# Identification and analysis of statistical patterns in human electroencephalogram signals at different degrees of obsessive-compulsive disorder


*Alexander A. Elenev*[1]
*Sergey A. Demin*[1]
*Valentin A. Yunusov*[1,2]
*Oleg Y. Panischev*[1]

*1. Institute of Physics, Kazan Federal University, Kazan, Russia*
*2. Institute of Computational Mathematics and Information Technologies, Kazan Federal University, Kazan, Russia*


Kazan Federal UNIVERSITY

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## Introduction

Obsessive-compulsive disorder (OCD) is a mental disorder characterized by compulsive states (obsessions) from which the patient attempts to escape through repetitive actions (compulsions). This disorder has different manifestations, and more often has a chronic character, interspersed with periods of absence of symptoms. At the present time, methodological approaches that have developed historically are used for the detection of OCD, but with different diagnostic criteria, which does not allow collecting them into a unified system and sufficiently studying the clinical dynamics. As a rule, such criteria contain information on the duration of OCD symptoms over a certain time period, decrease in quality of life, level of psychological discomfort, resistance to symptoms and control over them.

## Methods

The stochastic dynamics of the studying signals, registered in two different brain regions as the sequences $x_j$ and $y_j$ of random values $X$; $Y$:

$$X = \{x_0, x_1, x_2, \dots, x_{N-1}\},\quad Y = \{y_0, y_1, y_2, \dots, y_{N-1}\}$$

Mean values and fluctuations are determined as follows:

$$\langle X\rangle = \frac{1}{N}\sum_{j=0}^{N-1} x_j,\quad \delta x_j = x_j - \langle X\rangle$$

$$\langle Y\rangle = \frac{1}{N}\sum_{j=0}^{N-1} y_j,\ \delta_{yj} = y_j - \langle Y\rangle$$

To describe the probabilistic relation between the sequences of random variables $X$ and $Y$ we use the normalized time dependent cross-correlation function (CCF):

$$c(t = m\tau) = \frac{1}{(N-m)\sigma_x\sigma_y}\sum_{j=0}^{N-m-1} \delta x_j \delta y_{j+m}$$

Parameters $\sigma_x$ and $\sigma_y$ - are the mean-square derivations of random variables $X$ and $Y$.

Further we represent the CCF through the vectors of system state in time moment $t = m\tau$:

$$A_{m+k}^{m}(t) = \{\delta x_m, \delta x_{m+1}, \dots, \delta x_{m+k-1}\}$$
$$B_{m+k}^{m}(t) = \{\delta y_m, \delta y_{m+1}, \dots, \delta y_{m+k-1}\}$$

$$c(t) = \frac{\langle A_k^0(0) B_{m+k}^m(t)\rangle}{\langle A_k^0(0) B_k^0(0)\rangle}$$

To analyze the phase synchronization, we use the power spectra of memory functions:

$$\mu_i^{XY}(\nu) = \left|\tau \sum_{j=0}^{N-1} M_i^{XY}(j\tau) cos 2\pi\nu j\tau\right|^2.$$

Here $M_i^{XY}$ are determined as follow:

$$M_{n-1}^{XY}(t) = \frac{\left\langle \boldsymbol{W}_{n-1}^{X}\{1 + i\tau\hat{L}_{22}\}^m \boldsymbol{W}_{n-1}^{Y}\right\rangle}{\boldsymbol{W}_n^X \boldsymbol{W}_n^Y}$$

## Experimental data

In this paper, based on the author's methods of analyzing time signals: memory function formalism and flicker-noise spectroscopy, EEG signals of 30 subjects with different levels of OCD symptoms severity are investigated. The search for diagnostic patterns is performed in two directions: the study of bioelectrical activity of individual cortical areas of the brain in order to identify those in which the most significant functional changes are observed; the study of the effects of synchronization and coherence of signals generated by different cortical areas of the human brain. Sixty-four channel EEG was continuously recorded by active scalp electrodes according to the extended 10–20 international system of electrode placement (Fig.1). The sampling rate was 512 Hz. The data was then separated into 2 sec epochs, and bad channels were replaced by means of nearest neighbor interpolation.

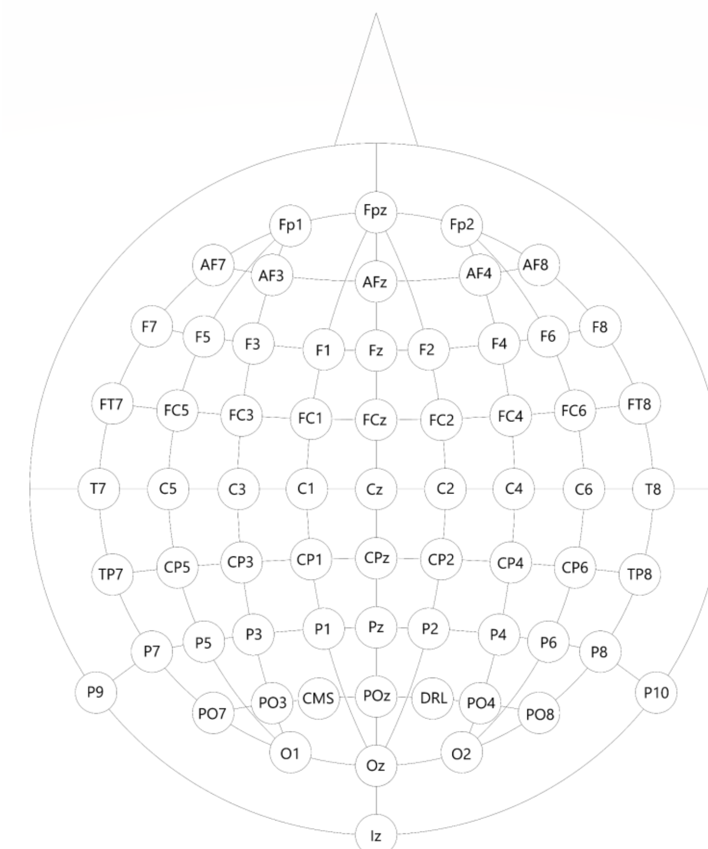

Fig. 1. Positions of the 64 electrodes including their number and their designations.

## Results

It is shown that the cerebral cortex signals from healthy people are characterized by high degree of long-range synchronization, whereas EEG of OCD patients has a strongly pronounced short-range synchronization (Fig. 2).

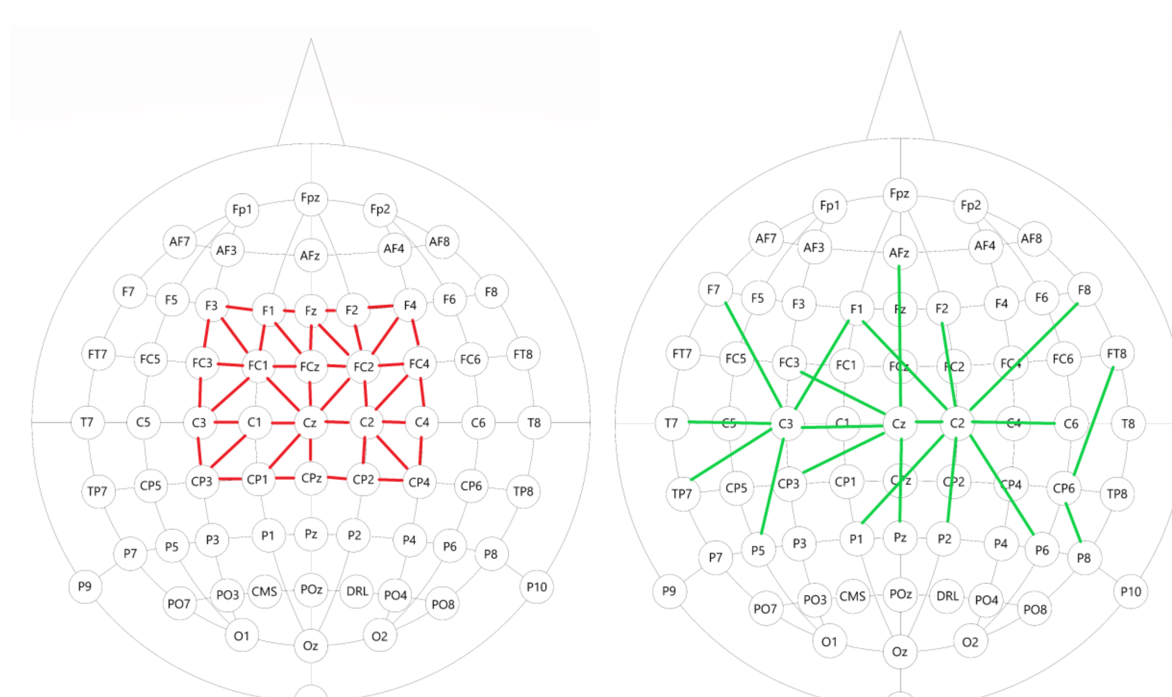

Fig. 2. Schematic representation of the ranges of strong phase synchronization at high OCD and low OCD symptoms.

Figure 3 demonstrates the local deviations of main frequency peak at high OCD symptoms and its stability at the low OCD condition.

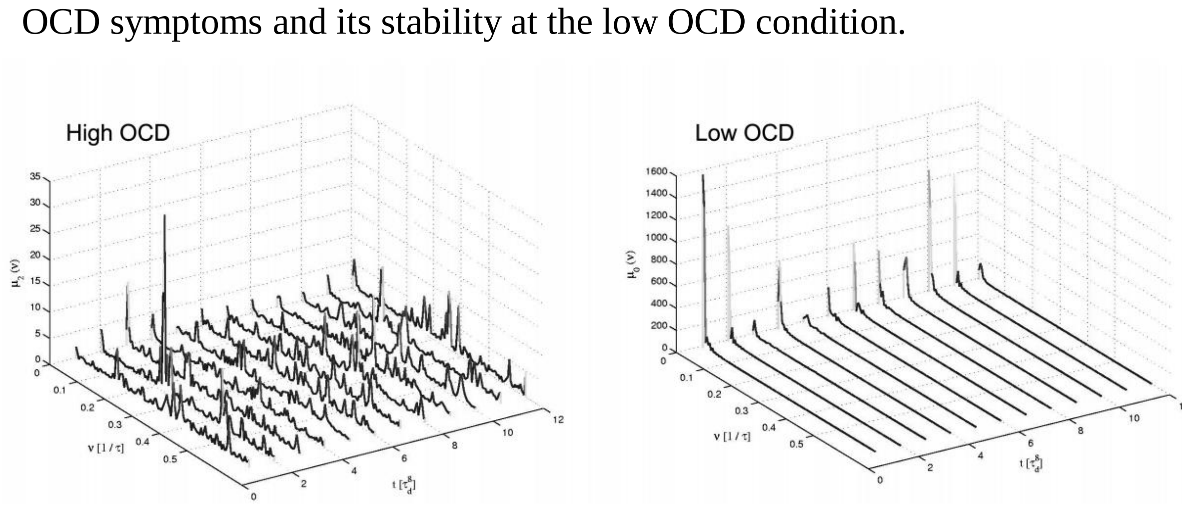


Fig. 3. Intermittency in phase synchronization at low and high OCD symptoms.

The results obtained will be of interest for computational biophysics, physics of living systems, evolutionary psychology, and psychiatry.


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