EEG indicators of emotional reactions

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Abstract. Nowadays nobody doubts that emotions govern all the fields of our activities. It can cause poor or good adaptation to the problem situation. But up to now we don't have any clear objective parameters to diagnose the emotional process, its degree (strong or week) and meaning (positive or negative). In such a situation nobody can build a convincing experiment concerning emotional states. In the present research it was shown that the dynamics of EEG-spectrum reflects the subjective emotional differences of stimulation. Intensity of spectrum in 6-8Hz diapason varies according to the pole of emotional reactions and depression of alpha rhythm varies according to intensity of emotions. It can constitute the base for a principal new method of objective diagnostics of emotional responses which can be used by doctors, future researches and publicity professionals.

Introduction

If we look trough our lives we can find ourselves every time and everywhere in different affective states. They accompany all our experiences assisting main cognitive function such as perception, memory and thought. They can also affect physical state of health and generally all the human activity.

According to the opinion of many scientists [8], [10], [11], ignorance of this research field is the main obstacle on the way to the integrative view of human-beings. Such a blind wastefulness was a reality since the first science program of Descartes. The division between emotion and mind and resourcefulness of affective problems were the major facts who affected all the researches in this field during at least three centuries.

Today situation is changing with the help of new data. More and more investigations on the interaction between affects and mind take place. According to them the influence of emotion extends to all aspects of cognition and behavior [4]. New concepts, e.g. "emotional intelligence", enlarge scientific view on the topic. We can see new journals (Cognition and emotion), handbooks, new notions (Affective mind, Affective neuroscience) devoted to affective system in its correlation to cognitive processes.

All these facts can be a signification of interest growth to the affective science. This interest has not only scientific and cognitive causes but it is also governed by social needs. On the one hand the concept of health (psychological and physiological) as the fundamental factor of well-being and self-efficiency is being developed. Today scientists are interested in the emotional influence on the clinical course of cancer, cardio-vascular, respirator and infectious diseases etc. [4]. On the other hand golden age of informatics, robotics and informational technologies makes popular

investigations in speech [14] and facial expression recognition of emotion [15].The other claimed area is developing of programs and computer models for calculation and recognition of emotion in auditory, visual or even olfactory messages.
The important place is occupied researches concerning role of emotion in the cognitive processes including attention, memory, psychological defense, attitudes and beliefs, decision-making etc. [4].
But in spite of affective neuroscience bloom till the moment we don't have effective means to clarify which kind of emotional reaction is developing in our subjects: if it is keen or feeble, hostile or hospitable. In such a situation nobody can build a convincing experiment concerning emotional states. In Psychology Science there were several traditional ways and methods of studying emotion. They were: continuous self-report, fixation of expressional movements, changes in the activity efficiency. In affective psychophysiology changes in skin resistance (e.g. galvanic skin reflex), electrocardiogram and activities of vessels were usually used. All of these parameters reflect vegetative reactions to emotional situation. Last years electroencephalogram becomes more popular because it gives us opportunity to touch the central nervous mechanisms of emotion. For this purpose MR-imaging (fMRI) and positron scan (PET) is also used. Unfortunately these two methods are powerless when higher that 1-2 seconds temporal resolution is required [4].
As it was matched by many authors ([10], [11], [8], [12]) emotion is a complex phenomenon and can be investigated only with a combination of psychological, physiological, linguistic and medical methods. Present work is just a singular attempt of such a complex approach to the vast and important field of affective neuroscience.

Investigation

According to the modern research results vegetative parameters can be effective signs of affective state and emotional tension presence. But they can not show as the quality and the intensity of emotional experience. That's why it was important to appeal to EEG. It can provide us by indexes of emotional processing. So, the object of present study is emotion manifestation in EEG. The main goal is allocation and investigation of EEG-indexes as the result of emotional reaction to visual stimuli of different emotional content. The following hypothesis is provided: subjective emotional differences in perception of stimuli should be reflected in electrical brain activity, namely spectral EEG characteristics.
14 right-handed people in age between 17 and 21 years old (8 males and 6 female) took part in the present research during 2001-2003 years.
It was used 16 slide-pictures to stimulate different emotions: 1. nature (3 slides for neutral emotions), 2. sensuality (3 slides for strong positive emotions), 3. skin disorders (3 slides for weak negative emotions), 4. snakes and insects (3 slides for strong negative emotions), 5. meal (3 for weak positive emotions); 6. grey screen (background for comparison). On account of stimulation specificity there were two sets of pictures different for male and female subjects.
Newness of the approach was made by combination of psychophysical and psychophysiological methods. Every subject went through psychological and psychophysiological series. In each series the same stimuli were used.

Psychological series were made by traditional methods of psychophysics. They are direct estimation and comparison of pairs. In the direct estimation task subjects were to estimate stimuli in the scale from “1” to “5”: “1” denoted strong negative impression, “0” – neutral reaction, “5” – strong positive impression. Average estimates were calculated both for the different stimuli and their entire groups. The results are presented in Table 1.

Table 1. Average direct estimation of stimuli in female sample. Name of separate stimuli: “er” – sensuality, “rani” – skin disorders, “gad” – snakes and insects, “eda” – meal, “nat” – nature, “grey” – neutral.

Stimulus		average estimate	average value in groups of stimulus	Dispertion
“neutral”	grey	3,17	3,17	0,17
	er1	3,67	3,94	0,27
	er2	4,00		0,80
"sensuality"	er3	4,17		0,57
	rani1	1,17	1,28	0,17
	rani2	1,17		0,17
"skin disorders"	rani3	1,50		0,30
	gad1	2,67	2,67	1,47
	gad2	2,17		0,57
"snakes and insects"	gad3	3,17		2,17
	eda1	4,33	4,22	0,67
	eda2	4,33		0,67
"meal"	eda3	4,00		0,80
	nat1	3,67	4,33	0,67
	nat2	4,50		0,70
"nature"	nat3	4,83		0,17

In the task of comparison subjects valued difference in emotional impression of two pictures in the scale from “0” (there is no difference) to “9” (two pictures are quite different). These data were processed with the method of multidimensional mathematical scaling using SPSS 9.0. On the output subjective spaces for our stimuli for each subject and for our two samples (males and females) were composed. The results of direct estimation were used as the support for data interpretation. It allowed to single out 2 main characteristics in differentiation of emotional impression: strength and evaluation (Fig. 1). It was the main result of psychophysical series. During comparison it were found out that spaces in different subjects and samples resemble each other.

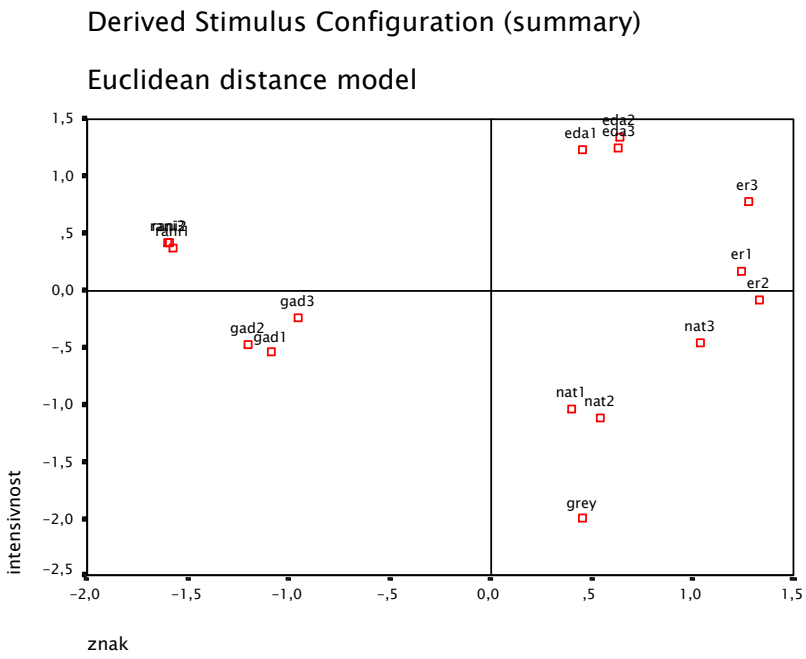

Fig.1. Mean female-sample subjective space of stimuli. Squares corresponds with following stimuli: er – sensuality, rani – skin disorders, gad – snakes and insects, eda – meal, nat – nature, grey – neutral. Euclidian distance model is used. Two significant characteristics are isolated: strength (intensivnost axis) and evaluation (znak axis).

During our psychophysiological series subjects were presented with 21 slides of different emotional content in such a consequence: neutral (30 sec) - 3 positive (10 sec for each one) – neutral – 3 negative – neutral – 3 nature – neutral – 3 negative – neutral – 3 positive – neutral. At the time of stimulation 21-channel of EEG were recorded. The international electrode system 10-20 was used. Next spectrum of the following electrodes was analyzed: F7-AA, F3-AA, F4-AA, F8-AA, P3-AA, P4-AA, O1-AA, O2-AA.

EKG and skin-galvanic reaction were also registered. It was used for on-line monitoring of emotional reaction in response to visual stimulation.

For registration and initial computing EEGDigitalSystem program was used. Then ten-seconds EEG-pieces were computed in BrainLoc program with fast-Fourier transform algorithm in band of 3-30 Hz with the gap of 0,1 Hz. Next the spectrum was exported and analyzed in MS Excel. For further analyses spectral capacity were summarized in the band of 6-8 Hz (theta), 8-12 Hz (alpha), 18-20 Hz (beta).

The received results don't allow further application of statistical computation. That's why the main part were played by visual comparison of spectral capacity. According to existing data F7-AA, F3-AA, F4-AA, F8-AA (lobe) and P3-AA, P4-AA, O1-AA,

O2-AA (parietooccipital) channel were chosen as significant in emotional processes. Since the difference between these groups of electrodes were not significant further analyses was hold on average of four channel groups: left forehead (F7, F3), right forehead (F4, F8), left occiput (P3, O1), right occiput (P4, O2).

Emotional reaction manifestation in the frontal electrodes

There is difference between theta-rhythm response to the neutral and the emotional stimuli in the frontal electrodes. *Theta capacity* is higher in the positive emotional reactions. In the right hemisphere this trend is stronger. Theta is suppressed with stimulation witch was shown as strong negative in psychological series. In the respond to the strong positive stimuli its aggravation is registered. This trend is stronger in female subjects. But we can see it also clearly in male subject K. (Fig.2).

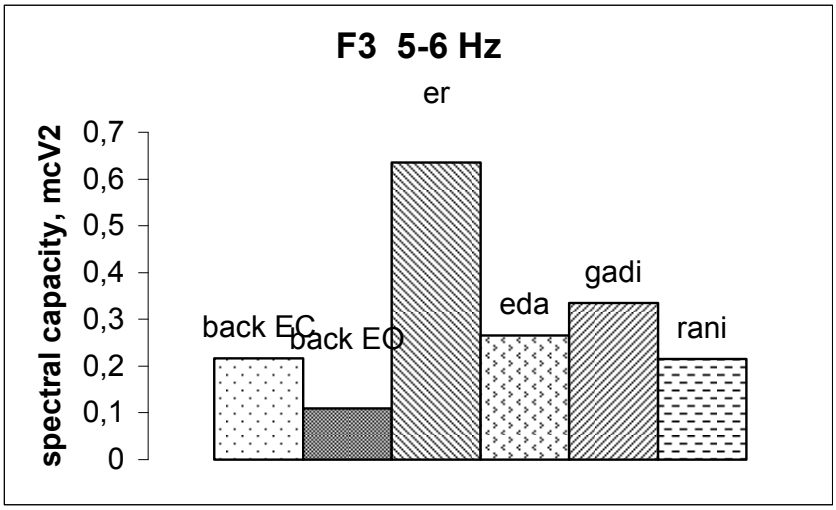

Fig. 2. Subject K. (male, 20 years). Theta-rhythm in the left frontal electrode. "er" – sensuality, "rani" – skin disorders, "gad" – snakes and insects, "eda" – meal, "nat" – nature, "back EC" – background EEG with closed eyes, "back EO" – background EEG with opened eyes.

Alpha capacity in the frontal electrodes doesn't very so clear in emotional and non-emotional situations. But both in the right and the left it's more suppressed by positive emotional stimuli. In other words in the frontal lobe alpha-rhythm responds to the positive emotion stronger.

Beta-rhythm in the frontal electrodes in the left hemisphere is the most powerful during "sensual" stimulation. Other stimuli lead uniform suppression in the comparison with background activity. In the right the most powerful beta-rhythm is

caused by “skin diseases” and “sensuality”. Correlation with subjective intensity of emotion is shown.
Thus the most sensible to emotional differences in the frontal channels band is theta-rhythm. Alpha-rhythm is sensible to a lesser degree. Beta-rhythm is more differentiated in the area of weak emotional responses.

Emotional reaction manifestation in the parietooccipital electrodes

In the parietooccipital electrodes the situation differs.
Theta-rhythm is suppressed by emotional stimulation. It is seen more clear in the right hemisphere. There is some dependence between subjective intensity of emotional reaction and theta-pattern. In the male sample there is reinforcement of theta activity during “sensuality” stimulation in the right. In the left there is correlation between theta-depression and subjective intensity (Fig.3).

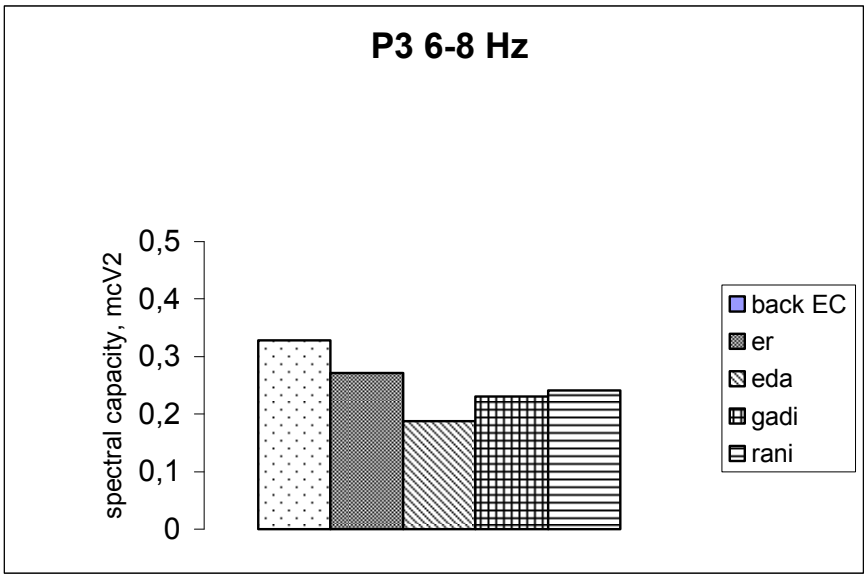

Fig. 3. Average in male sample. Theta-rhythm in the left parietal electrode. “er” – sensuality, “rani” – skin disorders, “gad” – snakes and insects, “eda” – meal, “nat” – nature, “back EC” – background EEG with closed eyes.

Alpha-rhythm in the parietooccipital electrodes is less depressed during negative emotional response. In the right it’s more suppressed.
Thus theta- and alpha-dynamics in the parietooccipital electrodes shows brightly response asymmetry: the right hemisphere reacts vastly.
Beta-rhythm in the occipital electrodes resembles in its pattern to the frontal one.

Discussion

In the present research all the stimuli were identical for all the subjects. Its choice were not based on any personal meaningful experience. It allow us to claim that differences in subjective estimate of emotional reaction reflects differences in strength of emotional arousal. This statement was checked in the psychophysical experiment. It was shown in it that subjects differentiate 4 groups of emotional reactions corresponding to the themes of slides.

In psychophysiological experiment it was found out that subjective intensity of emotional reaction could be reflected in the specific EEG spectrum bands. Responds to "meal" and "skin disorder" surpass "sensuality" and "snakes and insects". It correlates with the subjective data in the mathematical spaces of stimulation.

During perception of positive slides in the frontal electrodes capacity of 6-8Hz frequency increases. Negative slides led to increasing of 8-15 Hz activity. It conforms to the data of Ahern G.L., Shwartz G.E.[1] and Collet L., Duclaux R.[7].

In the present study the most depression of alpha-rhythm was shown in the right hemisphere. So, asymmetry in brain response can be used as additional indicator of emotion meaning.

In the whole there is connection between subjective differences in estimation of emotional impression and changes in electrical activity of the brain. These changes are very complicated and in every frequency band there are some indicators of emotional response.

Resume

As a result we found out that:

1. The dynamics of EEG-spectrum reflect the subjective differences of stimulation;
2. Intensity of spectrum in 6-8Hz diapason varies according to the pole of emotional reactions;
3. Depression of alpha rhythm varies according to intensity of emotions

These data can constitute the base for a principal new method of objective diagnostics of emotional responses which can be used by doctors, future researches and publicity professionals. But the only thing which detaches us from the creation of our method is lack of data.

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