Assymetry of coupling between the P3 and P4 electroencephalographic leads during the motions

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***Abstract* — Based on the coupling analysis we analyze electroencephalograms (EEGs) acquired in untrained humans (operators) during real and imaginary movements, and show a difference between the related EEG signals and the recordings performed during real movements or the background electrical brain activity.**

Keywords—asymmetry, EEG, connection, motion

I. Introduction

Diagnosing the connectivity parameters between leads is an important task that attracts the attention of many researchers [1-3]. However, often classical mathematical methods based on time-frequency, wave or component analysis do not allow to assess the degree of interaction between the systems [4,5] due to significant complexity, nonstationarity, noise and poorly structured data. Therefore, the application of various measures of nonlinear dynamics to these data is promising.

II. Data and methods

Specific dynamics of electrical brain activity is associated with "mental actions" being a compilation of imaginary commands. The study involved non-invasive EEG signals registered from 15 healthy subjects with (19 electrodes with a 10-20 arrangement) during special active experiments. All experimental studies were conducted in accordance with the Helsinki Declaration of the World Medical Association. Each subject participated in one experiment lasting about 30 minutes. For each subject, the active experiment was performed from 1 to 5 times. In active experiments, the special software randomly generated on the screen one of nine instructions about real or imaginary movements of the arms and legs, which the subject had to perform or imagine 10 to 15 times on commands at the moments of playing special sound signals.

The active experiment included the following instructions: "Raising the left leg with the leg locked in the upper position for 0.5 seconds", "Imagination of the left leg raising with the leg locked in the upper position for 0.5 seconds", "Raising the right leg with the leg locked in the upper position on 0.5 seconds", "Imagination of raising the right leg with fixing the leg in the upper position for 0.5 seconds", "Exercising the raising of the left hand with fixing the arm in the upper position for 0.5 seconds", "Imagination of raising the left hand with fixing the arm in the upper position on 0.5 seconds", "Raising the right hand with the fixation of the hand in the upper position for 0.5 seconds", "Imagination of raising the right hand with the fixation of the arm in the upper position for 0.5 seconds". Before and after conducting an active experiment, the background EEG recording was recorded without the subject performing special instructions. For further analysis we used theta band frequency range 3-7 Hz [6].

For data analysis we used a method based on modeling phase dynamics [7-9] between the signals of non-invasive scalp EEG leads P3 and P4. The main idea of the method consists in evaluating the impact measure to improve the forecast produced using a joint model of the phase dynamics of the systems under study, compared with the forecast obtained using an individual model. Exceeding the estimated coupling measure in the direction of impact from one of the systems to another can be interpreted as the direction of the prevailing influence in this case, the position of the maximum in the dependence of the impact measure estimate can be used to estimate the delay in connection corresponding to this direction impact. For the method of the phase dynamics analysis, the values of the delay parameters were selected equal to a single period and the range of the analyzed time shift between the rows of 1 second.

III. Results

Maximal observed coupling strength values are shown in Fig. 1. In a box and whisker plot: the ends of the box are the upper and lower quartiles, so the box spans the interquartile range. the median is marked by a vertical line inside the box. the whiskers are the two lines outside the box that extend to the highest and lowest observations. The "RHR" column corresponds to the right hand real movement, RHM — right hand imaginary, LHR — left hand real, LHM — left hand imaginary, LLR — left leg real, LLM — left leg

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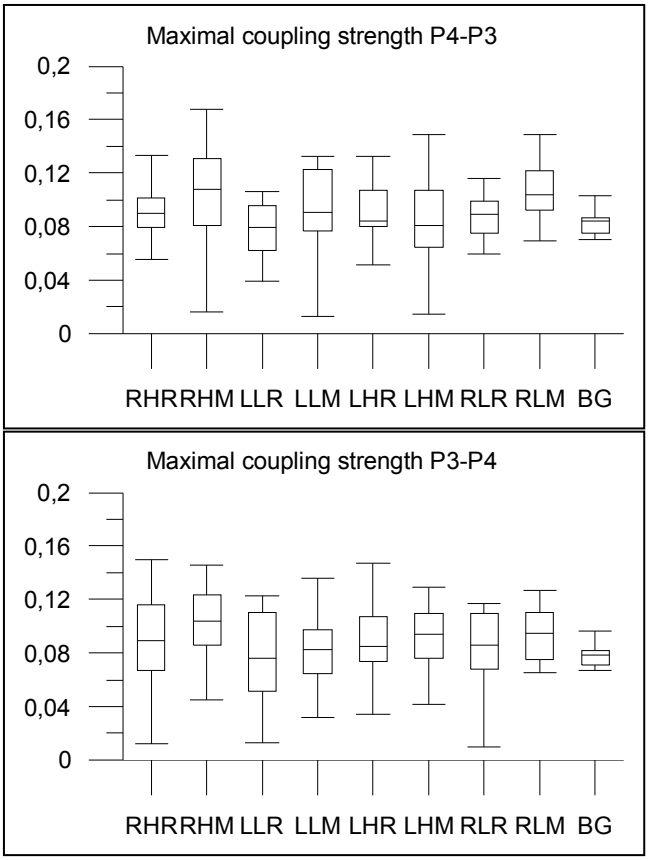

Fig. 1 Maximal observed coupling strength values for a different movement sessions. The box and whisker plot: the ends of the box are the upper and lower quartiles, so the box spans the interquartile range. the median is marked by a vertical line inside the box. the whiskers are the two lines outside the box that extend to the highest and lowest observations.

imaginary, RLR — right leg real, RLM — right leg imaginary, BG — background activity. Statistical analysis of the absolute values of the phase coupling showed that during the conduct of active movement sessions, the magnitude of the bond is equally likely to exceed or be less than the bond value in the background part of the experiment. We revealed an increase in the coupling strength force in the case of imaginary movement. Mean delays corresponding to the maximal coupling strength values are given in the Table 1. Statistical analysis of the delay values showed that during the conduct of active movement sessions mean delays are significantly lower than during background activity.

TABLE I.

Movement type	Direction P3-P4	
	Average Maximal Coupling strength delay	*Standard deviation*
Right hand real	0,145455	0,015207
Right hand imaginary	0,156842	0,036011
Left leg real	0,127273	0,027107
Left leg imaginary	0,145263	0,013518
Left hand real	0,18	0,072
Left hand imaginary	0,191579	0,109141
Right leg real	0,138182	0,009917
Right leg imaginary	0,183333	0,083704
Background activity	0,391429	0,230204
	Direction P3-P4	
	Average Maximal Coupling strength delay	*Standard deviation*
Right hand real	0,145455	0,017851
Right hand imaginary	0,184211	0,087535
Left leg real	0,154545	0,046612
Left leg imaginary	0,18	0,082105
Left hand real	0,136	0,0096
Left hand imaginary	0,224211	0,159114
Right leg real	0,127273	0,029752
Right leg imaginary	0,16	0,062222
Background activity	0,368571	0,343673

Such asymmetry in the coupling strength and delay between signals can be used to distinguish real and imaginary movements based on short fragments of experimental recordings that is important for potential application.

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