Short Communication

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Relationship between Depression and Recurrent EEG Parameters

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ABSTRACT

The study is devoted to finding the relationship between recurrent EEG parameters and depression, assessed using the Beck Depression Inventory. The experiments involved 40 people aged 20-25 years. Background EEG recording in rest with eyes open and closed was carried out in the following 14 leads: F3, F4, F7, F8, T3, T4, T5, T6, C3, C4, P3, P4, O1, O2. Seven indicators of recurrent dynamics obtained using Recurrence quantification analysis were calculated: RR, DET, DIV, L, LAM, TT and ENTR. Significant relationships were found for all types of recurrent EEG parameters with the Beck index scale reflecting the somatic manifestations of depression (Beck2). The fact that there is significant correlation between the recurrent EEG parameters and the scale reflecting the somatic manifestations of depression indicates that people with a more complex and less predictable EEG are better able to resist the somatic manifestations of depression. In other words, the high information capacity of the system allows it to respond flexibly to rapidly changing and unpredictable circumstances.

Keywords: Recurrent Quantative Analysis; Recurrent EEG Parameters; Human Depression; Beck Scale

Abbreviations: WHO: World Health Organization; DET: Determinism; DIV: Divergence; LAM: Laminarity; TT: Trapping Time; ENTR: Entropy

Introduction

According to the forecasts of the World Health Organization (WHO), depression will soon come out on top among all diseases, overtaking cardiovascular diseases and infectious diseases. According to WHO, more than 300 million people of all age groups suffer from depression worldwide, with about 800 thousand people annually ready to commit suicide. Among the reasons for the development of depression are three main factors: biological, psychological and sociological. The identification of biological and, first of all, neurophysiological mechanisms of depression plays a leading role, since knowledge of the brain mechanisms is invaluable in terms of compensation for this disease.

According to the American Neuropsychiatric Association, the sensitivity of quantitative EEG data for the detection of depression is 72-93%, and the specificity of the data is 75-88% [1]. There are many studies in the literature on EEG correlates of depression. These works are characterized by a rich phenomenology, but do not allow us to talk about common neurophysiological mechanisms underlying depression. Based on this, we stopped at the consideration of such a non-linear method of EEG analysis as the method of recurrent quantitative analysis (QRA), based on the quantitative assessment of recurrent diagrams. This method, developed by Zbilut & Weber [2,3], has become quite popular in recent years. Its important advantage is that it can be used for analysis of short noisy time series (Marwan, [4]). In addition, this method makes it possible to analyze the activity of the system, regardless of the number and dynamic nature of individual sources.

In our previous study [5], the EEG entropy index was taken as a basis. Entropy is a measure of disorder, a degree of uncertainty. It should be emphasized that entropy, in terms of importance, is put on a par with such fundamental concepts as matter, energy, time and space. We proceeded from the assumption that a higher EEG entropy corresponds to a more complexly organized EEG and allows you to

turn on compensation mechanisms and, therefore, is combined with lower depression. Depression was assessed using the Beck score. As is known, the Beck test consists of two components: the cognitive-affective subscale

1. And the subscale of somatic manifestations
2. Of depression.

In our work, it was shown that the second scale of the Beck index significantly correlated with the EEG entropy. The higher the EEG entropy, the lower the values of the Beck index.

In continuation of this study, in the present work, we calculated the relationships of a number of recurrent EEG parameters with Beck test scores. Study participants were 40 female volunteers (university students, 19 – 25 years old). EEG data was recorded at resting state with open and closed eyes (1 minute per condition). Scalp electrodes (F3, F4, F7, F8, T3, T4, T5, T6, C3, C4, P3, P4, O1, O2) were placed in accordance with the international 10–20 EEG System. Reference electrodes were placed on earlobes with the ground at GND. The EEG was recorded using the WinEEG (Mitsar) software (version 2.126.97) and the Mitsar-EEG 202 electroencephalograph with a sampling frequency of 500 Hz, an input impedance of more than 200 mOhm and an internal noise level of less than 0.25 μV. When performing the Beck test, the following results were obtained: no depression - 15 people; slight level of depression - 14 people; moderate depression - 4 people; moderate depression - 4 people; severe depression - 3 people.

Recurrent entropy being computed via special programme Recurrence quantification analysis (RQA). In the present study, 7 indicators of recurrent dynamics obtained using RQA were calculated: RR, DET, DIV, L, LAM, TT and ENTR.

1. RR - recurrence indicator, shows the density of recurrent points and reflects the probability of repeating the state.
2. Determinism (DET) - is related with the predictability of the dynamical system. DET characterizes the ratio of recurrent points that make up diagonal structures to the total number of recurrent points.
3. Divergence (DIV) - inversion of the maximum length of diagonal structures.
4. L - is related with the *predictability time* of the dynamical system and the trapping time, measuring the average length of the vertical lines. L can be considered as the average predictability time.
5. Laminarity (LAM) - This measure is called LAM and is related with the amount of laminar phases. A measure of intermittency, the ratio of the number of recurrent points forming horizontal lines to the total number of recurrent point.
6. Trapping Time (TT) - is related with the *laminarity time* of the dynamical system, i.e., how long the system remains in a specific state. TT characterizes the average time that the system can be in a certain state.
7. Entropy (ENTR) - measure of entropy reflects the complexity of the deterministic structure in the system.

In order to resolve the issue of the presence of a multiple correlation of recurrent EEG parameters with the Beck test, the following procedure was performed. First, the factor analysis of the corresponding recurrent EEG indicator was carried out using the method of principal components. At the next stage, the correlation of the first principal component with the individual values of the Beck test was calculated. The data obtained are presented in the (Table 1). As (Table 1) shows, out of 7 recurrent measures, 6 showed a significant correlation with the Beck score of the second scale and one (TT) also significantly correlated with the overall score. The question arises what factor could unite all these indicators. Their analysis suggests that the property of EEG predictability may be such a factor.

Table 1: Correlations of Beck's indices with the first principal component of recurrent measures EEG.

Recurrent EEG parameters	Beck	Beck1	Beck2
RR	.16	.108	.249
DET	.207	.121	.372 P=.02
L	.247	.151	.397 P=.01
DIV	-.237	-.166	-.370 P=.019
ENTR	-.259	-.163	-.409 P=.009
LAM	.229	.147	.388 P=.013
TT	.313 P=.043	.252	.482 P=.002

Note: P - significance level.

For example, the LAM indicator characterizes the presence of system fading states (when the system's movement along the phase trajectory stops or moves very slowly). Apparently, the higher its value, the higher the predictability of the system. In relation to the TT indicator, we can say that the longer the average time that the system can spend in a certain state, the higher the predictability of the process. Divergence reflects the rate of divergence of trajectories and, with the opposite sign, can be considered as the predictability of the process. Similarly, higher entropy corresponds to less predictability of the EEG process. In addition, all recurrent EEG parameters showed highly significant interindividual correlations with each other. Based on the presented material, it can be concluded that a person with high depression will have an EEG with high predictability. When interpreting this result, it is necessary to take into account a certain universality and unambiguity of the data obtained, i.e., they should be based on a mechanism reflecting some general regularity. It can be assumed that a less deterministic, less predictable and more complex EEG prevents the development of depression due to the blockade of repetitive so-called ruminant processes.

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