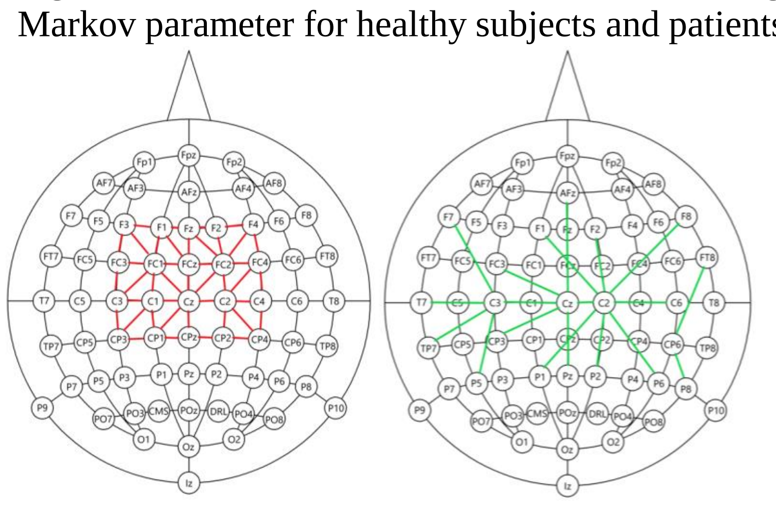

Fig. 5. Schematic representation of the highest values of the cross-parameter of non-Markov for healthy people (left) and for people with obsessive-compulsive disorder (right).

Conclusions

During the study of electroencephalogram data using the parameter of non-Markov, we found the electrodes for the signals from which the differences in the parameter between healthy and sick people differed most strongly. The processes occurring in the signals of people with pronounced OCD symptoms are more random because the value of their parameter of non-Markov is several times greater than that of healthy people. At the same time, for obsessive-compulsive disorder, the Markov nature of the interaction is characteristic for closely spaced regions, while for healthy individuals, high values of the cross parameter of non-Markov are observed for more distant regions than for patients.

[1] O. Y. Panischev, S. A. Demin, S. N. Panischeva, J. Bhattacharya, "How analyzing the interictal EEG can identify the epilepsy", Nonlinear Phenomena in Complex Systems, vol. 18(2), pp. 230-235, 2015.
[2] S. A. Demin, O. Y. Panischev, N. Y. Demina, "Cross MFF—analysis in studying the obsessive-compulsive disorder", Journal of Physics: Conference Series, vol. 741(1), p. 012073, 2016.
[3] R.M. Yulmetyev, S.A. Demin, O.Y. Panischev, P. Hänggi, "Age-related alterations of relaxation processes and non-Markov effects in stochastic dynamics of R-R intervals variability from human ECGs ", Physica A., vol. 353, p. 336, 2005.

This paper has been supported by the Kazan Federal University Strategic Academic Leadership Program ("PRIORITY–2030").