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Electrophysiological Features of Brain Electric Activity in Individuals with Different Social Behavior.

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ABSTRACT

The article is devoted to the study of differences in the brain's work of people with different social orientation by recording the electrical activity of the brain cortex. 120 (aged 21±4 years) individuals took part in the study. As a result of psychological testing (based on Leary-s test) all subjects were divided into two groups – altruistic and egoistic. Registration of electrical activity was carried out during "Stag Hunt Game" and during a specially developed model of social behavior "Mini Basketball Game". As a result, synchronization processes are better expressed in the individuals with egoistic sociotype, and desynchronization processes are better expressed in the individuals with altruistic sociotype in alpha- and betha-range. Sources of activity are represented by the structures of brain cortex frontal areas in altruistically directed individuals and by the structures of the brain cortex insula area in egoistic individuals.

Keywords: altruism, egoism, synchronization, desynchronization, reaction time.

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INTRODUCTION

Human social orientation and underlining neural mechanisms are outlined in the literature according to different concepts. Kahnemman, based on his neuroeconomics studies, showed that decision-making can be interpreted as activity of two relatively independent brain systems [1]. The interaction of "cognitive" and "emotional" mechanisms of decision-making determines the degree of rationality of human behavior. Sarlo is convinced that selfish social behavior determined by the initial stage of early emotions, which are related to the activity of the first system. At the same time altruistic social behavior is governed mainly by the mechanisms of the second system, associated with a conscious assessment of emotional component of behavior [2].

Differences between persons with different types of social behavior are widely differentiated at the level of the brain structures. The mechanisms of altruistic and selfish decisions are related to the activity of the limbic system and the prefrontal cortex [3]. These structures are responsible for the realization of opposite functions such as rapid emotional and slow considered decisions. Most actual studies in this area are based on fMRI and event-related potential (ERP) techniques [4].

Main differences in brain electrical activity are observed in the electroencephalogram (EEG) theta-range. At the same time the role of alpha and beta oscillation in realization of social functions are widely discussed [5]. Basically, such processes are studied using the ERP technique which shows differences in a short time interval after stimulus presentation (up to 1 s). However, changes in rhythmic activity can appear and continue for a few seconds [6]. Thus the appropriate technique of studying long-going oscillations in response to cognitive stimuli is event related synchronization/desynchronization (ERD/ERS) [7].

The goal of our study is to detect differences in the manifestation of the brain cortex rhythmic electrical activity depending on different human sociotypes.

MATERIALS AND METHODS

The research was conducted in Lesya Ukrainka Eastern European National University. 120 subjects (age 21±4.0 years, 50 females) participated in the study. The study consisted of two stages - psychological testing and EEG recording. Psychological testing was performed to assess the psychological characteristics of the subjects related to their psychological type, as well as general psychophysiological characteristics that may affect the study results. Testing was conducted with the aim to divide the subjects into groups according to their psychological features. The principal psychological test was interpersonal relations questionnaire by T. Leary [8]. Egocentric associative test and a questionnaire of temperament structure by Rusalov were also used to validate and confirm the results of Leary's test. Psychophysiological testing was conducted using paper printed tests immediately before EEG recording. Maximum duration of testing phase was limited to 30 min. All participants completed psychophysiological testing. All participants in the experiment were divided into two groups after analysis of all psychological characteristics based on the results of psychological tests – egoistic-directed social behavior (46 subjects) and altruistic-directed social behavior (54 subjects). It was difficult to identify the type of social behavior of 20 subjects, that's why they didn't take part in further stage of experiment.

EEG-session was conducted as the second stage of the experiment. The bioelectric activity of the brain cortex was recorded using the software complex "NeuroCom" EEG-equipment. The EEG was recorded under the following conditions: 1) rest-state (60 sec.), eyes closed; recording started after 1 min after closing the eyes; 2) "Stag Hunt" game (5 min); 3) "Mini-basketball" game (up to 20 min).

As a common approach, "Stag Hunt Game", which is widely represented in neuroeconomic researches, was used [9]. Subjects had to make a decision which option to choose – "Rabbit" option selection or "Stag" option selection according to the partner (computer) option. In this game "Stag" option selection was considered as altruistic and the "Rabbit" option selection – as egoistic. Because of equipment design no hand counter-balancing was used. Left button of control desk was used for selecting "Rabbit" option, right – for selecting "Stag" option.

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The interval between conditions was 3 min long. Due to special requirements to the ERD/ERS experiments there was a need for special behavioral model representating real social interactions. The game "Mini-basketball" was created with these concerns in mind. The game was presented as a set of images, organized in 20 series (4-5 images per each series). Subjects had to make a decision which option to choose according to the position in the game. Subject could choose several options, such as "Shot" or "Pass" if the subject had the ball and "Step right" or "Step left" if the opponent had the ball. According to the task the option "Shot" was considered as egoistic and the option "Pass" – as altruistic. The time for choosing was limited to 3 sec.

The following data was analyzed: ERD/ERS relative power values to evaluate the differences in brain activity of studied groups. Relative rower values were described in conventional units (c.u.) Differences between two groups for ERD/ERS results were described by spectrograms and by comparison of the EEG spectral power data. Decreasing power was associated with processes of cortical structures activation (desynchronization), while increasing power, primarily - in the alpha and lower beta ranges, was associated with a decrease in the activity of the corresponding cortex areas (synchronization). The localization of EEG activity sources was determined using a low resolution tomography method (LORETA). LORETA can be understood as an EEG-based neuro-imagining technique which computes a three-dimensional distribution of 2394 voxels of 7x7x7 mm of the generating electric neuronal activity in the grey matter [10]. LORETA analysis of limited frequency bands can be used to determine which regions of the brain are activated during different states or mental tasks, helping to determine if the brain is operating in an optimal way. The main differences in electrical activity were shown on the brain images. Blue color indicated higher activation in altruistically directed individuals, red color indicated hire activation in selfishly directed individuals.

RESULTS

During the "Stag Hunt Game" differences between groups are observed in the range of 15-20 Hz after stimulus onset in case of "Rabbit" option selection. It should also be noted that the prestimulus EEG shows differences in the 5-10 Hz range, but they disappear on response. These significant differences are observed in P3 site for 15 Hz and 17 Hz frequencies at 2 second post-stimulus interval (fig.1). The negative values of relative EEG power (-0.69 c.u.) indicated the predominance of desynchronization processes in altruistic-oriented individuals and the positive values of relative EEG power (0.33 c.u.) indicated the processes of synchronization in egoistic-oriented individuals.

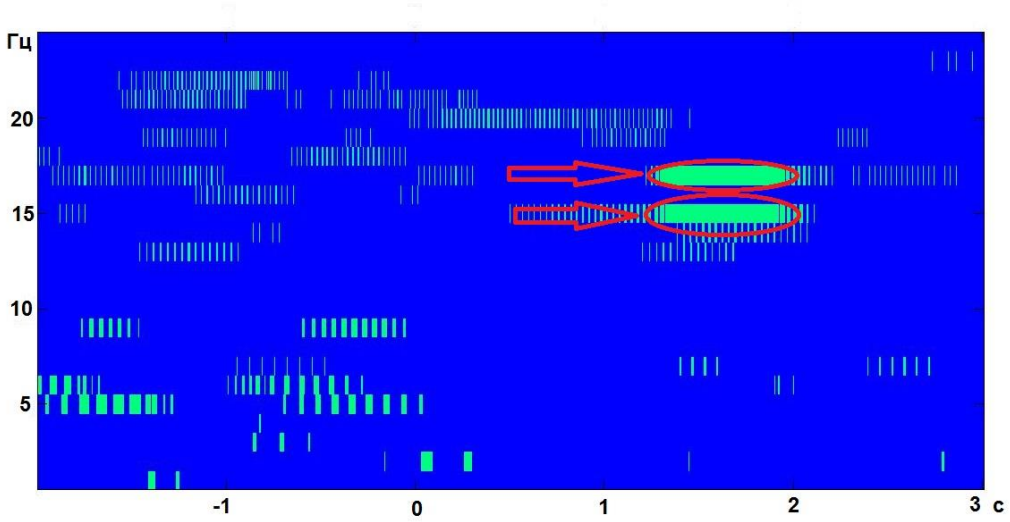

Fig.1. ERD/EDS analysis during the "Stag Hunt Game" (stimulus onset with "Rabbit" option chosen) in P3 site.

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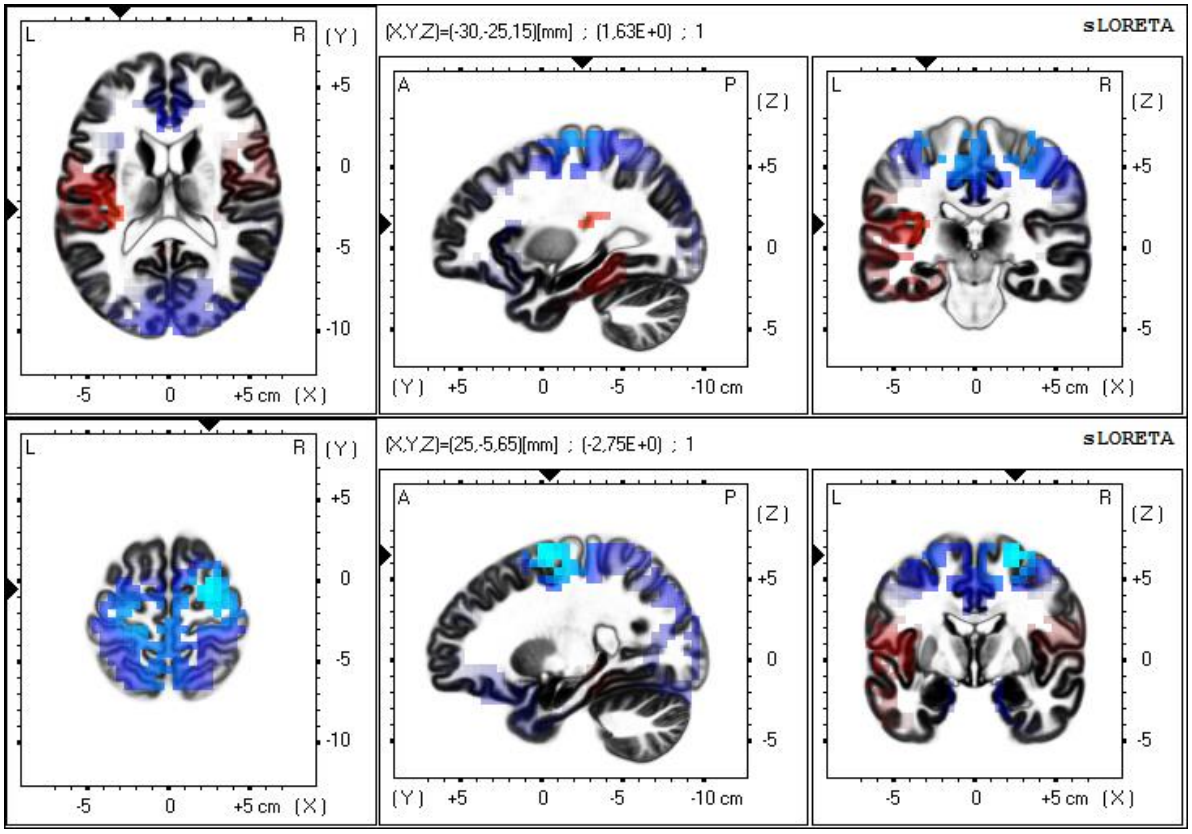

Fig.2. Spatial localization of activity sources during the choice of "Rabbit" option selection for 2 s after stimulation

According to LORETA analysis the highest activity level was localized in the insula area in egoistic-oriented individuals and in the middle frontal gyrus in altruistically-oriented individuals (fig. 2). This region is often discussed in relation to gain/loose conditions in social dilemma neuroscience studies. Engemann showed that anterior insula is activated while manifestation of emotions associated with risk assessment and concentration on personal gain [11].

The most significant difference was also observed in P3 site at 17 Hz at 2 second after the stimulus onset for "Stag" selection condition during “Stag Hunt Game” (fig. 3).

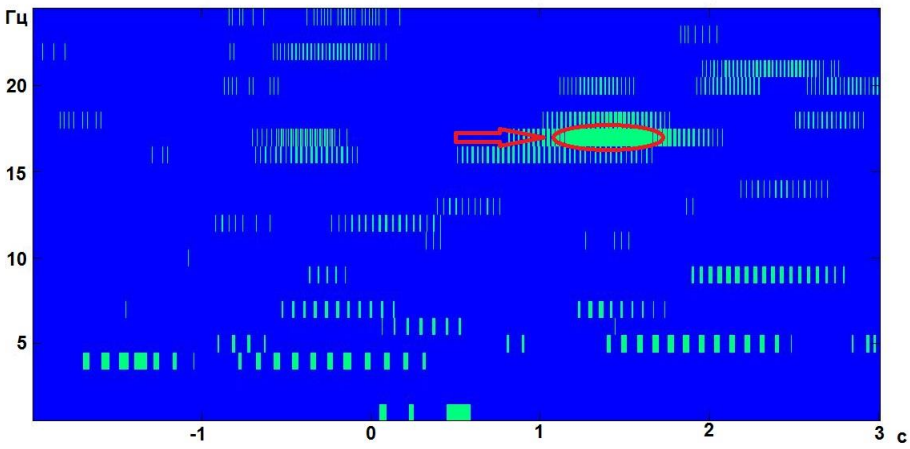

Fig.3. ERD/EDS analysis during the “Stag Hunt Game” (stimulus onset with “Stag” option chosen) in P3 site.

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The predominance of desynchronization processes in altruistic-oriented subjects and the prevalence of synchronization processes in egoistic-oriented subjects are indicated by negative and positive values of the relative EEG spectral power (- 0.61 c.u.; 0.89 c.u. respectively).

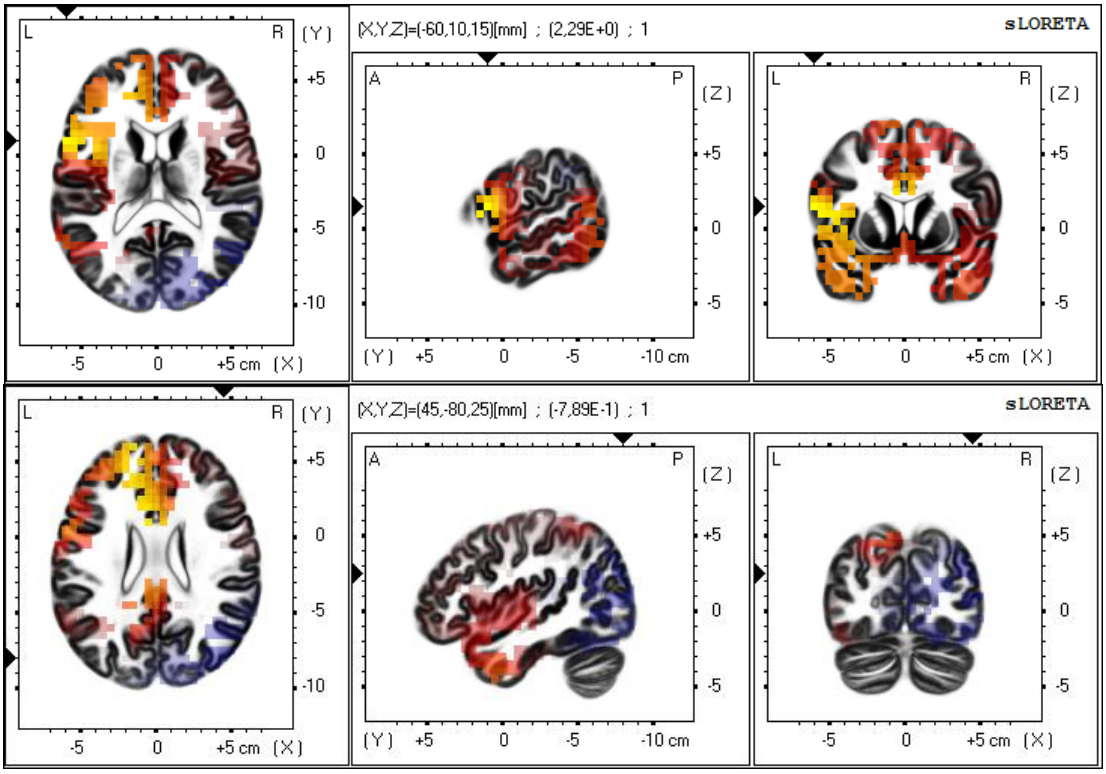

Fig.4. Spatial localization of activity sources during the choice of "Stag" option selection for 2 s after stimulation

According to LORETA analysis the reaction to “Stag” option selection activated precentral gyrus areas in egoistic-oriented subjects and superior occipital gyrus in altruistically-oriented subjects (fig.4).

The significant difference between studied groups on the egoistic "Shot" option in the second testing situation was observed in C3 site (fig.5). Negative power values (-0.25 c.u.) indicated desynchronization within 11 Hz frequency range in altruistic-oriented subjects.

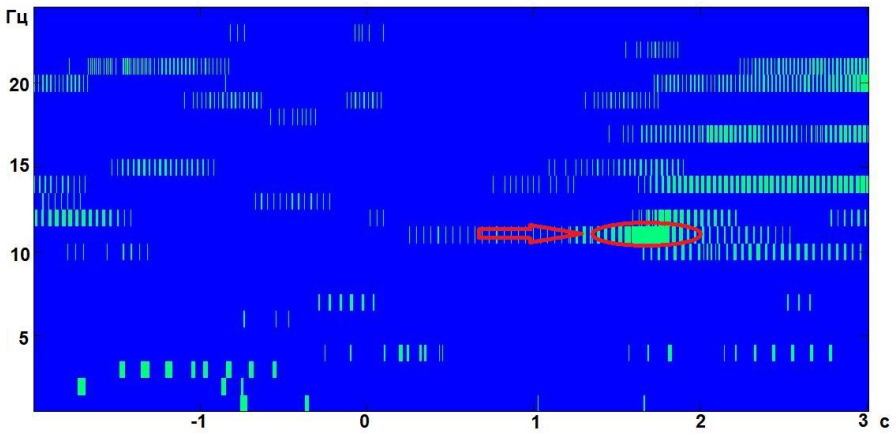

Fig.5. ERD/EDS analysis during the “Mini Basketball Game” (stimulus onset with “Shot” option chosen) in C3 site.

Areas of the cerebral cortex, which were characterized by the most significant difference between the studied groups, were identified during the analysis of EEG data for the "Shot" option selection (fig.6).

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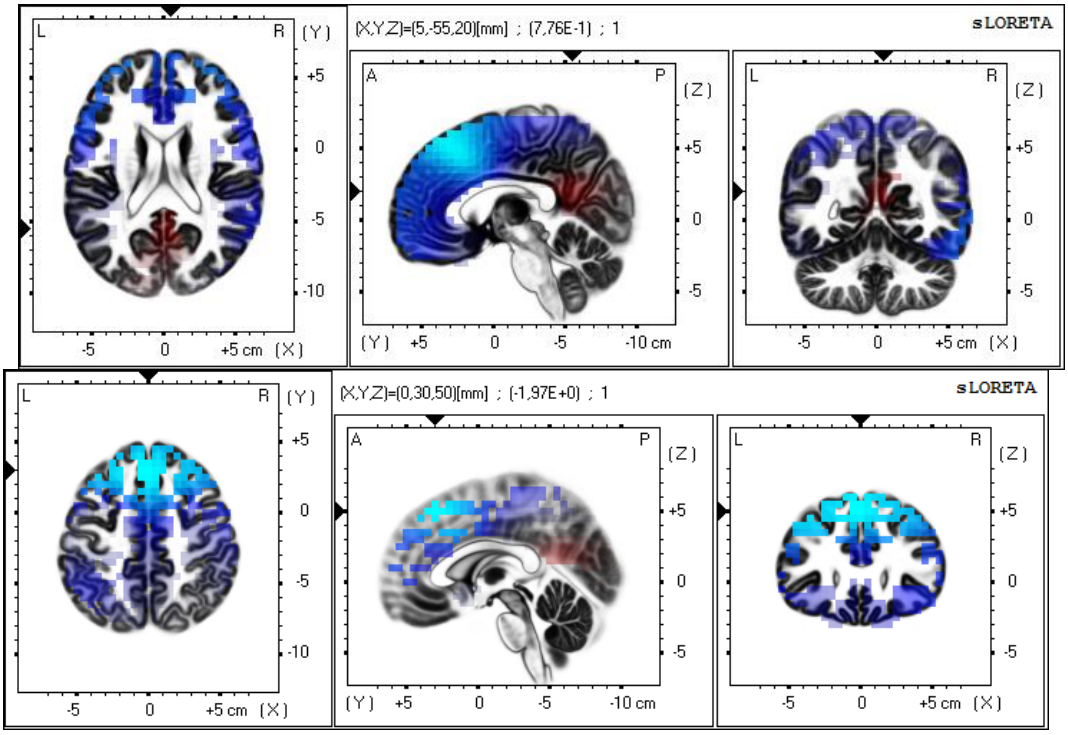

Fig.6. Spatial localization of activity sources during the choice of stimulus "Shot" 3 s after stimulation.

Activation of brain structures was specific for the posterior cingulate gyrus (Brodman area 23), which corresponds to the limbic lobe in subjects with egoistic social behavior (fig.6). The activity of altruistically-oriented subjects for the "Rabbit" option selection is stronger in the frontal areas mainly within the middle frontal gyrus according to the LORETA.

The most significant difference between the groups for the altruistic "Pass" option selection was observed in the F8 site in frontal areas of brain cortex. Synchronization process is specific for the subjects with egoistic social behavior within 17 Hz (fig.7).

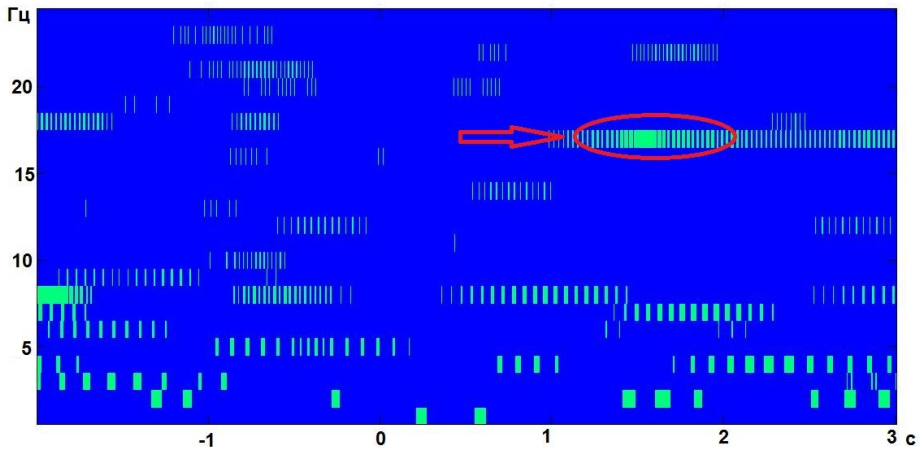

Fig.7. ERD/EDS analysis during the “Mini Basketball Game” (stimulus onset with “Pass” option chosen) in F8 site.

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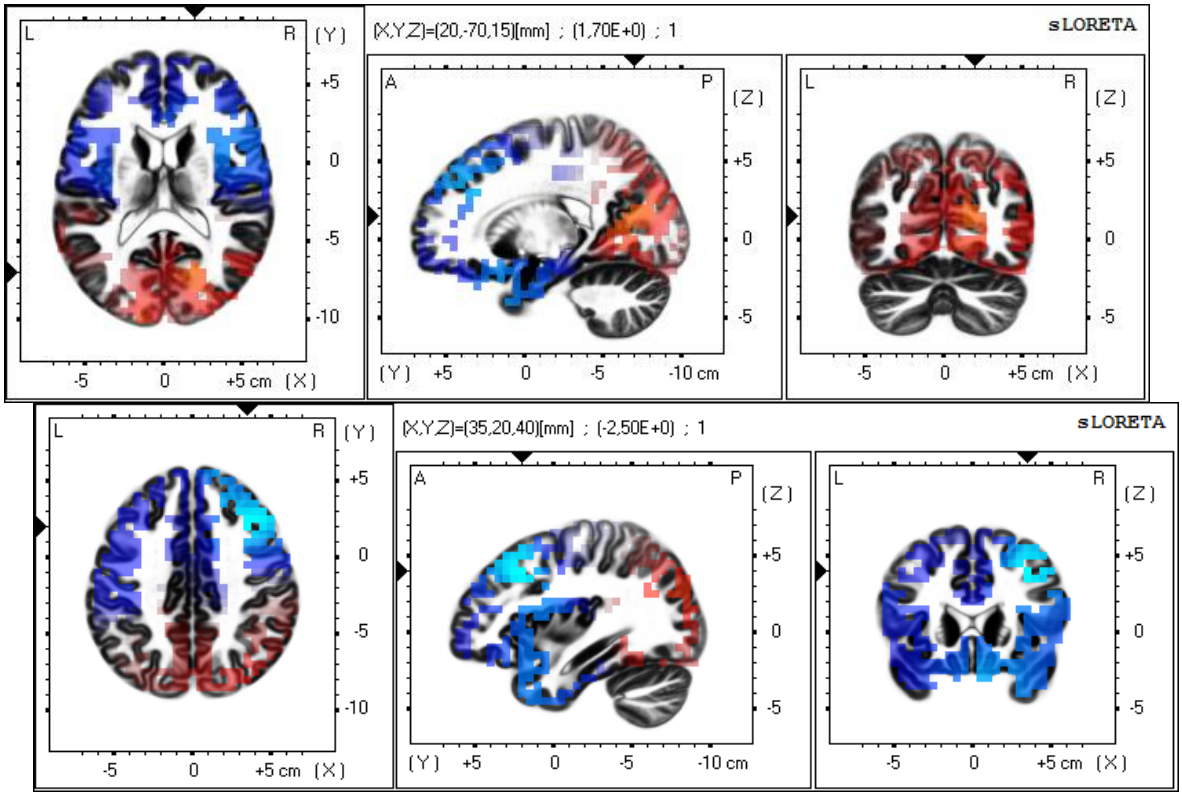

Fig.8. Spatial localization of activity sources during the choice of stimulus "Pass" for 3 s after stimulation.

According to LORETA analysis the choice of the "Pass" stimulus led to higher activation in the precuneus area in subjects with egoistic social behavior (fig.8). In altruistic-oriented subjects activation was highly specific for the precentral gyrus.

DISCUSSION

The results of this study go in line with existing neurophysiological studies related to decision-making process as interaction of two brain systems which is usually related as dual process theory [12]. We suppose, that the desynchronization of alpha rhythm in altruistic-oriented individuals contributes to a reduction in brain load showing that brain accumulates more resources to make a more optimal decision. Thus, subjects with altruistic sociotype have higher chances to engage the second system of decision-making. Selfishly directed individuals, on the contrary, are guided in the decision-making process by the first system, which requires less time, but is behaviorally less beneficial on long terms and may be considered as less rational in terms of possible gain/loose. Underlying neural process are manifested as synchronization EEG activity, mainly in beta-range.

The activation in subjects with altruistic social behavior in prefrontal cortex in our opinion is due to the fact that these areas are responsible for the gain/loss probability computation during decision-making [13]. Hence, we consider the prefrontal cortex in altruistically directed individuals to be in the principal position for the control of cognitive and social brain mechanisms because of its direct connection with limbic structures. Anterior insula lobe was also activated as the signature of risk assessment, probably related to negative subjective feeling of possible loss, as this was shown for neuroscience studies focused on Ultimatum and Dictator games as experimental conditions [14].

CONCLUSIONS

- Synchronization processes are better expressed in the individuals with selfish sociotype, and desynchronization processes are better expressed in the individuals with altruistic sociotype.

- These effects are revealed mainly in the EEG alpha and beta ranges for selection of options, which are of opposite type to the sociotype of the subjects.
- Sources of activity in altruistically directed individuals are represented by the structures of brain cortex frontal areas.
- The sources of activity in selfishly directed individuals are represented mainly by the structures of the brain cortex insula area.

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