Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Using of the interictal EEGs for epilepsy diagnosing

To cite this article: O Yu Panischev *et al* 2015 *J. Phys.: Conf. Ser.* **661** 012021

Using of the interictal EEGs for epilepsy diagnosing

O Yu Panischev, S A Demin, E M Zinatullin

Kazan Federal University, Institute of Physics, Kazan, 420008 Russia

E-mail: opanischev@gmail.com

Abstract. In this work we apply a new method to determine the differences in characteristics of the cortical electroencephalographic (EEG) activity, measured during interictal stage (i.e., period between seizures), between healthy subjects and patients with epilepsy. To analyze the dynamical and spectral properties of bioelectric activity we use power spectra and phase portraits which are introduced on the basis of the Memory Function Formalism (MFF). We discover the significant differences in the types of power spectra of the EEG for healthy subjects and patients. We reveal the cerebral cortex areas for which the EEG activity of considered groups of subjects has a different structure of the phase portraits. The proposed approach can be used as an additional method for diagnosis of epilepsy during interictal stage.

1. Introduction

Epilepsy is one the most common chronic neurological diseases, which is characterized by recurrent seizures, due to different abnormalities of the brain activity [1]. Inasmuch as the seizures can occur in different abnormalities of the brain and central nervous system, it is necessary to note that the epilepsy diagnosing during the interictal period is a complicated problem. To solve it, the EEG before, during and after seizure are used [2]. EEG monitoring, as a noninvasive method to define epileptogenic cortex, effectively reveals the characteristics of brain activity in several epilepsy-related syndromes. The epileptic cortical brain activities have specific spike-wave patterns of EEG discharge. Another important problem in treatment of epilepsy is the long-range prediction of recurrent seizure in patients. Epileptogenesis episodes can be separated by different extended periods, when disease is not manifested. To detect epileptic seizures the long-term EEG monitoring during ictal and interictal stages is used [3].

A reduce in synchronization of interictal EEG activity have been found in epilepsy patients contrast to healthy people [4, 5].

To develop an additional method of the EEG-based diagnostic of the epilepsy during the interictal stage, in this paper we use the memory function formalism [6, 7, 8].

2. Background of the memory function formalism method

Within the framework of MFF [6, 7, 8], we consider stochastic dynamics of the EEG signal as the sequence $\{x_j\}$ of a random value X:

$$X = \{x(T), x(T+\tau), x(T+2\tau), \dots, x(T+(N-1)\tau)\} = \{x_0, x_1, x_2, \dots, x_{N-1}\}, \quad (1)$$

$$x_j = x(T+j\tau), \qquad \langle X\rangle = \frac{1}{N}\sum_{j=0}^{N-1} x_j, \qquad \delta x_j = x_j - \langle X\rangle, \qquad \sigma^2 = \frac{1}{N}\sum_{j=0}^{N-1} \delta x_j^2, \quad (2)$$

where T is the initial time point, τ is the time interval of signal discretization, $\langle X\rangle$ is the mean value of X, δx_j is fluctuation.

To describe the probabilistic relations in the sequence of X we use the normalized time-dependent correlation function

$$a(t = m\tau) = M_0(m\tau) = \frac{1}{(N-m)\sigma^2}\sum_{j=0}^{N-m-1} \delta x_j \delta x_{j+m}, \quad (3)$$

which is rewritten further as a scalar product of vectors of the initial state

$$\mathbf{A}_k^0 = \mathbf{A}_k^0(0) = \{\delta x_0, \delta x_1, \dots, \delta x_{k-1}\} \quad (4)$$

and of system state in time moment t

$$\mathbf{A}_{m+k}^m = \mathbf{A}_{m+k}^m(t) = \{\delta x_m, \delta x_{m+1}, \dots, \delta x_{m+k-1}\} \quad (5)$$

as follows:

$$a(t) = \frac{\langle \mathbf{A}_k^0(0)\mathbf{A}_{m+k}^m(t)\rangle}{\langle |\mathbf{A}_k^0(0)|^2\rangle}. \quad (6)$$

The technique of projection operators was used to calculate the kinetic and relaxation parameters ($\hat{L}$ is the Liouville's quasioperator, see [6, 7, 8] for details):

$$\lambda_n = \frac{\langle \mathbf{W}_{n-1}\hat{L}\mathbf{W}_{n-1}\rangle}{\langle |\mathbf{W}_{n-1}|^2\rangle}, \qquad \Lambda_n = i\frac{\langle |\mathbf{W}_n|^2\rangle}{\langle |\mathbf{W}_{n-1}|^2\rangle}, \quad (7)$$

the dynamic orthogonal variables:

$$\mathbf{W}_0 = \mathbf{A}_k^0(0), \qquad \mathbf{W}_1 = (i\hat{L} - \lambda_1)\mathbf{W}_0, \qquad \mathbf{W}_2 = (i\hat{L} - \lambda_2)\mathbf{W}_1 - \Lambda_1\mathbf{W}_0 - \dots, \quad (8)$$

the memory functions of the n order $(a(t) = M_0(t))$:

$$M_n(t = m\tau) = \frac{\langle \mathbf{W}_n \{1 + i\tau \hat{L}_{22}\}^m \mathbf{W}_n \rangle}{\langle |\mathbf{W}_n|^2 \rangle}, \tag{9}$$

and their power spectra:

$$\mu_n(\nu) = \left| \tau \sum_{j=0}^{N-1} M_n(j\tau) \cos 2\pi\nu j\tau \right|^2. \tag{10}$$

3. Experimental Data

Data of EEG activity were analyzed in 8 healthy people (with no reported psychiatric or neurological disorders, mean age of 32.5 years) and 8 patients with epilepsy (mean age of 28.4 years), the subjects were within the age range 18-65 years. All experimental procedures were performed with the consent of the subjects. Multichannel EEG activity was recorded using 16 electrodes: F1, F2, 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 (Fig. 1) from 1 to 16. During the EEG recording the eyes of subject were closed. The sampling rate was 200 Hz and the signal was filtered between 0.1-70 Hz. A notch filter of 50 Hz was also used. An epoch length of $\sim$ 10 s of uninterrupted EEG data, which were free from any visual complexes, (e.g., the spike wave complexes for seizure patients) were chosen for analysis. Baseline drift was subtracted by a polynomial of 2nd order [4].

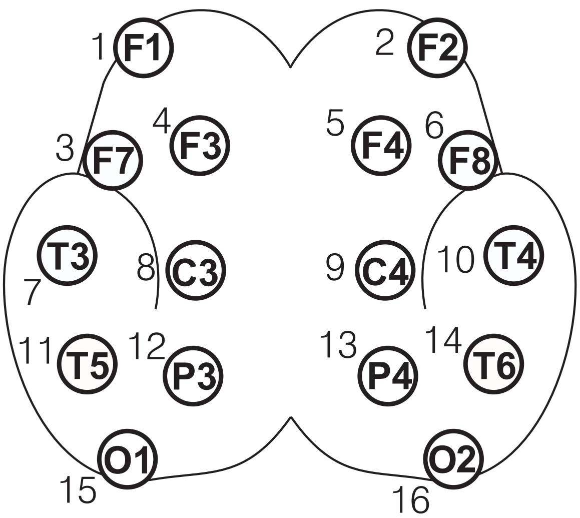

Figure 1. Positions of the 16 electrodes including their number and their designations. The schemata are based on the internationally established 10-20 system. Midline electrodes are exempted from this study.

4. Dynamical and spectral analysis of the interictal EEG

Analysis of EEG activity showed that in all subjects the power spectra has 4 types relative to the frequency bands. I-type spectra ranged within 1–4 Hz frequency band without peak

(Fig. 2a). The II-type and III-type had the peak within 5–16 Hz and 49–52 Hz frequency bands, respectively (Fig. 2b, c); while IV-type spectra had both peaks of frequency bands as II-type and III-type (Fig. 2d).

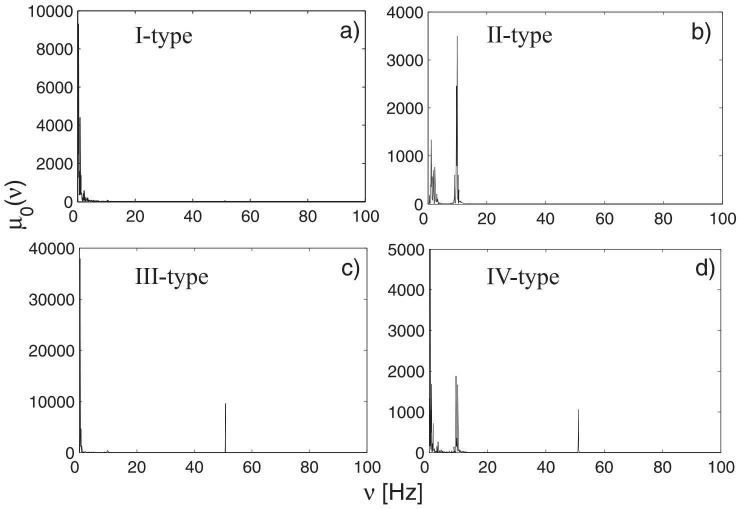

Figure 2. Power spectra of EEG activity for four frequency bands from all the subjects (a typical form of the spectra).

Fig. 3 illustrates four types of power spectra presented for different areas of EEG recording in healthy subjects and patients with epilepsy. In control group of subjects the I-type spectra of EEG activity was found in the fronto-polar (F1, F2), temporal, parietal, occipital cortical fields, while in patient with epilepsy I-type spectra was not observed in similar fields. EEG electrodes which differ in type of spectra between the studied groups: F1, F2, T5, P3, P4, T6, O1, O2.

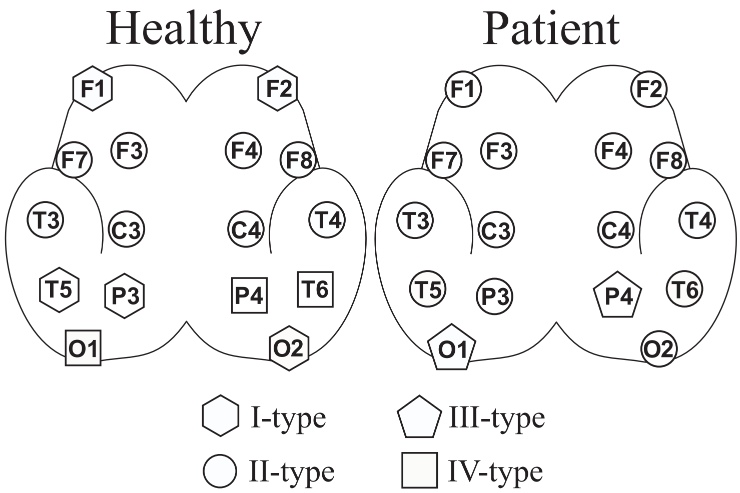

Figure 3. Types of spectra for the different areas of EEG activity in healthy subjects and patients (group average).

The epilepsy existence leads to alterations in size, form and location relative the origin of coordinates of the phase portraits (Fig. 4). The phase portraits are the simple graphical method for qualitative analysis of the studied dynamics [6, 7]. EEG activity variation is wider and has asymmetric shape in patients in contract to healthy subjects. Phase portraits of

EEGs from healthy subjects are characterized by compact symmetrical structure with separate circumferential points. In case of epilepsy for several electrodes (F1, T5, O2) we see the specific structure with high number of circumferential points. These electrodes F1 (Frontal lobe), T5 (Parietal lobe), O2 (Occipital lobe) have a high diagnostic significance for epilepsy identification during the interictal stage.

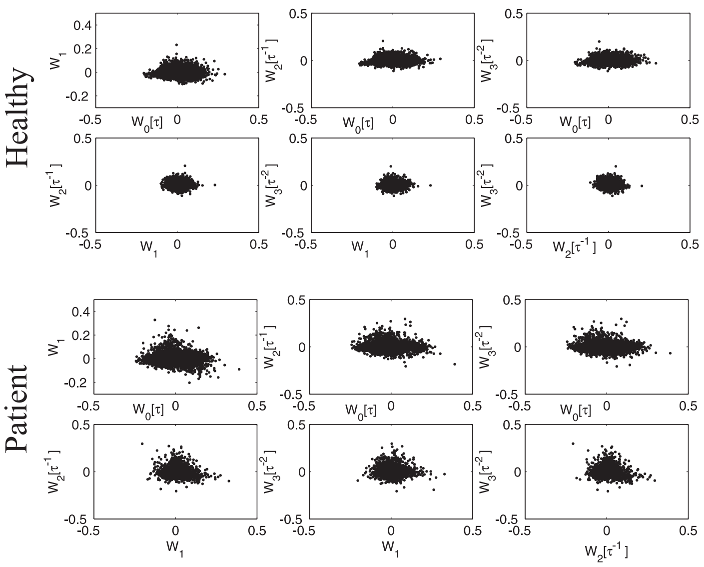

Figure 4. Phase portraits of the dynamic orthogonal variables of EEG signal from F1 electrode for one of healthy subjects and epilepsy patients.

5. Conclusions

Studying the interictal EEGs is one of the important problem for early detection of the epileptogenesis. Using the modern methods of time series analysis gives a deeper understanding of the processes at the pathology [9]. The MFF-based approach allows to reveal the dynamic and spectral properties of the EEG activity at the epilepsy during the interictal stage. Particularly, we have determined the types of the power spectra for EEG from the various cerebral cortex areas of healthy subjects and epilepsy patients. To determine qualitatively the pathology we use the phase portraits of the certain cerebral cortex areas. The proposed method could be applied (as an additional method) for the epilepsy diagnosis during period between seizures.

6. Acknowledgments

The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University. This work was supported by the Russian Foundation for Basic Research, grant No 14-02-31385_mol_a.

References

[1] Chang B S, Lowenstein D H 2003 *N. Engl. J. Med.* **349** 1257

[2] Sander J W, O'Donoghue M F 1997 *BMJ* **314** 158

[3] Xie S, Krishnan S 2014 *TSWJ* **2014** Article ID 419308

[4] Bhattacharya J 2001 *Acta Neurobiol. Exp.* **61** 309

[5] Mormann F, Kreuz Th, Andrzejak R G, David P, Lehnertz K, Elger Ch E 2003 *Epilepsy Res.* **53** 173

[6] Demin S A, Yulmetyev R M, Panischev O Yu, Hänggi P 2008 *Phys. A* **387** 2100

[7] Panischev O Yu, Demin S A, Bhattacharya J 2010 *Phys. A* **389** 4958

[8] Panischev O Yu, Demin S A, Kaplan A Ya, Varaksina N Yu 2013 *Biomed. Engin.* **47** 153

[9] Panischev O Yu, Demin S A, Panischeva S N, Bhattacharya J 2015 *NPCS* **18** 230