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*PSYCHOPHYSIOLOGICAL INDICATORS OF SHORT DRAMATIC TEXT PERCEPTION**

SUMMARY. The article analyzes the dynamic of brain electric activity changes during perceiving short texts based on classic stories by adults (n=148). The author used expert evaluation methods and developed a step-by-step presentation technology to select and validate the stimulus data. Spectral and non-linear analyses were applied to the EEG that had resulted from the tests. The author proves that the type of a plot affects EEG fractal dimension. The plot "adultery" and aquiprobably vague plots resulted in the highest EEG fractal dimension since such information tends to be filtered out and its perception requires functional resources to be mobilized. Perception of the plot "inequity" resulted in the lowest EEG fractal dimension which can be explained by the negative emotional message sent by such plots.

KEY WORDS. Text perception, psychosemantics, EEG

Psychology and psychophysiology have devised a number of approaches and theories to analyze consciousness as a phenomenon and perception as a process. At times they are contradictory since different researchers use different terminology and methodology. However, nowadays everyone agrees that consciousness and CNS are closely interconnected. What is important is to determine psychophysiological indicators related to perception. Our objective is to research the dynamics of EEG fractal dimension alterations while perceiving short dramatic texts.

Theory. The contemporary cognitive psychophysiology related to the phenomenon of consciousness comprises researching weak subliminal stimuli perception [1; 202-208], revealing peculiarities of emotionally significant stimuli perception [2; 796-801], studying peculiarities of functional brain asymmetry related to creativity [3; 134-161] and peculiarities of decision-making [4; 138-153], [5; 500-510]. It is generally acknowledged that brain electrical activity, recorded as EEG, reflects variable and unsteady oscillating processes which have chaotic and fractal dynamics [6; 6]. A signal is considered to be fractal if its low-scale pattern is identical to a composite one and has some recurrence that is unchangeable in the broad band, i.e. after averaging statistically independent samples of a time series

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[7; 95-99]. Currently, fractals and mathematical chaos are considered the best ways to research the dynamics of irregular natural processes which include brain spontaneous electrical activity [8; 9-10]. As a matter of fact, electroencephalogram (EEG) itself as a recording of brain electrical activity represents a fractal [9; 30-31]. The same EEG recording can have different chaotic attractors dimension depending on the brain activation degree [10; 35-42]. Traditionally, EEG is regarded a multifractal - a nonhomogeneous fractal object which has a number of dimensions (Hausdorff, informational and correlated) [11; 251]. Nowadays, EEG recordings have been more and more frequently analyzed based on the dynamic chaos theory. It is believed that a fractal analysis of the system indicators fluctuations enables to rate its stability quantitatively [12; 131]. Brain studies of people suffering from anxiety and phobic disorders prove that EEG power spectra don't always reflect changes in the brain functional condition, whereas alterations in multifractal parameters are more reliable [13; 30-36]. Generally, a fractal EEG analysis reveals and rate the correlated dimension of a restored attractor. Such dimension reflects the system complexity of a process under consideration. The more complicated a system is and the more equations are required, the higher correlated dimension is and the closer the process is to white noise. Thus, the dimension can be used to measure the stochasticity of the process [14; 124-125]. Consequently, EEG fractal dimensions, in a way, can be considered as indicators of brain informational activity.

Methodology. To select the story lines and texts for the experiment, the author carried out two surveys. First of all, a group of people were asked to evaluate 36 dramatic plots [15; 51-53]. The subjects of the survey were to grade each plot (from 1 to 10 points) based on how relevant it was personally to them. They were to assign 10 points to the plots that were most frequent in their lives and 1 point to the least probable ones. After the factor analysis of the results, 5 out of 36 initial story lines turned out to have relevance, namely: (1) adultery; (2) intellectual achievements; (3) gross injustice; (4) self-sacrifice; (5) threat to one's family. Since the first three dramatic plots have more factor loading and are considered the basic ones, they were included in the experiment; the other two are supplementary.

The next stage comprised selecting short stories based on the three basic plots. We had chosen Aesop's Fables and Greek mythology since, in our opinion, these stories corresponded best of all to verbal stimulus criteria of the experiment. The subjects of the experiment were asked to read 21 fables and myths, and to match each story line to one of the five plots. After analyzing the results, only seven stories were singled out: six of them evoked a similar response (the results coincided 100% for two stories, then, correspondingly, 97.5%, 90%, 82.5% and 77.5%). The seventh text, characterized by an equiprobably vague plot, was included to reveal the dominant orientation of the subjects. The step-by-step method was used to "grasp" the instant of perception. The method had been validated by recognizing relations between the basic parameters of "lexical solution" [1; 227-229] and the speed of plot type perception in the experiment.

The final psychophysiological experiment included 148 people (aged 18-30, 103 female, 45 male). The sequence of the tasks was similar for all the subjects. Electrodes were placed according to the international 10-20 system (with 19 recording electrodes). After initial EEG recordings were made, the subjects of the experiment have to read the 7 texts (8 times each one). Then standard one-minute recordings (with open and closed eyes) were made again.

Data Interpretation. The author used the standard EEG rhythmic activity frequency bands (delta, theta, alpha, beta-1, beta-2, gamma). Then, the EEG signal fractal dimension was calculated by finding the power spectrum natural logarithm in the bands from 2 to 34 Hz with the 2-Hz interval. After taking the logarithm of power and frequencies, the regression coefficient was found which reflected the linear relation of spectrum power logarithms to frequency logarithms according to the formula:

$$LnP = -\beta * Lnf + a \qquad (1)$$

where *LnP* is an EEG power logarithm, *Lnf* is a frequency logarithm,

ß is a regression coefficient (a slope ratio)

a is an absolute term of equation.

The slope ratio of the linear function is inversely proportional to the signal frequency dimension, since it reflects the spectral density decline rate during increasing rythmics frequency [9; 48-51].

The ß coefficient is linearly related to the fractal dimension according to the formula:

$$D_f = \frac{5-\beta}{2} \qquad (2)$$

where *D* is a dimension, β is a regression line slope.

Subsequently, the EEG fractal dimensions, that we got after placing 19 recording electrodes (leads) and applying formula 2, were factored by the principal components method. To decrease the data dimensions, we chose the factor analysis, and the principal components (PC) method replaced traditional factor analysis methods due to a number of strong correlations between the original data. In order to compare the PC of different conditions, we analyzed the repeated lead changes (which made 19x3=57 variables) of 148 subjects of the experiment. Thus, we analyzed 19 variables and performed 148x3 observations. The experiment resulted in two factors that explained a 74.47% total dispersion. The 38.30% total dispersion reflects the occipital fractal dimension due to the predominant functioning of the right hemisphere (leads O1, O2, P3, P4, T6, C4). The other 36.16% of the total dispersion includes the frontal leads with the predominant functioning of the left hemisphere (leads Fp1, Fp2, F3, Fz, F4, F7, F8). Later, the factors were interpreted (applying the regression method) for the 444 observations which resulted in 2 variables – the calculated factors labeled correspondingly F1 and F2. Then, the two factors were reconstructed as repeated changes for three conditions and represented as 2x3=6 variables for N=148 observations. These data were analyzed applying the two-factor dispersive analysis with the repeated changes.

Research Results. Table 1 represents the result of the dispersive analysis reflecting the influence of a perceived plot on the fractal EEG dimension which amounts to the sum of Fp1, Fp2, F3, Fz, F4, F7, F8 leads EEG fractal dimension.

The influence of plot perception on the fractal EEG dimension
The effect: $F(6.672)=1.7830$, $p=.09997$

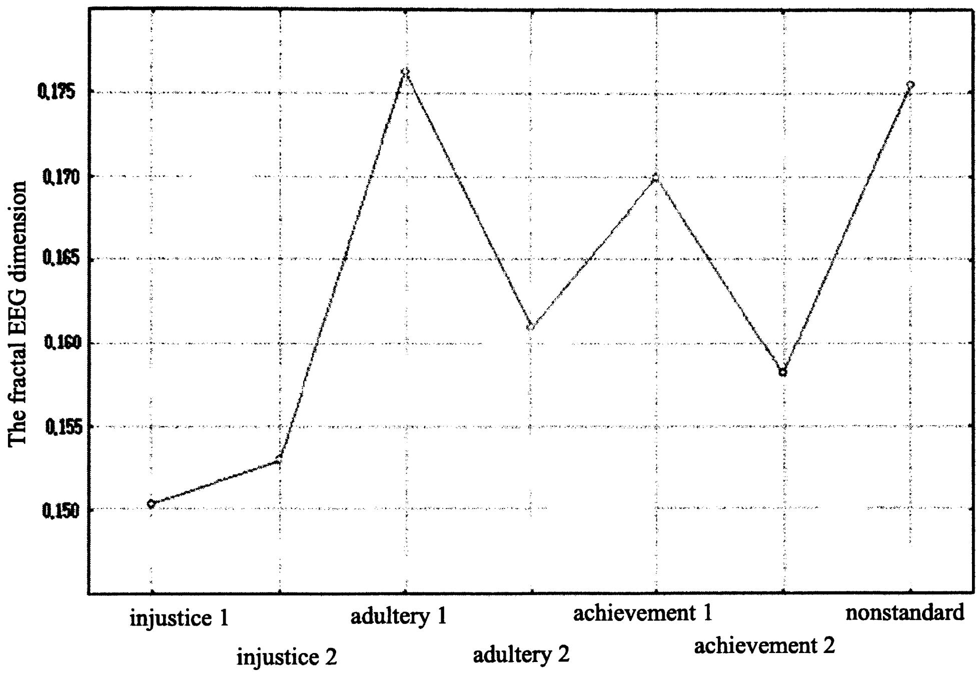

Table 1. The result of the dispersive analysis reflecting the influence of a perceived plot on the fractal EEG dimension

The ordinate axis represents fractal EEG dimensions, whereas the abscissa axis represents the seven texts used in the experiment (indices 1 and 2 refer to texts based on the same story line). Text 7, referred to as "nonstandard", had no definite story line. Table 2 demonstrates that this text perception resulted in significant EEG fractal dimension increasing.

Table 2 displays the dispersive analysis results, taking into account the summarized differences based on the three basic story lines depending on the EEG fractal dimension change (Fp1, Fp2, F3, Fz, F4, F7, F8 leads).

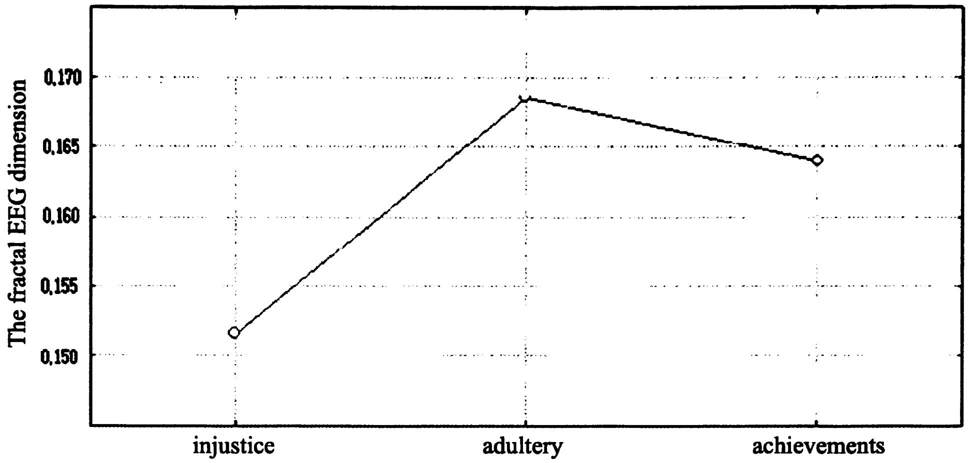

Table 2. The dispersive analysis results, taking into account the summarized differences based on the three basic story lines depending on the EEG fractal dimension change

The table testifies to the fact that the most significant increase in EEG fractal dimension occurs while perceiving the second type of the plots, namely, adultery and its consequences.

Results and Their Discussion. As it has been already mentioned, a degree of EEG fractal dimension can be used to rate the informational complexity of brain functioning at a given moment. Perception of a vague plot and the plot "adultery" brought about the highest EEG fractal dimension. The first case has most likely to do with an option of equal decisions a subject has to choose one from. The second case differs since such a story line inherently is difficult to be perceived by one's consciousness as being at crossing of psychological standards and prohibitions, which, moreover, go hand in hand with psychological defense. That is why to perceive such a story line, the subject triggers more reserves than to perceive others.

It is already proved that a perception threshold and a consciousness threshold differ, as well as the first one is an indispensable element of any information processing. A typical experiment includes the consciousness identification of different layers – as neutral, as well as emotional [2; 799]. The tests have proved negative influence on the current consciousness by stimuli causing unintentional conflicts [16; 341-357]. Subliminal stimuli tend to make words and other objects perceived quicker [17; 204-212]. In other words, any information perceived earlier can affect the latter perception. It was experimentally proved (i.e. "Lexical Solution" method [1; 228]) that subliminal stimuli have caused a stronger reaction than a situation that was somehow expected [18; 151-161].

Therefore, a human's brain tends to get the most information load and, consequently, spends the most amount of energy when the subjects perceive "conflict" story lines somewhat in opposition to conventional principles, or a plot is vague.

It was the topic of intellectual achievements that caused the next high EEG dimension. Most likely it has to do with analyses of one's endeavor when it was crucial to break the limits and demonstrate flexibility while tackling a task. We are later planning to verify these assumptions by a cognitive experiment taking into account the cognitive parameter. The creativity model [19; 137-141] asserts that it is the left hemisphere that plays the key role in our decision-making. On the contrary, case-studies of functional hemisphere asymmetry mostly demonstrate the decision-making of the right hemisphere. This particularity of the right hemisphere has been proven by the researchers applied different methods [3;142-148], [4; 138-153], [5; 500-510]. Most likely, the contradiction has to do, first of all, with the nature of an issue (verbal or image-bearing), as well as the stage of the solution the issue is focused on. It is the right hemisphere that is dominant while looking for a decision, since it calls up distant associations and unexpected links, as well as metaphoric and humorous viewpoint [20; 1549-1561]. Therefore, probably, if all subjects of our experiment had been divided according to their cognitive style, "impulsive synthetics" would have digested such story line relatively easily and, consequently, it wouldn't have resulted in a higher EEG fractal dimension, since they are mostly characterized by a high right hemisphere activity which brings distant association easily. Whereas, "reflective analysts" are prone to a slower perception of such plots resulting in a higher EEG dimension.

The issue of injustice has to do with negative emotions generally resulting in a lower EEG fractal dimension [21;328-329] which explains the lowest fractal EEG dimension of the experiment. It was predominantly the right hemisphere which unconsciously influenced the subjects by extramental verbal stimuli [22; 633-651].

Undoubtedly, the stories used in the experiment need to be mentioned. It is worth noting that five out of four plots corresponding to the basic story lines are written by Jorge Luis Borges [23; 3].

Conclusions. The information complexity of our brain changes perceiving classical dramatic stories. An EEG fractal dimension fluctuates depending on the plot. The highest informational complexity in the brain was registered while it was perceiving uncertain plots contradicting conventional standards. The lowest brain activity was register while perceiving plots with negative emotions.

REFERENCES

1. Marcel, A.J. Conscious and unconscious perception: Experiments on visual masking and word recognition. *Cognitive Psychology*. 1983. Vol. 15. Pp. 197-237.

2. Lewicki, P., Hill, T., Czyzewska, M. Nonconscious acquisition of information. *American Psychologist*. 1992. Vol. 47. № 6. Pp. 796-801.

3. Razumnikova, O.M. Information selection peculiarities in the process of creative thinking. *Zhurnal Vysshej shkoly jekonomiki — Graduate School of Economics Journal*. 2009. Vol. 6. № 3. Pp. 134-161. (in Russian).

4. O'Boyle, M.W., Alexander, I.W., Benbow, C.P. Enhanced right hemisphere activation in the mathematically precocious A preliminary EEG investigation. *Brain. Cogn.* 1991. Vol. 17. № 2. Pp. 138-153.

5. Jung-Beeman, M., Bowden, E.M., Habei-manj, Frymime, J.L., Arambel-Liu, S., Gieenblatt, R., Reber, P.J., Konnios, J. Neural activity when people solve verbal problems with insight. *PLoS Biology*. 2004. Vol. 2. Pp. 500-510.

6. Nurujjaman, M., Narayanan, R., Sekar Iyengar, A.N. Comparative study of nonlinear properties of EEG signals of normal persons and epileptic patients. *Nonlinear Biomedical Physics*. 2009. Vol. 3. P. 6.

7. Mandelbrot, B.B. The Fractal Geometry ofNature / Ed. W.H. Freeman. San Francisco, 1983. Pp. 95-99.

8. Kronover, R.M. *Fraktaly i haos v dinamicheskih sistemah. Osnovy teorii* [Fractals and chaos in dynamic systems. Basics]. Moscow, 2000. Pp. 9-10. (in Russian).

9. Vasserman, E.L., Kartashev, N.K., Polonnikov, R.I. *Fraktal'naja dinamika jelektricheskoj aktivnosti mozga* [Electric brain activity fractal dynamics]. St.-Petersburg: Nauka, 2004. Pp. 30-31, 48-51. (in Russian).

10. Pritchard, W.S., Duke, D.W. Measuring chaos in the brain: a tutorial review of nonlinear dynamical EEG analysis. *Neurosci.* 1992. Vol. 67. № 1-4. Pp. 35-42.

11. Shreder, M. *Fraktaly, haos, stepennye zakony. Miniatjury iz beskonechnogo raja* [Fractals, chaos, degree laws. Miniatures from infinite paradise]. Izhevsk, 2001. P. 251. (in Russian).

12. Slezin, V., Korsakova, E., Dytjatkovsky, M. Multifractal analysis in the diagnostics of mental disorders. *Abstracts from the 28th Nordic Congress of Psychiatry «New tools for clinical practice». Tampere–Tammerfors. Finland. 16–19 August 2006.* Pp. 131-134.

13. Dik, O.E., Svjatogor, I.A., Ishinova, V.A., Nozdrachev, A.D. Fractal characteristics of functional brain condition of patients suffering from anxiety and phobic disorders. *Fiziologija cheloveka — Human Physiology*. 2012. Vol. 28. № 3. Pp. 30-36. (in Russian).

14. Mekler, A.A., Bolotova, E.V. Age-related changes of non-linear dynamic EEG characteristics [Vozrastnye izmenenija nelinejnyh dinamicheskih harakteristik EEG]. *Psihologija XXI veka: m-ly Mezhdunar. konf.* (XXI Century Psychology: Materials of the International Conf.). St.-Petersburg, 2005. Pp. 124-125. (in Russian).

15. Lunacharskij, A.V. *Iskusstvo i revoljucija: Sbornik statej* [Art and revolution: Collection of Articles]. Moscow, 1924. Pp. 51-53. (in Russian).

16. Silverman, L.H., Ross, D.L., Adler J.M., Lustig, D.A. Simple research paradigm for demonstrating subliminal psychodynamic activation: Effects of oedipal stimuli on dart throwing accuracy in college males. *Abnormal Psychology*. 1978. Vol. 87. Pp. 341-357.

17. Nasledov, A.D., Filippova, M.G. Dual images: invisible or visible but not perceived? *Fundamental'nye problemy psihologii — Funfamental Problems of Psychology*. St.-Petersburg, 2003. Pp. 204-212. (in Russian).

18. MacLeod, C., Hagan, R. Anxiety and the selective processing of emotional information. *Behavior Research and Therapy*. 1992. Vol. 30. Pp. 151-161.

19. Finke, R.A., Ward, T.B., Smith, S.M. Creative cognition: theory, research, and application. Cambridge: MIT Press. 1992. Pp. 137-141.

20. Grossman, M., Smith, E.E., Koenig, P., DeVita, L., Moore, P., McMillan, C. The neural basis for categorization m semantic memory. *Neurolmage*. 2002. Vol. 17. Pp. 1549-1561.

21. Gorbunov, I.A., Mekler, A.A. Physiological mechanisms of emotions evaluated at different levels of subjective reflection, and new foundations for their classification [Izuchenie fiziologicheskih mehanizmov jemocij, ocenivaemyh na raznyh urovnjah sub„ektivnogo otrazhenija i novye osnovanija dlja ih klassifikacii]. *Zona blizhajshego razvitija v teoreticheskoj i prakticheskoj psihologii: M-ly XXI Mezhdunarodnyh chtenij pamjati L.S. Vygotskogo* (Newest Research in Theoretical and Practical Psychology: Materials of XXI International Conf. in Memory of L.S. Vygotsky. Moscow. 2010. № 15–18). / Ed. by Kudrjavcev V.T. Moscow, 2010. Pp. 328-329. (in Russian).

22. Velmans, M. The Limits of Neurophysiological Models of Consciousness. *Behavioral and Brain Sciences*. 1995. Vol. 18. № 4. Pp. 702-703.

23. Borhes, H. *Chetyre cikla* [The four cycles]. St.-Petersburg, 1992. P. 3. (in Russian).