The FNS-based analyzing the EEG to diagnose the bipolar affective disorder

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Abstract. Here we demonstrate a capability of method based on the Flicker-Noise Spectroscopy (FNS) in analyzing the manifestation bipolar affective disorder (BAD) in EEG. Generally EEG from BAD patient does not show the visual differences from healthy EEG. Analyzing the behavior of FNS-parameters and the structure of 3D-cross correlators allows to discover the differential characteristics of BAD. The cerebral cortex electric activity of BAD patients have a specific collective dynamics and configuration of the FNS-characteristics in comparison with healthy subjects.

1. Introduction

Modern medical science has the powerful capabilities in solving many tasks in diagnosing and monitoring of the treatment quality. However, there are many difficulties connected with correct diagnosing in specific fields. First of all, it can be illustrated on example of the psychiatric disorders. The most disorders haven't the objective diagnostic criteria. At this rate, schizophrenia or a bipolar affective disorder are diagnosed based on criteria in either the American Psychiatric Association's fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM 5), or the World Health Organization's International Statistical Classification of Diseases and Related Health Problems (ICD-10). However in various papers \([1, 2]\) it is shown that BAD and epilepsy are manifested in the specific behavior of synchronization effects and in spectral properties of alpha rhythm. In \([3]\) on the basis of the flicker-noise spectroscopy (FNS) authors have formulated the criteria of degree of the susceptibility to schizophrenia in children/adolescents. In \([4]\) it is demonstrated that the method based on the memory function formalism (MFF) can discover the susceptibility to schizophrenia by analyzing the collective phenomena in the cerebral cortex bioelectric activity.

Bipolar affective disorder (earlier called manic-depressive illness) is a mental disorder characterized by periods of elevated mood and periods of depression. The elevated mood is significant and is known as mania or hypomania depending on the severity or whether there is psychosis. During periods of depression there may be crying, poor eye contact with others, and a negative outlook on life. In this paper within the framework of the flicker-noise spectroscopy \([5, 6]\) we demonstrate a capability to formulate the objective diagnosing criteria for BAD using the analysis of EEG signals. The FNS method separates the analyzed signal into three components: low-frequency regular component corresponding to system-specific “resonances” and their interferential contributions, stochastic random-walk component at larger frequencies corresponding to dissipation effects, and highest-frequency inertial “spike” component corresponding to flicker noise. Also the method contains equations for describing the frequency-phase synchronization.

We show here that the BAD existence leads to decreasing the resonance components and to increasing the chaotic components of the EEG-signal from the certain electrodes. Also we have discovered the crucial cerebral cortex areas for the BAD diagnosing. According to the hypothesis about dependence between the pathological abnormalities and the synchronization properties of bioelectrical activity we have revealed the characteristic features of the EEG collective dynamics in healthy people and BAD patients. It is shown that the cerebral cortex signals from healthy people are characterized by high degree of long-range synchronization, whereas EEG of BAD patients has a strongly pronounced short-range synchronization.
2. Basic relations of the Flicker-Noise Spectroscopy

The essence of the FNS [3, 5, 6] method consists in assigning the information sense to distinct types of irregularities in considering time series: spike-like irregularities (“chaotic” components) and jump-like irregularities (“resonant” components). It allows parameterizing the studied dynamics by means of short set of variables describing the evolution in different frequency ranges.

Within the framework of FNS six parameters are introduced $T_{01}$, $S_{S}(T_{01}^{-1})$, $n$, $\sigma$, $T_{i}$, $H_{i}$: $T_{01}$, the correlation time for jump- and spike-like irregularities after which the self-similarity observed in power spectrum estimate breaks down; $S_{S}(T_{01}^{-1})$, the “spikiness” factor – power spectrum estimate at frequency $T_{01}^{-1}$, which accounts for the “intensity” of jump- and spike-like irregularities in the highest-frequency interval; $n$, the flicker-noise parameter, which characterizes the rate of loss of correlations in the series of high-frequency irregularities in time intervals $T_{01}$; $\sigma$, the standard deviation of the value of the measured dynamic variable from the slowly varying resonant (regular) component, which is based solely on jump-like irregularities; $T_{i}$, the correlation time for jump-like irregularities in stochastically varying signal $V(t)$; $H_{i}$, the Hurst exponent (this estimate of the Hurst component is also referred to in literature as the Hausdorff exponent), which describes the rate at which the dynamic variable “forgets” its values on the time intervals that are less than $T_{i}$.

3. Experimental Data

The background EEG signals were recorded from electrode locations Fp1, Fp2, F7, F3, F4, F8, T3, C3, C4, T4, T5, P3, P4, T6, O1, O2 on the scalp according to the standard 10-20 International electrode placement system. The electrodes are numbered (figure 1) from 1 to 16. An average reference was used. The subjects were placed in a sound proof, light attenuated air-conditioned (20°C) room and instructed to relax and close their eyes for some time during the data acquisition period. The sampling frequency was 200 Hz and the signal was filtered between 0.1-70 Hz. A notch filter of 50 Hz was also used. The data were stored on an optical disk drive and then later transported to a hard disk for further analysis. Sixteen subjects were chosen belonging to two broad groups (each group consisted of eight subjects): control subjects with no reported psychiatric or neurological disorders, and subjects with bipolar affective disorder. The subjects were within the age range 18-65 years with the mean ages of 32.50, and 30.44 years for the two groups respectively. All the subjects gave written consent prior to the recording. An epoch length of ~ 10 s of uninterrupted EEG data, which were free from any visual complexes, were chosen for analysis. Baseline drift was removed by subtracting a polynomial of 2nd order [1, 2].

![Figure 1](image)

Figure 1. Positions of the 16 electrodes including their number and their designations. The schemata are based on the internationally established 10-20 system. Midline electrodes are exempted from this study.

4. Discussion

Figure 2 (a – c) demonstrates the FNS parameters $S_{S}(T_{01}^{-1})$, $n$, $\sigma$, which are not demonstrate the differences for EEG dynamics of healthy and patients. But the following parameters (Figure 2 d – f) $T_{01}$, $T_{i}$, $H_{i}$: allow to determine the differences in correlation characteristics of EEG from healthy and patients. The main differences are in frontal and top cerebral cortex areas. Also we observe the differences in other areas.
Figure 2. The ratios of mean values of FNS parameters for healthy and patients.

Cross correlator, introduced within the frameworks of FNS (figure 4) shows in healthy people the strong phase synchronization between the long range areas and more low its degree for short range areas. Another picture is observed for BAR patients: close areas have a significant synchronization at just long range areas demonstrate low synchrony.

Figure 3. Coupling the remote and neighboring cortical areas in BAD patients and healthy people.
5. Conclusions

In this paper we have presented a diagnosing method of psychiatric disorders based on the FNS analysis. To find the diagnosing criteria for bipolar affective disorder (BAD) we use the FNS method to analyze the behavior of EEG signals and collective phenomena in the cerebral cortex electric activity. We reveal the differences in “chaotic” and “resonant” characteristics of EEGs in healthy and BAD patients. Also we identify the differences in coupling of the neighboring and remote cortical areas in the BAD patients and healthy subjects. At the pathology the high degree of synchronization is observed in close proximity cortical areas, at that in healthy people have a high synchrony in remote ones. Thus we have demonstrated a capability to use the EEGs to develop a new diagnostic methods of the psychiatric disorders.

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