Auto- and cross-correlation patterns in the diagnosis of obsessive-compulsive disorder using electroencephalogram analysis

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***Abstract*—In this work auto- and cross-correlation patterns in the diagnosis of obsessive-compulsive disorder are investigated. Analysis of electroencephalograms was made by the author's method: Memory Functions Formalism. For autocorrelations, the subject of the study was the non-Markov parameter. The most informative electrodes were found for 30 subjects, in which the greatest difference was observed between the non-Markov parameter for the group of patients and conditionally healthy people. For cross-correlations, synchronization effects were investigated, which were significantly different for the patients and conditionally healthy group. The results obtained will be of interest to sciences such as data sciences, computational biophysics, physics of living systems and psychiatry.**

Keywords—time signal analysis, living systems, electroencephalogram, memory function formalism, diagnostic, obsessive-compulsive disorder

I. Introduction

The human brain is a subject of study for such sciences as complex systems physics and intelligent analysis of biomedical data. This is because random processes can occur in the brain, which may have Markovian or non-Markovian behavior. A non-Markovian process is characterized by system memory: the future state of the system depends on its previous states. In brain physics, individual regions can be investigated for non-Markovian processes [1]. For this purpose, we used the author's methods for analyzing time signals: Memory Functions Formalism (MFF) [1, 2]. Initially, the MFF was developed to study nonequilibrium processes in multiparticle physical systems, and later it was adapted to analyze the discrete-time dynamics of complex systems of non-Hamiltonian nature.

This paper examines the electroencephalograms (EEG) of people suffering from obsessive-compulsive disorder (OCD). This disorder is characterized by obsessive thoughts – obsessions, which the person tries to cope with by repeating certain actions – compulsions. Historical methods are used to diagnose OCD, which includes information about the duration of OCD symptoms, decreased quality of life and resistance to symptoms. These criteria do not provide qualitative information about the variety of obsessions and compulsions, which is a disadvantage of these methods. For example, such a method is the Yale-Brown scale. It includes 10 points, of which 5 are used to assess obsessions, and 5 for compulsions. The total score determines the OCD severity.

Like other psychiatric disorders, OCD symptoms cause abnormalities in the brain that are hard to distinguish from abnormalities caused by other disorders. In addition, it is difficult to distinguish between these disorders. Therefore, electroencephalographic clinical studies and corresponding methods of processing digitized EEG signals hold out hope for solving the problems of diagnosing OCD and increasing the objectivity of diagnoses.

II. Experimental data

The work involves an electroencephalographic analysis of 30 subjects. They are divided into two groups of 15 people each. The first group is people with high manifestation of OCD-symptoms. The second group is people with weak or no OCD symptoms. Sixty-four EEG channels were continuously recorded with active scalp electrodes according to the expanded international «10-20%» electrode placement system.

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 [3, 4].

The data were obtained through an international collaboration with Joydeep Bhattacharya.

III. Results

Within the framework of the MFF a significant spectrum of analytical characteristics and parameters can be calculated directly from the initial time signals: orthogonal dynamic variables, phase portraits of combinations of dynamic variables, correlation functions, frequency dependences of correlation functions, measures of statistical memory, kinetic and relaxation parameters. The MFF implements procedures for localization of individual parameters to study local features of time signals. In the present paper, we do not touch upon the main provisions of the MFF, but only dwell on some of the results obtained.

In particular, differences in the manifestation of statistical memory effects in the dynamics of time signals of representatives with strong and weak levels of OCD symptoms were established. The non-markness parameter allows us to compare relaxation times and statistical memory times in the studied dynamics. We performed a comparison of the average values of the non-markovance parameter for the electrodes of the representatives of both groups.

When examining the non-Markov parameter for auto-correlations, the most significant electrodes were identified: F_7 and Fpz (Fig. 1).

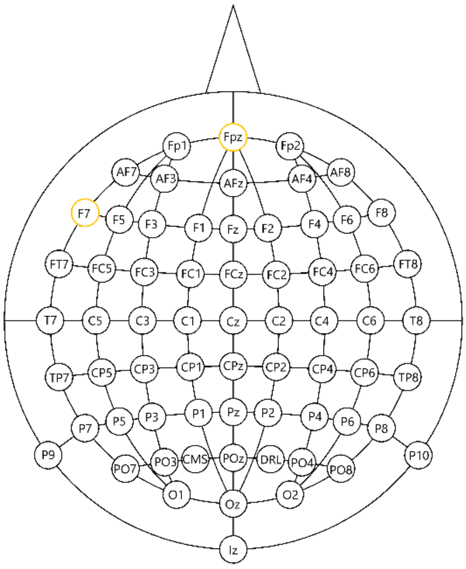

Fig. 1. Spatial diagram illustrating the differences in the manifestation of statistical memory effects for representatives with different levels of OCD-symptoms manifestation

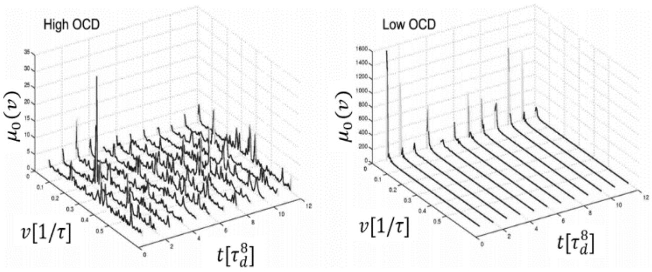

Fig. 2. Window-time behavior of the power spectrum of the time correlation function calculated for subjects with different levels of OCD manifestation

Within the framework of the MFF, expressions for the time correlation functions (TCF) and statistical memory functions, as well as their frequency dependences, are determined. As an example, we present the power spectrum of the initial TCF for representatives of two groups. We obtained local deviations of the main frequency peak with strong OCD symptoms and its stability with weak OCD symptoms (Fig. 2).

To study the effects of synchronization, a cross-correlation coefficient was calculated for all electrodes from both groups.When examining the effects of synchronization, the following results were obtained: for people with high manifestation of OCD-symptoms, synchronization on the short-range path is characteristic, and for people with weak OCD-symptoms, synchronization appears on the long-range path (Fig. 3).

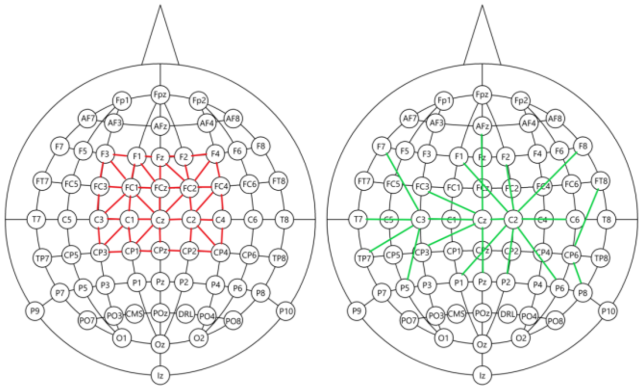

Fig. 3. Schematic representation of the ranges of strong phase synchronization at high OCD (left column) and low OCD symptoms (right column)

IV. Conclusions

In the present paper, we present preliminary results of the identification of auto- and cross-correlation patterns from the analysis of EEG signals of the subjects with different levels of manifestation of OCD-symptoms. Within the framework of the memory function formalism, we found differences in the manifestation of statistical memory effects, spectral behavior, as well as the nature of cross-correlations of the signals under study.

Our further plans relate to more detailed study of autocorrelations and effects of synchronization of the specified signals for establishment of objective diagnostic criteria of obsessive-compulsive disorders, and also other boundary conditions of the person [5]. The results obtained will be of interest for computational biophysics, physics of living systems, evolutionary psychology, and psychiatry.

Acknowledgment

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References

[1] Yulmetyev, R.M. Age-related alterations of relaxation processes and non-Markov effects in stochastic dynamics of R-R intervals variability from human ECGs / R.M. Yulmetyev, S.A. Demin, O.Y. Panischev, P. Hänggi // Physica A. – 2005. – Vol. 353. – P. 336.

[2] Demin, S.A. Statistical quantifiers of memory for an analysis of human brain and neuro-system diseases / S.A. Demin, R.M. Yulmetyev, O.Y. Panischev, P. Hänggi // Physica A. – 2008. – Vol. 387. – P. 2100.

[3] Jones, R. A role for the precuneus in thought–action fusion: Evidence from participants with significant obsessive–compulsive symptoms / R. Jones, J. Bhattacharya // NeuroImage: Clinical. – 2014. – Vol. 4. – P. 112.

[4] Jones, R. Alpha activity in the insula accompanies the urge to neutralize in sub-clinical obsessive–compulsive participants / R. Jones, J. Bhattacharya // Journal of Behavioral Addictions. – 2012. – Vol. 1. – P. 96.

[5] Timashev, S.F. Analysis of cross-correlations in electroencephalogram signals as an approach to proactive diagnosis of schizophreni / S.F. Timashev, O.Y. Panischev, Y.S. Polyakov, S.A. Demin, A.Y. Kaplan // Physica A. – 2012. – Vol. 391. – P. 1179.