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SHORT COMMUNICATIONS

Variability of the EEG Autocorrelation Structure in Adolescents with Schizophrenia Spectrum Disorders

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Abstract—Quantitative analysis of changes in the autocorrelation structure of EEG short segments (in the range of several seconds) was performed in healthy adolescents ($n = 39$) and adolescents with schizophrenia spectrum disorders ($n = 39$). The variability of the EEG autocorrelation structure was shown to be higher in patients with the greatest trend in the frontal leads. It is suggested that psychopathology of the schizophrenia spectrum is accompanied by a break in the mutual determination of cortical neural networks with predominant localization of this process in the frontal areas of the brain cortex.

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The notion of a predominantly piecewise pattern of the EEG that was formed in the 1970s–1980s [1–3] and developed in subsequent years [4–6] made it possible to create nonparametric methods of structural EEG analysis [7, 8]. These methods are efficiently used for estimation of changes in functional [9] and pathological [10] states of the human brain. However, up to now, the description of the structural characteristics of the EEG with nonparametric methods has been mainly based on the amplitude characteristics of the signal [11]. In a previous work [12], we suggested that functionally significant structural EEG features also manifest themselves in the variability of its autocorrelation characteristics. To quantitatively estimate this EEG characteristic, we introduced the index of EEG autocorrelation structure variability (CSV), which makes it possible to distinguish rearrangements of this structure above the level of the stochastic variability of this index [11].

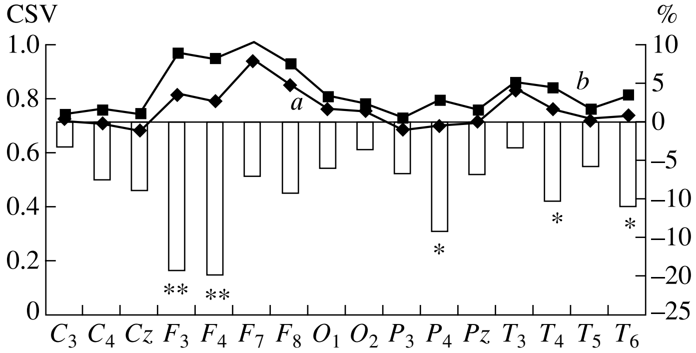
The purpose of this work was to compare the CSV indices in healthy adolescents and adolescents with schizophrenia spectrum disorders.

Analysis of the variability of the EEG autocorrelation structure was performed for EEG records obtained from 45 10- to 14-year-old boys with schizophrenia spectrum disorders (schizophrenia (childhood-onset), schizotypic disorder, or schizoaffective psychosis) with comparatively homogeneous symptoms. A clinical characterization of these adolescents was provided by experts from the National Center of Mental Health of the Russian Academy of Medical Sciences. The control group consisted of 39 healthy 11- to 13-year-old boys. Monopolar EEG recordings 1–2 min in duration were carried out with eight pairs of symmetrical electrodes (O_1, O_2, P_3, P_4, Pz, T_5, T_6, C_3, C_4, Cz, T_3, T_4, F_3, F_4, F_7, and F_8) located according to the international 10–20 system in reference to coupled earlobe electrodes. During the examination, all subjects were in the state of quiet wakefulness with the eyes closed. The statistics of the difference moments of the second order or the structure function (SF) [13] was used for the estimation of the mutual variability of neighboring EEG samplings. This function is similar to the autocorrelation function but ensures a finer differentiation of time series. As a certain approximation, the SF reflects the mutual amplitude variation of successive EEG samplings separated by an interval of n samplings. In this work, n varied from 0 to 8.

For the calculation of the SF, each 1-s EEG segment was standardized by recalculation of the initial values into a series of numbers with a zero mean and a variance of 1. Then, for successive 1-s segments of the standardized EEG in the form $\{h(t_k)\}$, $t_k = k\Delta t$, where Δt is a sampling interval, SFs of the second order were calculated,

$$\Phi^2(\tau) = \frac{1}{M}\sum_{k=1}^{M}|h(t_k) - h(t_k+\tau)|^2, \quad M = N - \tau/\Delta t,$$

where τ varied from 1 to 8 Δt. For a sampling rate of 128 Hz ($N = 128$, $\Delta t = 1/128$ s), the range of enumeration of the values of τ corresponded to time intervals from 7.8 to 62.5 ms. Then, for each τ, the SF values were compared in each pair of successive 1-s EEG segments taken with a shift in ΔT equal to 2 s. In each comparison of EEG segments, SF differences were fixed for the values of τ corresponding to the maximum SF dif-



The CSV index for 16 EEG leads in groups of healthy adolescents and adolescents with schizophrenia spectrum disorders. The left ordinate shows CSV; the right ordinate shows the difference between the CSV values in (*a*) healthy subjects and (*b*) patients (in percent of normal values). Bars show relative differences between the curves. Significance of differences: * $p < 0.05$; ** $p < 0.01$.

ferences, rather than for all τ. Thus, each EEG record was characterized by a set of values of the maximum difference (MD) in the SFs for all pairs of compared 1-s segments. It was estimated thereby how much the SFs differed from one another upon the transition from one EEG segment to another.

Preliminarily, we estimated the stochastic MD threshold for each EEG record. This threshold was determined as the MD for a decorrelated analogue of this EEG plus one standard deviation [12]. The CSV index was calculated as the mean value of superthreshold MDs over all comparisons of SF pairs for a given EEG record. Evidently, the higher the CSV index, the more significant the short-term changes in the autocorrelation structure in the given EEG (for more details, see [12]).

The Mann–Whitney *U* test was used for statistical estimation of the differences between the CSV indices in the two adolescent groups.

For the majority of the EEG leads, the CSV index averaged for all subjects varied approximately in the same relatively narrow range from 0.7 to 0.8 arbitrary units (figure) despite the known substantial differences between these leads in the expression of EEG spectral components. In both adolescent groups, the CSV index was noticeably higher for the frontal leads than the other leads (figure); however, this difference was not significant.

The differences between the groups in the mean CSV indices for the same EEG leads were more contrasting. As can be seen from the figure, the frontal (F_3 and F_4) CSV indices in healthy adolescents were 20% lower than in patients ($p < 0.01$), while those in the P_4 lead were 15% lower in the control group than in patients ($p < 0.05$). With a lower statistical significance ($p < 0.05$), this tendency was also observed for the right temporal leads T_4 and T_6 (figure).

For all the remaining EEG leads, the CSV index was a little higher in patients than in healthy adolescents. This difference was not significant, but its sign was the same in all cases (figure).

The question arises of whether the unidirectional shift of the CSV indices is a trivial reflection of the well-known [14] generalized decrease in α activity in schizophrenia. The phenomenon of α rhythm depression in schizophrenia was confirmed earlier for the samples of subjects tested in this work [15]. To test the above suggestion, we calculated Pearson's correlation coefficients between the CSV indices and the power of the α activity in different leads for both groups of subjects. No mutual determination was found between the EEG spectral and structural characteristics. It can be assumed that the CSV index reflects specific EEG features that are not correlated strongly with its spectral characteristics.

Evidently, the increased variability of the EEG autocorrelation structure from segment to segment in the time range of several seconds can be attributed to the functional insufficiency of intracortical functional connections in schizophrenia. These results accord with the hypothesis on the disintegration of cortical neural networks in schizophrenia spectrum disorders [16]. The break in the local [10] and distant [15] synchronization of cortical neural networks in schizophrenia that we observed earlier in the same groups of subjects also confirms Friston's hypothesis [16].

The increased variability of the EEG autocorrelation structure in schizophrenia is most pronounced in the frontal areas of the brain cortex. This finding further confirms the relationship between this phenomenon and the given form of psychopathology because the functional deficiency of the prefrontal cortex is most closely associated with the etiology and pathogenesis of schizophrenia [17].

CONCLUSIONS

The results suggest that the autocorrelation structure of the EEG of adolescents with schizophrenia spectrum disorders differs from the same EEG characteristic in healthy subjects of the same age by more frequent rearrangements in the range of several seconds. The most evident and statistically significant differences are characteristic of the frontal cortical areas. The results testify to a decrease in the mutual determination of cortical neural networks, which points to a certain hypofrontality in patients with schizophrenia spectrum disorders [18].

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