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Analysis of Evoked EEG Synchronization and Desynchronization in Conditions of Emotional Activation in Humans: Temporal and Topographic Characteristics

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Studies in 20 healthy right-handed subjects analyzed evoked EEG synchronization and desynchronization in the δ, θ_1, θ_2, α_1, α_2, β_1, β_2, β_3, and γ ranges in response to sequential presentation of stimuli from the International Affective Picture System (IAPS) with low, medium, and high emotional activation impact. Each signal presentation was accompanied by subjective scaling of the extent of its emotional impact. EEG traces were recorded in 62 channels as signals were presented. These experiments showed that the degree of emotional impact of the signal was significantly associated with increases in evoked synchronization in the δ, θ_1, θ_2, β_1, β_3, and γ ranges and with the effects of combined changes in evoked synchronization and desynchronization in the α_2 frequency range. The interhemisphere distribution of evoked changes in power provided evidence that not only the posterior areas of the right hemisphere were involved in analyzing the emotional significance of images, as indicated by changes in evoked θ_1 and θ_2 synchronization and α_2 desynchronization, but also the anterior areas of the left hemisphere, as indicated by changes in evoked θ_2 synchronization. From the standpoint of affective chronometry, the earliest discrimination of the emotional content of stimuli, regardless of the sign of the emotion, occurred in the lower θ range and was seen at 0–600 msec after the start of stimulus presentation. This process was delayed to 600–1000 msec in the θ_2, α_2, and γ ranges.

KEY WORDS: EEG, emotion, evoked synchronization and desynchronization, emotional activation.

The cognitive approach to studies of the emotional sphere in humans has developed the so-called *dimensionality* or *component* theory of emotions, based on results obtained by factor analysis of verbal assessments of emotional experiences (For example, [37, 40]). According to this theory, the nature of *emotional experience* is determined by two main dimensions – *valence*/*sign* (positive/negative, pleasant/unpleasant) and *activation* (calm/excited). Emotions of different signs can be accompanied by either high (joy, fear) or low (satisfaction, melancholy) activation. Current psychophysiological studies of the affective sphere in humans have take account of this demarcation [10, 11, 24, 30, 33, and others]. However, the cortical mechanisms of interactions between different aspects of activation and valence are to a large extent unknown, mainly because of the inadequate amount of study devoted to each of these dimensions.

Data from EEG studies of emotions in humans have provided evidence that "affective" interhemisphere asymmetry is characterized by significant heterogeneity in the anteroposterior direction [1, 5, 8, 10, 11, 15, 33]. The anterior areas of the cortex of the left and right hemispheres are associated predominantly with the valence dimension of emotion [16], while the posterior (especially of the right hemisphere) are associated with the processes of emotional activation regardless of valence [22, 24, 30].

However, to date it remains unclear how the characteristics of the interhemisphere distribution of EEG frequency-amplitude characteristics depend on the activated dimensions of the emotional signal, and this also applies to the

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temporal dynamics of the development of this process. The present study addresses this aspect of emotional reactions, as follows.

1. Stimuli consisted of signals (scanned photographs) from the International Affective Picture System (IAPS), which allows the valence and emotional activation factors to be controlled [14].

2. The stimulus presentation time was 6 sec and was sufficient to allow evaluation of both early assessment (up to 1 sec) and later ("experiential") aspects of the processing of afferent information.

3. Studies of cortical activity were based on evoked desynchronization/synchronization. Sensory, cognitive, affective, and motor activity can lead to changes in EEG power in the form of evoked synchronization (ES) or desynchronization (ED). Both phenomena are characterized by clear temporal connections with events and high specificity in relation to EEG frequency bands. Spatial mapping of ED/ES has been used for studying the topology and temporal dynamics of cortical activity [35]. Occasional studies of emotions using this approach have revealed relatively fine individual-typological cortical differences in affective reactivity [9], along with EEG correlates reflecting the characteristics of emotional reactivity to different types of affective stimuli [1, 10, 11, 29].

4. Use of high-resolution EEG (62 channels) allowed better topographic analysis of regional activatory processes.

Thus, the aim of the present work, based on the ED/ES method with the IAPS visual stimuli ranked in terms of emotional activity, was to obtain a topographic and temporal assessment of the modulating influences of emotional activation of cortical activity and regional activatory asymmetry at different frequency ranges.

METHODS

A total of 20 right-handed students at Novosibirsk State University (13 male, seven female; aged 18–26 years) took part in the study.

Visual IAPS stimuli (Center for the Study of Emotion and Attention, CSEA-NIMH, 1999) selected depending on the normative values on the valence scale (VAL) and emotional activation (A) were divided into five categories (eight stimuli per category): 1) neutral, with low activatory content (NeutLA); 2) positive, with intermediate activatory content (PosIA); 3) negative, with intermediate activatory content (NegIA); 4) positive, with high activatory content (PosHA); 5) negative, with high activatory content (NegHA).*

The 62-channel EEG was recorded in a monopolar regime with a bandpass of 0.3–50 Hz at a digitization frequency of 500 Hz using the Scan 4.1.1 program of the ESI-128 system (NeuroScan Labs) and a modified 64-channel cap with silver chloride electrodes (QuikCap, NeuroSoft Inc., Fig. 1, *A*). The reference electrode was located on the tip of the nose and the ground electrode was located in the center of the forehead. Eye movement artefacts were monitored by additional recording of vertical and horizontal electrooculograms.

Subjects were placed in a comfortable chair in a darkened room. The rest state was recorded with the eyes open (EO) and closed (EC) in the following sequence: EO (90 sec), EC (90 sec), EO (90 sec), EC (180 sec). After recording of the rest state, subjects were presented with experimental stimulation on the monitor (ViewSonic 17GS) of the stimulus computer. Each stimulation cycle had the following time sequence: dark screen (1 sec), presentation of the "+" symbol on the dark screen (4 sec), presentation of an IAPS stimulus (6 sec), presentation of the dark screen (1 sec). Thus, the total duration of EEG recording was 12 sec (5 sec before and 7 sec after the start of stimulus presentation). After presentation of each stimulus, subjects evaluated their emotional impression on a ten-point scale, which was displayed on the stimulation monitor. Each of these scales was a series of manikins (Self-Assessment manikin – SAM [13]): 1) "pleasant-unpleasant"; 2) "calm-excited." After the scale was reported, the next stimulation cycle was started. The start of presentation of each stimulus was synchronized with the EEG recording. Subjects were trained before experiments started. Each experiment consisted of 80 presentations, divided into two randomized blocks of 40 stimuli each. Since the afferent accent of the stimulus was not always located in the center of the map, each stimulus was presented the second time in the mirror orientation. In each block, the order of presentations was pseudorandom. Subjects rested for 5 min between the first and second blocks.

After EEG recordings were made, eye-movement artefacts were corrected using a special algorithm. Additionally, visual analysis was followed by exclusion of epochs containing non-correctable eye-movement as well as myographic, movement, and other artefacts. The mean number of artefact-free epochs per category were as follows: NeutLA = 12.85; PosIA = 12.80; NegIA = 12.75; PosHA = = 12.15; NegHA = 11.90. In accord with the ES/ED method [35], changes in power in the test period (6 sec from the start of stimulus presentation) were measured as the percentage increase (ES) or decrease (ED) in power in a given frequency range as compared with the reference interval. The reference interval was obtained by the average power level of eight EEG fragments of duration 8.192 sec recorded in the state of rest with the eyes open. ES/ED was analyzed for each subject in the frequency ranges 2–4, 4–6, 6–8, 8–10, 10–12, 12–18, 18–22, 22–30, and 30–45 Hz

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* The stimuli used were: NeutLA – 7002, 7004, 7006, 7009, 7010, 7020, 7150, 7175; PosIA – 2010, 2345, 2501, 2530, 2540, 5200, 5760, 5780; NegIA – 1930, 2205, 3300, 9008, 9340, 9421, 9911, 9920; PosHA – 1440, 1460, 1722, 1920, 4658, 4659, 4660, 4660; NegHA – 2800, 3080, 3150, 3170, 3261, 9040, 9405, 9410.

with a resolution of 100 msec and subsequent averaging of epochs for the five affective categories (for details of the method see [11, 29, 35]).

For statistical analysis, all electrodes were distributed into 12 clusters (six cortical zones for each hemisphere, Fig. 1, *A*): the anterotemporal (AT), frontal (F), central (C), parietal-temporal (PT), parietal (P), and occipital (O). The resulting ES/ED values were averaged between electrodes within each cortical zone for each stimulus category.

In the preparative phase of statistical analysis, values of ES/ED values associated with intermediate and high levels of emotional activation were discriminated by the following data transformations: positive and negative emotional stimuli with intermediate levels of activatory content were averaged to form categories of signals with intermediate activation. After analog transformation of stimuli of the opposite sign with high activatory content, the category of signals with high activation was defined. The category with low activatory content consisted of neutral stimuli. The result was that instead of five categories, three were obtained (with low, intermediate, and high levels of activatory content – LA, IA, and HA respectively). Subjective evaluation data were transformed using an analog method.

Subjective scaling data were subjected to unifactorial ANOVA analysis with repeat measurements on the Activation factor (A 3: LA, IA, HA). Changes in local power were assessed for each of the frequency bands by four-factor ANOVA with repeated measurements according to the scheme: Activation (A 3: LA, IA, HA) × Hemisphere (HS 2: left, right) × Location (LOC 6: AT, F, C, PT, P, O) × × time 6: 1, 2, 3, 4, 5, and 6 sec after stimulus presentation). Depending on the effects identified, additional ANOVA was used with changes in the structure of the time and location factors (see Results section). For all types of analysis, values of statistical significance were corrected where required using the Greenhouse–Geisser (G–G) and Huynh–Feldt (H–F) tests. Post hoc comparisons were performed using the Sheffe, Tukey and LSD tests.

RESULTS

Subjective assessment data. According to the main effect of the activation factor ($F(2.38) = 60.85$, $p < 0.000$), all affective categories were significantly different in terms of the level of subjectively experienced activation, which was greatest for HA (4.92 ± 0.34), intermediate for IA (3.85 ± 0.25), and lowest for LA (2.51 ± 0.26) stimuli.

The delta range (2–4 Hz). According to the effects of the activation factor ($F(2.38 = 13.72$, $p < 0.000$) and the interaction A × LOC ($F(10.190) = 4.04$, $p < 0.016$), the HA and IA stimuli, as compared with LA stimuli, induced significantly greater ES in areas C, PT, P, and O (Fig. 1, *B*, *1*). Other effects associated with the activation factor were not seen.

The theta$_1$ range (4–6 Hz). The lower theta range showed the effect of the activation factor ($F(2.38) = 16.65$, $p < 0.000$) and the interaction A × LOC ($F(10.190) = 10.06$, $p < 0.000$; Fig. 1, *B*, *2*). Analysis of the latter showed that ES was more marked for the HA and IA stimuli than for the LA stimulus, and this was seen in all areas of the cortex apart from AT. Additional ANOVA for individual areas revealed the interaction A × HS ($F(2.38) = 3.30$, $p < 0.048$; Fig. 2, *1*) in the PT area, demonstrating an increase in ES in the right hemisphere in response to the HA stimulus as compared with the LA stimulus. Analysis of the first 2 sec of the test interval revealed the interaction A × TIME ($F(18.342) = 2.68$, $p < 0.034$) for the posterior areas of the cortex (PT, P, and O), according to which the most marked differences between the neutral and emotional stimuli arise at the early stages of stimulus presentation, i.e., at 200–400 msec (Fig. 3, *1*).

The theta$_2$ range (6–8 Hz). The upper theta range also showed the effects of the activation factor ($F(2.38) = 12.80$, $p < 0.001$) and the interaction A × LOC ($F(10.190) = 21.60$, $p < 0.000$; Fig. 1, *B*, *3*). Analysis of this interaction showed that ES was more marked for the HA and IA stimuli than for the LA stimulus, this being seen in the C, PT, P, and O areas. At the same time, the existence of the interaction A × HS × TIME × LOC ($F(50.950) = 1.86$, $p < 0.020$, H–F) provided evidence for a relationship between the anterior and posterior "emotional" cortical asymmetries and the time factor. In fact, additional ANOVA for the posterior cortical areas (PT, P, and O) revealed, over the interval 0–6 sec, the interaction A × HS ($F(2.38) = 6.47$, $p < 0.009$; Fig. 2, *2*), which demonstrates an increase in ES in the right hemisphere in response to the HA and IA stimuli as compared with the LA stimuli. At the same time, in the anterior leads (AT, F), the interaction A × HS was significant ($F(2.38) = 4.63$, $p < 0.019$; Fig. 2, *3*) only over the interval 1–6 sec, provided evidence for an increase in synchronization in the left hemisphere in response to both categories of affective stimuli (Fig. 2, *3*). In the time areas, the first 2 sec of the test interval showed the interaction A × TIME ($F(18. 342) = 2.90$, $p < 0.014$) in the posterior areas of the cortex (PT, P, and O), indicating that significant differences between the neutral and emotional stimuli appeared rather later than in the lower theta range (about 400–600 msec; Fig. 3, *2*).

The alpha$_2$ range (10–12 Hz). In the alpha$_2$ band, the anterior (AT, F, and C) cortical areas showed effects of synchronization for all categories of stimuli, these being most marked in the first half of the test interval (0–3 sec), while in the posterior (PT, P, and O) areas the effects of desynchronization dominated throughout the whole test period (0–6 sec). Analysis of mean A × LOC interactions ($F(2.38) = 5.54$, $p < 0.001$) provided evidence that significant effects of emotional activation were seen only in the anterior (AT, F) cortical areas, in which the HA stimuli induced greater ES than LA stimuli (Fig. 1, *B*, *4*). According to the interaction A × TIME ($F(18.342) = 4.18$, $p < 0.001$),

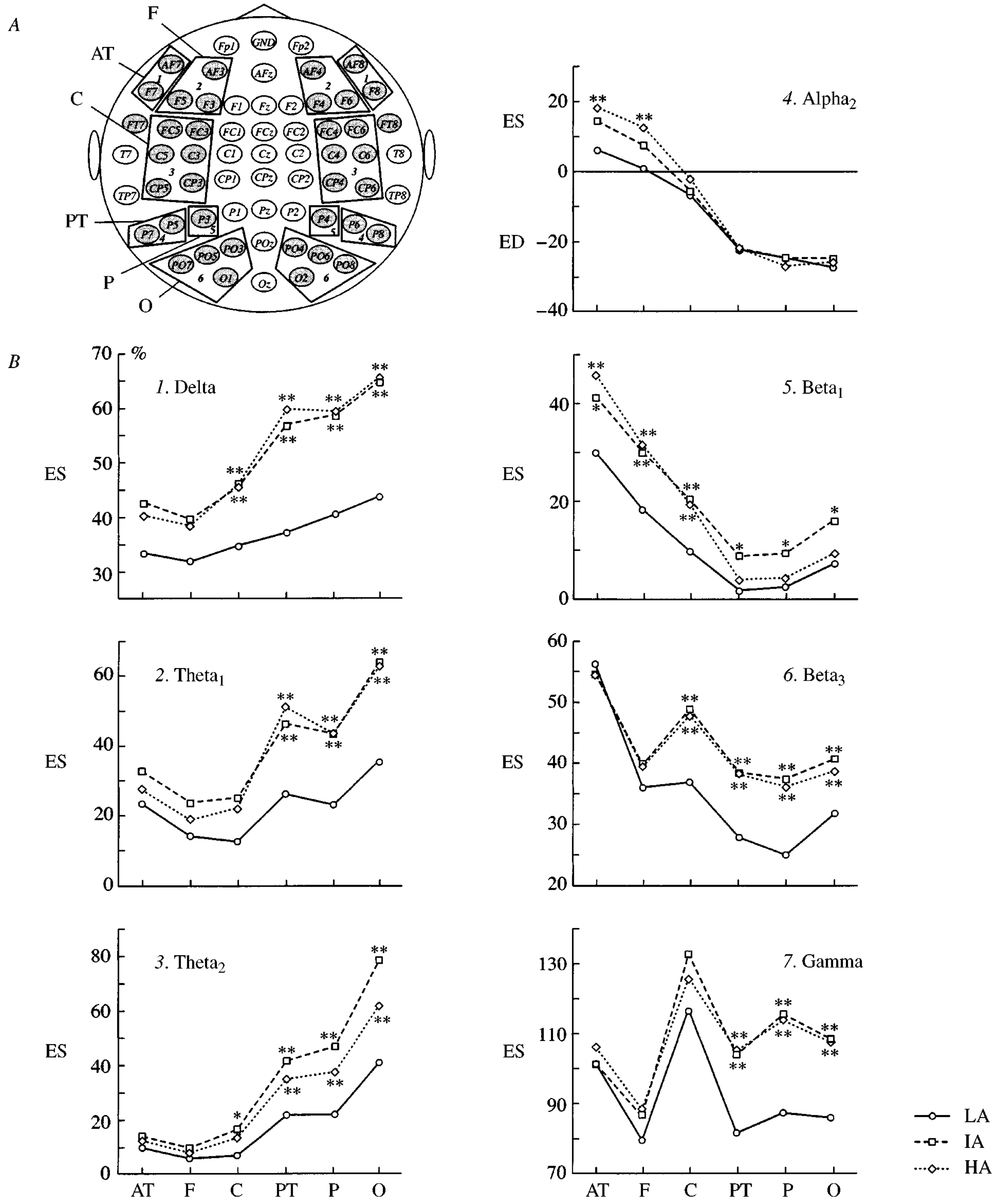

Fig. 1. Topography of the distribution of recording electrodes and the effects of evoked synchronization (ES) and desynchronization (ED). *A*) Diagram showing the positions of electrodes located in 12 clusters (six for each hemisphere); *B*) *1–7*) topographic distributions of ES and ED effects in the delta (*1*), theta_1 (*2*), theta_2 (*3*), alpha_2 (*4*), beta_1 (*5*), beta_3 (*6*), and gamma (*7*) ranges in response to presentation of stimuli with low (LA), intermediate (IA), and high (HA) activational content over the test period 0–6 sec. The horizontal axis shows areas of the cortex (AT, F, C, PT, P, O); the vertical axis shows ES and ED (%, increases in synchronization shown upwards, increases in desynchronization shown downwards from the zero line). Asterisks show significant (*$p < 0.05$; **$p < 0.01$) differences between the HA and IA stimuli on the one hand and the LA stimuli on the other.

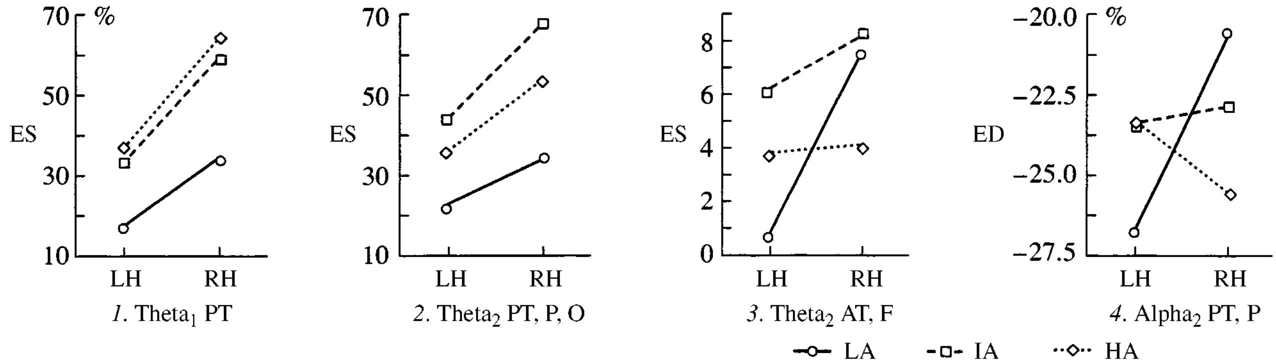

Fig. 2. Interhemisphere distribution of ES and ED effects (%) in the posterior cortical areas in the theta$_1$ (*1*), theta$_2$ (*2*), and alpha$_2$ (*4*) over the time period 0–6 sec on presentation of LA, IA, and HA stimuli, and in the anterior areas of the cortex in the theta$_2$ range (*3*) over the time period 1–6 sec. LH = left hemisphere; RH = right hemisphere.

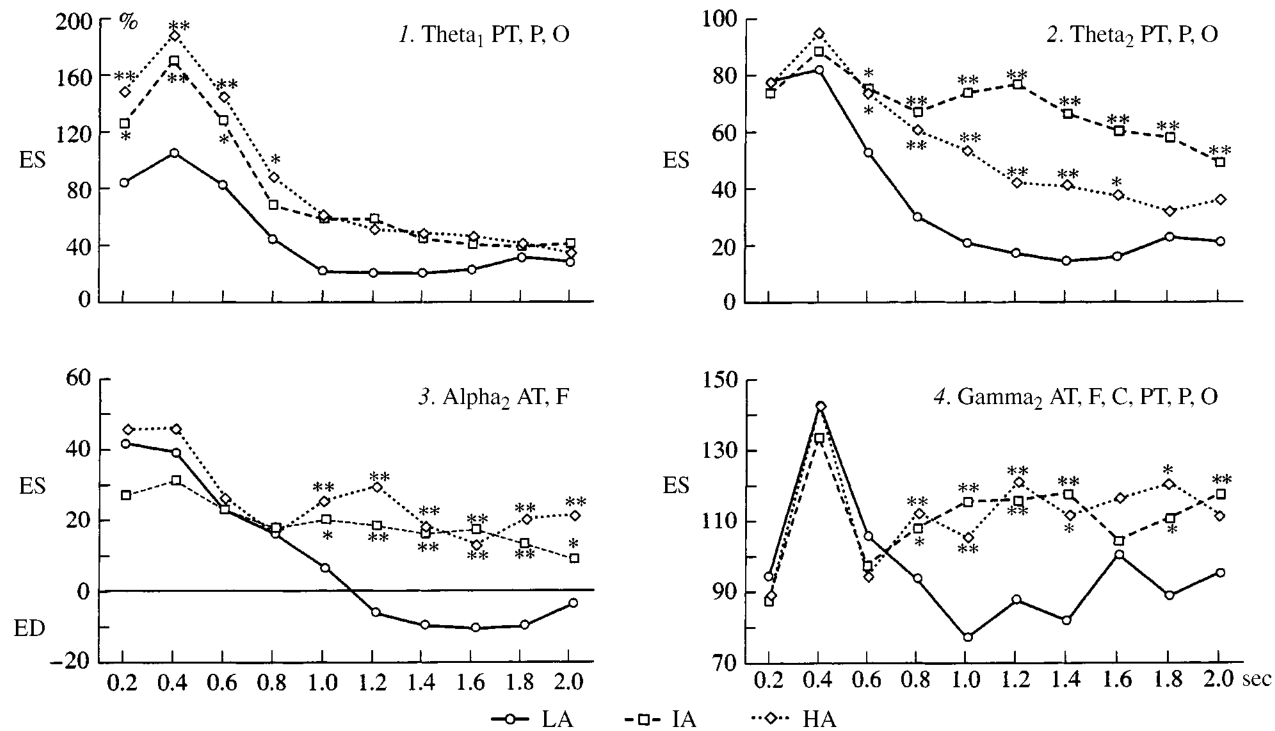

Fig. 3. Time dynamics of ES and ED in response to presentation of LA, IA, and HA stimuli in the theta$_1$ (*1*), theta$_2$ (*2*), alpha$_2$ (*3*), and gamma (*4*) ranges over the interval 0–2 sec from the start of stimulus presentation. The abscissa shows time; the ordinate shows ES and ED (%). Asterisks indicate significant (*$p < 0.05$; **$p < 0.01$) differences between the HA and IA stimuli on the one hand and LA stimuli on the other.

obtained in these areas for the first 2 sec of the test interval, differences between the LA and IA stimuli and the HA stimuli appeared only at the end of the first second from the start of stimulus presentation (800–1000 msec; Fig. 3, *3*). At the same time, the posterior areas (PT, P) showed effects consisting of an asymmetrical distribution of ED, which was supported by the interaction A × HS ($F(2.38) = 6.80$, $p < 0.004$; Fig. 2, *4*). Analysis of this interaction showed that as compared with the LA stimuli, the IA and HA stimuli increased ED in the right hemisphere.

The beta$_1$ range (12–18 Hz). According to the effect of the activation factor ($F(2.38) = 8.93$, $p < 0.003$) and the interaction A × LOC ($F(10.190) = 6.63$, $p < 0.001$), on the background of general synchronization, the IA and HA stimuli induced significantly greater increases in power in the anterior and central (AT, F, and C) areas of the cortex than did the LA stimuli (Fig. 1, *B*, *5*). Other effects associated with the activation factor were not seen.

The beta$_3$ range (22–30 Hz). As shown in Fig. 1, *B*, *6*, and considering the effects of the activation factor ($F(2.38) = 4.82$, $p < 0.017$) and the interaction A × LOC ($F(10.190) = 3.44$, $p < 0.049$), on a background of general synchronization, the IA and HA stimuli induced greater increases in power in the C, PT, P and O cortical areas than did the LA stimuli. No other effects of emotional activation were seen.

The gamma range (30–45 Hz). The gamma range also showed effects for the activation factor ($F(2.38) = 7.49$, $p < 0.003$) and the interaction A × LOC ($F(10.190) = 7.12$, $p < 0.000$; Fig. 1, *B*, *7*), according to which ES in the posterior (PT, P, and O) cortical areas was increased in response to emotiogenic stimuli as compared with neutral stimuli. Special analysis of the first 2 sec of the test interval in terms of the time area demonstrated the interaction A × TIME ($F(18.342) = 2.78$, $p < 0.007$) for all parts of the cortex, demonstrating the appearance of differences between neutral and emotional stimuli at the end of the first second (600–800 msec; Fig. 3, *4*).

Thus, this study demonstrated that evoked changes in the power of EEG rhythms dependent on the degree of emotional activation were seen in the delta, theta$_1$, theta$_2$, and alpha$_2$, beta$_1$, beta$_3$, and gamma frequency bands and had different temporal and topographical characteristics.

DISCUSSION

Comparison of subjective assessments in response to presentation of stimuli of different affective categories provided clear evidence that at the subjective level, emotiogenic stimuli elicited significantly more activation than neutral stimuli. This supports results obtained from other studies using the IAPS stimuli [11, 24, 31, 33].

ES/ED data showed that affective stimuli induced increases in power in the delta range only in the posterior leads, this being seen at the early stages of signal presentation (up to 1 sec) without any regional lateralization. Despite the fact that delta oscillations are regarded mainly as a correlate of a decreased functional state of the brain (sleep or pathology), they can accompany active states. In conditions of internalization of attention, cognitive (mental counting [20]) and affective (extraction of emotional images from memory during the process of generating emotions [5, 6]) tasks produced increases in power in the delta range. Given that the role of delta oscillations in the process of higher nervous activity and emotional functioning have received little study, we can say only that neural networks oscillating at delta frequencies are involved in the processes of detecting the affective significance of a stimulus.

The motion-inducing properties of signals were associated with increases in power in the lower and upper theta ranges in the posterior and anterior areas of the cortex. The theta rhythm is currently regarded as a basal rhythm associated with cognitive functions and cortico-hippocampal interactions, functionally integrating different parts of the nervous system (for reviews see [12, 13]). The “limbic” theta rhythm, so-called because of its “emotional” origin, appears not to be entirely related to the cognitive component of emotional reacting in humans, and increases in this rhythm in emotions do not lead to simple activation of the neocortex by limbic structures [7]. Contemporary views suggest that increases in theta activity in the anterior and posterior areas of the cerebral cortex in humans are regarded as a manifestation of increased activation. This suggestion is based on results obtained from experimental studies showing that the increases in theta power in these areas of the cortex are associated with increases in orientational responses [12, 13] and concentration of attention [38], the efficiency with which new information is encoded in memory and subsequently reproduced [26, 27], and the mechanisms of processing of emotional information [1, 5, 6, 10, 11, 29].

The marked increases in power in both theta ranges in the posterior areas of the cortex in response to affective stimuli with a clear accent on increases in the dominance of the right hemisphere may reflect analysis of the affective significance of the stimulus, accompanied by activation of processes accessing memory and extracting information associated with previous emotional experience [6]. Considering that the theta power of cognitive evoked potentials (EP) correlates positively with the amplitude of the P300 component in the posterior areas of the cortex in tasks involving significant signals [39], data showing increases in the amplitudes of P300 and late positivity in response to affective (identically to positive and negative) as compared with neutral stimuli in the posterior areas of the cortex, with a greater contribution from the right hemisphere [18, 25], provide evidence supporting this suggestion. In turn, only the upper theta range showed the effects of “affective” interhemisphere asymmetry in the anterior cortical areas – emotiogenic signals induced time-dependent asymmetrical activation seen from the second second after presentation started and consisted of an increase in evoked synchronization in the left hemisphere over the interval 1–6 sec. Increasing amounts of data are currently accumulating which suggest the existence of two basic systems mediating the appearance of emotions and motivations, associated with achievement or avoidance. The anterior cortex of the left hemisphere is regarded in association with the *achievement* system, while the symmetrical areas of the right hemisphere are associated with the *avoidance* system (for review see [16]). As demonstrated in relatively recent EEG studies, the emotion of anger, which has negative valence but is associated with a motivational tendency towards achievement, leads to increases in the activity of the anterior areas of the left and decreases in the activity of the symmetrical areas of the right hemisphere. The authors suggested that the anterior activational asymmetry reflects the activity of the motivational systems more than the sign of the emotion being experienced [19]. In this regard, the increases in $theta_2$ synchronization observed in the anterior areas of the cortex of the left hemisphere may reflect actualization of the motivational tendency to *achievement* with the aim of obtaining a more detailed evaluation of the potential significance of the stimulus. In turn, more detailed evaluation of the signal may support simultaneous actualization of analytically sequential left-hemisphere strategies of information processing (see [21]), especially when account is taken of the predominant association of activity in the anterior areas of the cortex in the upper theta range with the cognitive aspects of information processing [23, 32]. An additional explanation can be based on the concept of the involvement of the left hemisphere in the mobilizing mechanisms of orientational-investigative and seeking behavior [2, 3] and the leading role of the anterior areas of the left hemisphere in maintaining high levels of general brain activation regardless of the sign of the emotion.

Interpretation of changes in alpha power can be based on the concept of the functional heterogeneity of different alpha ranges. According to data obtained from recent special studies, desynchronization in the lower alpha range is associated with such processes of external attention as vigilance and expectancy, while desynchronization in the upper alpha range is associated with increases in cognitive activity itself [26].

In the current study, the lower alpha range showed no effects of the emotiogenicity of signals, which might result from the characteristics of the experimental protocol and the stimuli used. The structure of the study, based on the use of signals with static emotional content and presented in a "passive" observation regime with the aim of increasing the intrinsic emotional component of the analysis, did not imply the inclusion of accompanying tasks (quick responses to stimuli, assessment of the signal at the moment of presentation, tracking a test signal, etc.) needing inclusion of additional mechanisms of external attention associated with activity in the lower alpha range [26]. It is significant that the insensitivity of alpha activity to signal emotiogenicity, albeit over the wide range of 8–12 Hz, has been noted by other authors in a similar experimental model of "passive" viewing of IAPS stimuli [33].

In the "cognitive" alpha band, stimuli with high activational content induced significant synchronization in the anterior areas of the cortex on both sides, with asymmetrical desynchronization in the posterior cortical zones. It should be noted that the performance of some cognitive tasks also demonstrates the effects of simultaneous alpha-synchronization in the anterior and desynchronization in the posterior cortical zones [34]. Not only desynchronization, but also synchronization of alpha activity in some cases is regarded as an indicator of the activity of functionally involved areas reflecting the specific operation of higher brain functions (see [28, 34, 35]). It is well known that the cognitive aspect of affective reacting is modulated by the functions of both the right and left hemispheres (for review see [21]). In this regard, synchronization evoked in the anterior areas of the cortex by emotiogenic stimuli may reflect increases in cognitive involvement in the processing of signals with high emotional activatory contents, accompanied by simultaneous actualization of right-hemisphere (rapid, holistic) and left-hemisphere (analytically-sequential) strategies for processing survival-important information. Nonetheless, at this phase of the studies, the effect observed by ourselves should be regarded as essentially indicative. At the same time, the asymmetrical increase in evoked desynchronization in the parietal and parietal-temporal leads of the right hemisphere in response to strong emotiogenic signals are direct experimental evidence for the concept that these cortical areas are involved in the processes discriminating the activational component of emotional reacting [17, 22, 24, 30].

Overall, at the high frequency ranges, affective stimuli led to increases in power as compared with neutral stimuli, these increases being predominant in the $beta_1$ band in the anterior and the $beta_3$ and gamma bands in the central and posterior areas of the cortex. These data correspond to significant observations, in EEG studies of emotions, of increases in high-frequency activity in conditions of emotional activation (see, for example, [5, 15, 33]). However, in these ranges, no interhemisphere differences associated with emotionality were seen in these frequency ranges.

From the point of view of affective chronometry [16], analysis of the temporal dynamics of evoked synchronization in the lower theta range in the posterior areas of the cortex provides clear evidence that the extraction of emotionally significant signals from the neutral context starts at the early stages of stimulus presentation – at 0–400 msec. Data on the early involvement of neuronal theta oscillators in the process of discriminating affects is in good agreement with results obtained in recent studies of "emotional" EP, which demonstrated that this process occurs over the time interval 150–260 msec after signal presentation [24]. This time is sufficient for an emotiogenic stimulus to activate the motivational systems involving the cingulate cortex and/or the amygdala, as well as the hypothetical "very short-term conceptual memory system" [24, 36]. Considering that it is the early stages of signal presentation (at 0–500 msec) in which evoked theta activity is associated with the mechanisms of the orientational reaction, selective attention and memory (for review see [12]), early evoked theta synchronization in the posterior areas of the cortex reflects essentially *evaluation of the affective significance of the stimulus*, rather than the experience of emotion. In the upper theta, $alpha_2$, and gamma ranges, the activity of the process discriminating stimulus emotiogenicity was delayed to 600–1000 msec. Considering the association of the upper theta, $alpha_2$, and gamma activity with various aspects of cognitive functioning [13, 23, 32], the later discrimination of affective stimuli in these frequency bands may be associated with these stages in the wider cognitive analysis of an emotiogenic stimulus.

In conclusion, it should be noted that the features of interhemisphere distribution of EEG frequency-amplitude characteristics due to the activation dimension of an emotiogenic stimulus, as observed here, provides evidence of the involvement not only of the posterior areas of the right [22] but also the anterior areas of the left hemisphere in processes modulating emotional activation. In addition, the characteristics of the temporal dynamics allow us to suggest that an emotional reaction is associated with simultaneously or alternating activity of a whole set of neuronal ensembles which, having different topographic attributes, support the realization of its main components.

CONCLUSIONS

1. Analysis of evoked EEG synchronization and desynchronization in different frequency bands in conditions of presentation of neutral and emotiogenic visual stimuli established that the emotiogenicity of signals is significantly associated with increases in evoked synchronization in the delta, theta_1, theta_2, beta_1, beta_3, and gamma ranges, as well as with the effects of simultaneous increases in evoked synchronization and desynchronization in the alpha_2 band.

2. Emotiogenic signals, as compared with neutral signals, induce asymmetrical increases in activity in the posterior areas of the cortex of the right (indicated by evoked synchronization in the theta_1 and theta_2 and desynchronization in the alpha_2 ranges) and anterior areas of the left (indicated by evoked synchronization in the theta_2 range) hemispheres.

3. From the point of view of affective chronometry, discrimination of the activation dimension of a stimulus, without regard to the sign of the emotion, occurs in the lower theta band at 0–600 msec after stimulus presentation. At the same time, this process is delayed to 600–1000 msec in the theta_2, alpha_2, and gamma ranges.

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