Systemic processes in the brain: The EEG study on the emotions of different hierarchical levels and signs

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Introduction The studies on physiological mechanisms of emotions are quite popular in the modern cognitive science. These studies are mostly focused on the influence of the emotion sign on the functional state of the brain and other physiological processes. In our opinion more detailed study of the neurophysiologic mechanisms underlying emotions requires more differentiated approach to emotions which are being stimulated in the experiments. However in the present there is no universal system of the emotions classification. This obstructs studies on emotions. According to L.M. Vekker's theory of mental processes (Vekker, 1997, 2000) emotions may be divided at least into two groups according to the levels of mentality they touch – lower level, which concerns mainly vital needs and higher, which concerns, for example, ethical values. In this paradigm of the study of emotions it is helpful to implement the criterion of self-informativeness of their subjective evaluations. This makes it possible to divide emotions into different classes just in the process of the experiment. In the present work we suggest a study of different kinds of emotions and their relationship with electroencephalogram (EEG) fractal dimension. This study is designed taking in account reasons we talked about above.

Experiment Fifteen healthy volunteers – students of Saint-Petersburg State University and Saint-Petersburg State University of Culture and Arts – participated in our study. The study was conducted in accordance with ethical norms. The procedure included watching the different video clips (1 – 3 minutes each) which excite different emotions. At the same time the EEG from the subject was recorded. We took the equal number of videos which synopsis excites positive and negative emotions. Also each group of videos included two subgroups. First subgroup aimed the lower level emotions stimulation. Lower level emotions in mental processes hierarchy are tied to main vital needs. In the case of positive emotions subjects watched, for example, food (attractive looking meat or sweets); in the case of negative ones–scenes of crocodile attacking man or a person's vomiting etc. Higher level emotions according to L.M. Vekker's theory are related to socio-ethical and spiritual feelings. For example, positive emotions of this kind were stimulated by watching humorous scenes and negative–scenes of asocial behavior, theft for example.

After the raw data was acquired, we checked how properly we selected stimuli according to the theory. The criterion of self-informativeness was implemented for this purpose. Just after experiment subjects were asked to evaluate the differences between the videos according to their feelings. It was done for all possible pairs of videos. Difference was evaluated by 10-score scale. As a result we have got matrixes of distances between videos for every subject. Then these matrixes were averaged over all subjects and this gave generalized matrix. Then we applied a cluster analysis to this matrix. As a result we obtained three groups of videos. We have found in one group videos, exciting low-level positive emotions, in another–low-level negative emotions and in the third–high-level emotions, both positive and negative. Videos in the latter group were clustered into two subgroups–positive and negative–at much lower distance level in comparison with clustering of groups we mentioned above. So, in further study we dealt with tree groups of video clips. The relatively small distance between the subgroups could be explained by high complexity of high-level feelings, excited by short video clips. So complex feelings subjects did not distinguished as well as low level–vital–emotions. Thus, almost all videos got into in the same groups as we implied. Only one of the clips which we considered as a "high-level, positive" got into the group "low-level, negative". This could happen due to the same matter–ambivalence of emotions in real life, especially when we evoke very complex emotions of high level. Also, for control, subjects watched clips, which do not excite pronounced emotions.

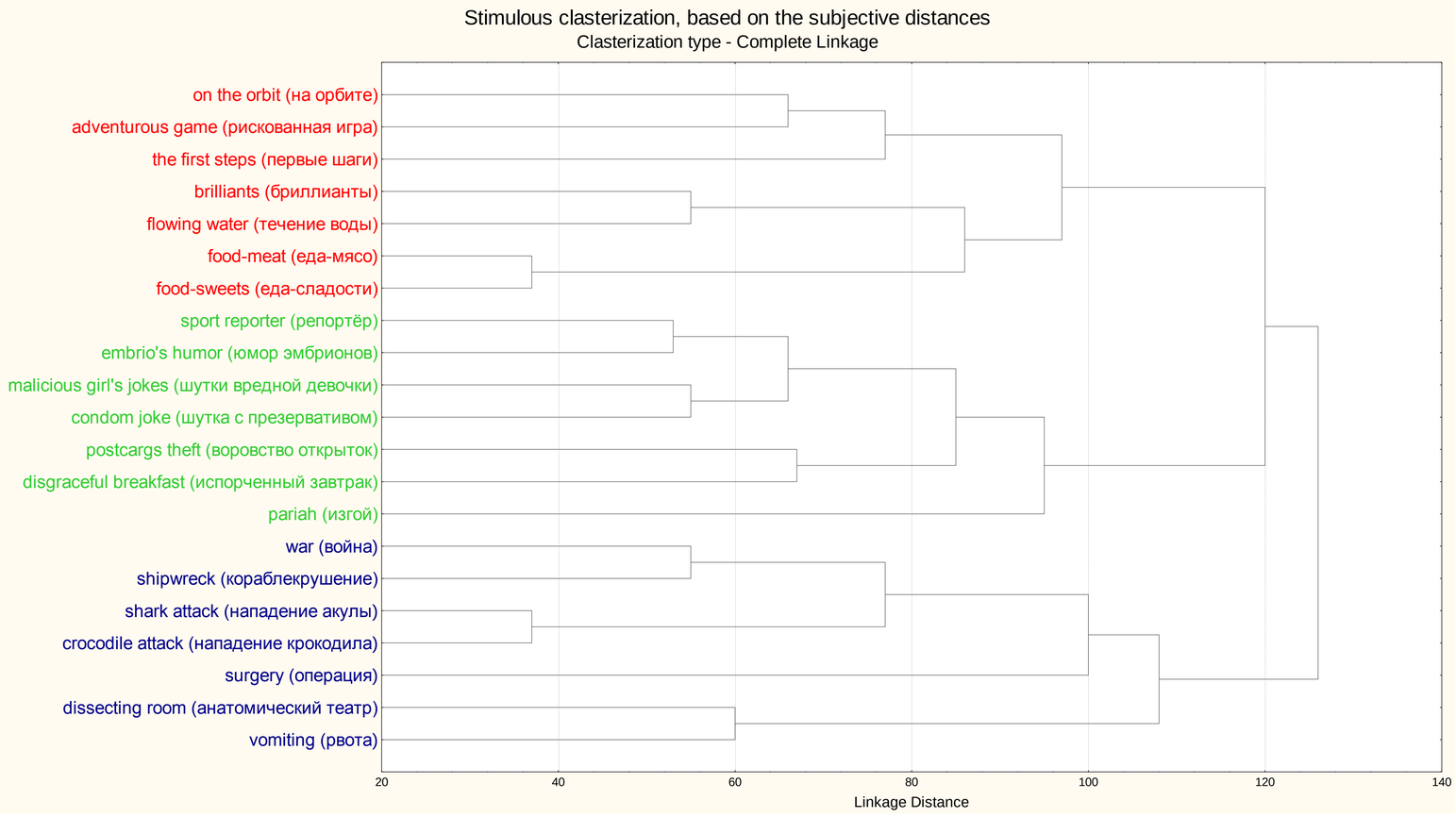
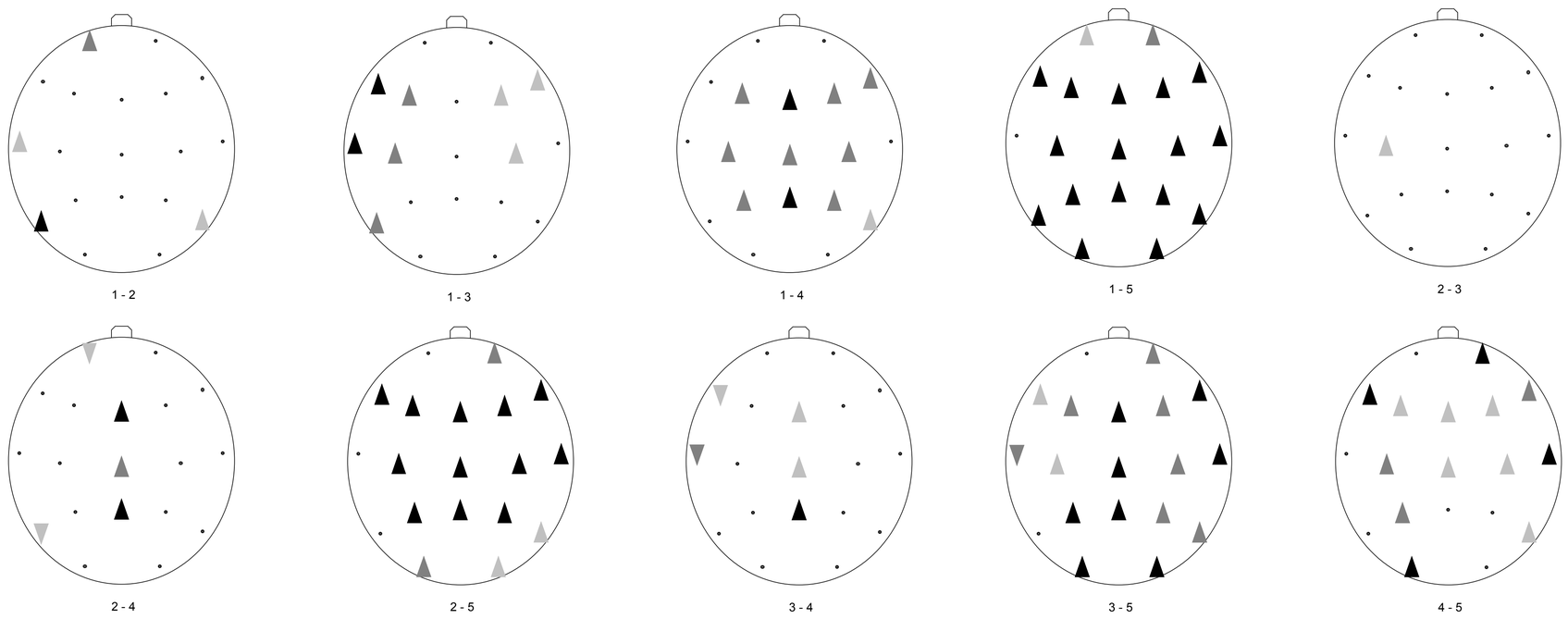


Fig. 1. Results of the stimulus clusterization according to the criterion of self-informativeness. Low level, positive – red; low level, negative – blue; high level, complex feeleings - green

EEG study. EEGs were recorded during the clips watching. Electrodes location on the scalp was according to international system 10-20. After the EEGs were recorded we have visually inspected them and deleted fragments with artifacts. Then 50 Hz notch filter was applied in order to eliminate the mains hum. After that we calculated the Fractal dimension D_0 (Higuchi's alghorhitm) of EEG curve – and averaged it over the EEGs recorded during the watching of the clips from each group. After that we applied ANOVA to evaluate the differences in the fractal data dimension of EEGs recorded in three states. ANOVA showed significant (p<0.001) changes of EEG D_0 effected by the factor of the sign of emotion. Then the post-hoc criterion (Fisher's LSD) was applied. It showed significant differences in the D_0 of EEG in different emotional states in different leads. It was found, that EEG recorded during emotive clips differs from neutral ones in anterior, parietal, posttemporal and occipital leads.



1 – Neutral stimuli
2 – simple negative
3 – simple positive
4 – complex negative
5 – complex positive

Apex up – increasing when condition changes
Apex down – decreasing
p-level gradations are reflected in the level of gray:
– 5%
– 1%
– 0.1%

Fig. 2. EEG fractal dimension (D_0) changes in different leads during watching the clips. Arrow up means D_0 increasing.

Conclusions. In general, judging these results one can suppose that stronger, but, at the same time, less complex negative emotions are accompanied by the withdrawal behavior planning function activation that is in turn accompanied by activation of actions programming structures–third functional block, according to A.R. Luria (1973). Moreover, the EEG is more complex when the test subject experiences positive emotions -- in comparison with the EEG when experiencing negative emotions. This effect is more transparent when experiencing high-level emotions in comparison with low-level emotions. In all cases, the EEG complexity was higher during the watching emotiogenic clips rather than emotionally neutral clips.

Thus, the hypothesis that the complexity of the brain processes dynamics during the emotions experiencing increases when two factors are applied: 'positiveness' of emotions and ethic component incorporated in emotion.

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