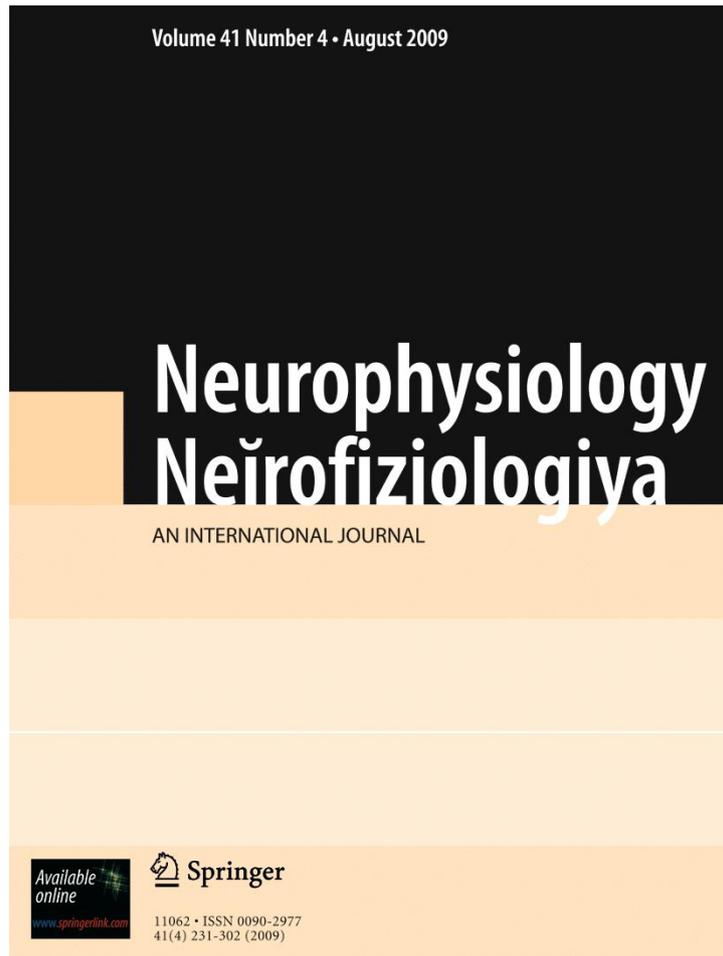


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REVIEWS

Emotional Significance of the Stimulus and Features of the Personality as Factors Reflected in the Pattern of Evoked EEG Potentials

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This review generalizes the data of modern studies of individual peculiarities of the spatial/temporal and amplitude characteristics of evoked EEG potentials (EPs) in humans. A brief description of EPs, characteristics of their components, sources of generation, and functional correlates is presented. Possible effects of the emotional significance of the stimulus and of individual peculiarities of the personality on the amplitude/temporal characteristics of EPs are considered. It is supposed that the aminergic cerebral systems play a crucial role in the formation of peculiarities of emotional responses, expression of the definite EP components, and biologically determined features of the human personality.

Keywords: evoked potentials, emotions, features of the personality, aminergic systems.

INTRODUCTION

Within the last decades, recording of evoked EEG potentials (EPs) began to be extensively used in medicine, neurophysiology, and psychophysiology as an important technique for studying cerebral mechanisms of higher mental functions in humans [1-3].

Due to its rather high temporal and spatial resolution, the technique of recording of EPs allows researchers to obtain a relatively detailed spatial/temporal pattern of the train of electrical events produced in the brain before, within, and after realization of one psychophysiological task or another and, therefore, to observe sequential stages of processing of information related to these behavioral phenomena. According to the existing concepts, each EP reflects, in some way, both processes related (exclusively or mostly) to the arrival of sensory information (these processes determine early short-latency components of the

response) and those related to processing/storing of information in the cerebral systems, which allows a subject to decide to perform one action or another and to realize this action *per se* (these processes correlate with late long-latency components of the response) [4]. The value of studies of EPs is, to a considerable extent, determined by the fact that this non-invasive technique allows one to examine mechanisms of the neural control and to reflect the dynamics of the activity of the human brain with a resolution capability of the millisecond range. Results of neuropsychological studies also demonstrated that definite characteristics of EPs can serve as an informative marker of the level of development of the nervous system in general and reflect the development of specific cognitive abilities [5]. At the same time, it should be recognized that the general feature of EPs, such as their high variability (both inter- and intra-individual), significantly interferes with the extensive use of EPs in clinical and research practice.

Numerous factors considerably influence the amplitude/temporal parameters of the EP components. We, together with a number of researchers, believe that individual psychological peculiarities of the personality and an emotional tint of the stimulus should be included in the list of such factors. Despite

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a great number of the studies dealing with these specific aspects (e.g., see reviews [6, 7]), the question on correlations of the pattern and parameters of EPs with the current state of the emotional sphere and with the psychological characteristics of the personality remains open from many aspects.

Taking this into account, we tried in our review to generalize some results of the studies dealing with identification of relations between the EP characteristics, on the one hand, and emotional content of the stimulus and psychological characteristics of the personality, on the other hand. We briefly describe the main types of EPs, characteristics of their components, probable sources of generation, and probable functional significance. At the same time, results of specialized studies where emotogenic images of the facial expression of emotions were used as the stimulus material are analyzed to a limited extent (see reviews [8, 9]). The data of the studies of affective disorders of the personality and neurophysiological analysis of the fear emotion also were not included in our review (see reviews [10, 11]).

GENERAL CHARACTERISTICS OF CEREBRAL EPs IN HUMANS

All changes in the mass (field) potentials in all divisions of the CNS elicited under the influence of determined external and internal factors and generated in a relatively strict temporal correlation with the action of these factors are qualified as the EPs [12]. As is believed, cortical EPs (EEG EPs) represent, in general, summarized manifestations of postsynaptic (mainly, dendritic) potentials developed in extensive populations of neocortical neurons activated within a definite time period [13]; the contribution of other sources of generation of EPs (e.g., those of a glial nature) remains disputable.

In the structure of EPs, a few components are detected; for their identification, the amplitude/temporal parameters (polarity, duration, latency, magnitude, etc.) and also the spatial distribution of the amplitudes of EPs within the head surface (scalp), relation to one event or another (and/or to the characteristics of these events), and relation to a behavioral task are taken into consideration [3]. As a rule, the components are designated according to their polarity (negative, N, and positive, P, ones) and sequence of the appearance (e.g., N1, P2, etc.). To designate the component, an approximate latency of its maximum (peak) measured in milliseconds is frequently used (N100, P200, etc.).

In most cases, the measurements of the latency of one EP component or another *per se* (i.e., the delay of its initiation with respect to the moment of application of the stimulus) with a satisfactory accuracy meet significant difficulties because moments of transition of a preceding component to the subsequent one cannot be precisely identified. To provide higher objectivity, we prefer in this review to designate the components by their polarity and sequence of generation and not by precise values of their latencies because the latter vary depending on a number of factors.

In addition to the polarity and latency, the characteristics of EPs frequently include description of their topographic distribution across the scalp or designations of the electrodes (leads) where the maxima (peaks) of the components are usually observed. Such information can be valuable for interpretation of the components initiated within the same time interval but in different cortical regions and related to different sensory and/or cognitive processes [14].

In addition, differentiation between exogenous and endogenous EPs was proposed [15]. As is supposed, the exogenous EP components are mostly determined by physical properties of the external stimulus, while the endogenous components can be elicited in the absence of external stimulation; their characteristics depend on the intrinsic state and behavior of the subject and on his/her personal psychological peculiarities. These characteristics correlate to a greater extent with subjective experience, intents, and decisions of the subject than with physical characteristics of the stimulus [12, 16]. Results of subsequent studies showed, however, that such differentiation is to a significant extent conventional because one and the same component (e.g., N1 or P2), depending on the parameters and nature of the stimulus, can correspond, according to its properties, to both the above-mentioned groups of indications [17].

If we take into account the great diversity of the paradigms of experiments where EPs were recorded, techniques of the analysis of experimental data, and approaches to their functional interpretation, it is rather difficult to form an integral picture containing an enormous amount of the materials obtained in the respective studies. Significant disagreements in terminology also add certain difficulties. The term "event-related potentials, ERPs," acquired extensive use in the English-language scientific literature; this term was proposed by Vaughan in 1969 [18]. At the same time, the use of this term in the countries of the former USSR was more limited; only slow, "long-wave" EPs correlating with the events that were not

directly related to application of certain stimulus were called ERPs. As the ERP-initiating events, admission of the stimulus in their series, cerebral processes preceding a motor reaction (e.g., pressing the contact), identification of a definite stimulus in their series, etc., were considered. Among these potentials, such cognitive ERPs as the readiness potential (RP) and contingent negative variation (CNV) related to a definite decision and realization of a recognized behavioral reaction have been examined at present to the greatest extent. These potentials have been described in detail in the respective publications (see, e.g., the reviews [6, 19, 20]); this is why we do not present their detailed characteristics. We also do not describe the earliest “purely sensory” EEG phenomena related to transmission and processing of information at the non-cortical levels [3, 21].

COMPONENTS OF EPs AND THEIR POSSIBLE FUNCTIONAL CORRELATES

Component P1 develops in about 50-70 msec after presentation of an auditory signal; in the case of presentation of the visual signals the delay is about 100 msec long. This component is interpreted as a neurophysiological marker of predominant attention to the input sensory influence and suppression of information, which does not attract attention; this component is also considered a reflection of the general level of cerebral activation [14].

Component P1 elicited by presentation of an auditory-modality stimulus arrives with the shortest latencies and reaches the highest amplitude in the frontal and central cortical regions [22]. Using a magnetoencephalographic technique, sources of generation of this component were shown to be localized in the superior temporal gyrus [23]. As is believed, the auditory P1 component in humans is formed from a few superimposed subcomponents, and some of them can be related to the process of initiation of a motor response [24]. There are indications for the dependence of manifestation of this component on the activity of the ascending reticular activating system [25]. Generation of the P1 wave is probably mediated, to a considerable extent, by the activity of the ascending aminergic pathways projecting to the neocortex [26]. It is supposed that component P1 is mostly of a dipole nature and is related to postsynaptic excitation of the neuronal somata and dendrites localized in layers III and IV of the sensory cortical zones resulting from incoming of the activity via the

specific thalamo-cortical pathways [27].

Upon presentation of the stimuli of the visual modality, the P1 component differs from the auditory P1 component in the latency of the maximum, distribution across the scalp, and sources of generation. Neurophysiological mechanisms and neurocognitive aspects of the P1 component in visual EPs are also sufficiently specific. As was found, upon visual stimulation the P1 develops later than the auditory one, and the maximum amplitude of this component is observed in the occipital cortical regions [28]. According to the data obtained using techniques for detection of localization of dipole sources and positron-emission tomography, probable sources responsible for generation of component P1 of visual EPs are localized in the ventral and lateral portions of the occipital (visual projection) cortical zone [29, 30]. This is indicative of both striate [31] and extrastriate (posterior fusiform gyrus, [32]) genesis of the above-mentioned component.

Numerous studies demonstrated that significant correlation exists between the characteristics of the P1 component and the state of attention. Most authors mentioned that the amplitude of the P1 developed upon application of the stimuli attracting attention is relatively greater, while the P1 amplitude in the case of the stimuli being outside the sphere of attention corresponds to the mean values of this parameter or is smaller [12, 33]. Basing on these data, it was hypothesized that augmentation of the P1 component is related to suppression of the irrelevant signals [34]. According to some authors [35], increases in the amplitudes of the early P1 and N1 components reflect intensification of the processes of perception. Results of a few studies where the P1 amplitude was compared in the cases of presentation of the stimuli localized within the spatial regions attracting attention and within the regions where attention was not focused also supported the existence of correlation of the P1 characteristics with attention [36].

A concept was formed that the amplitude/temporal characteristics of the P1 in visual EPs vary depending on spatial characteristics of the object (such as localization of a visual stimulus in space) and are related to the specificities of distribution of visual spatial attention [37, 38]. Later on, however, it was found that the P1 is influenced by other, nonspatial, characteristics of the visual stimulus [39]. Results of the respective studies showed that the visual P1 reflects, to a certain extent, processing of information about the contours and shape of the visual stimulus incoming to the cortex; the amplitude of this component

is modulated by the characteristics of the presented image stimulus, such as its contrast and complexity [40]. The sensitivity of the P1 characteristics to the stimuli possessing special subjective significance for a given person was also shown [39].

Basing on the facts that the temporal characteristics of component P1 correspond to the EEG alpha rhythm frequency, and alpha oscillations are functionally related to inhibition of the cortical neuronal systems and reflect the existence of the inhibitory control of the neocortex [41], Freunberger et al. [42] proposed a theory that the P1 component and EEG alpha oscillations are characterized by certain functional similarity. Taking into account that the amplitudes of both the P1 EP component and the alpha-frequency component of background EEG were higher upon presentation of irrelevant distorted images, the above authors hypothesized that component P1 can (at least partially) be generated due to synchronization of evoked alpha oscillations, and this component reflects suppression of the processes irrelevant with respect to the visual task [42].

Thus, an increase in the P1 amplitude can be interpreted multifacially, namely as a reflection of intensification of the sensory input volley related to the stimulus applied to the zone of attention, as an effect of some temporal synchronization of separate responses to switching on of the stimulus, as manifestation of suppression of irrelevant information, and as reflection of the control of the processes, which are components of a "ventral flow" coming via visual projections to the temporal cortical region where the functions of analysis of characteristics and recognition of the objects are realized (this control is provided by the system of attention) [12, 33, 36].

Component N1 within the paradigm of dichotic hearing was first examined by Hillyard et al. [43]. It was believed that the characteristics of the N1 reflect selective attention to fundamental characteristics of the stimulus, initial selection of the patterns of stimuli for their further recognition, and intentional (purposeful) recognition of these stimuli [44]. The latency and amplitude of the N1 peak depend noticeably on the stimulus modality. Presentation of auditory stimuli evokes the N1 components of a higher amplitude and with shorter latencies than visual stimulation [28].

Component N1 in the responses elicited by stimuli of the auditory modality develops within a 100 to 120 msec range after the beginning of presentation of such stimuli and reaches the maximum magnitude within the frontocentral leads [45] and vertex region [46]. The greatest number of strong negative correlations

between the amplitudes and latencies of the peak values of component N1 was found in the central/lateral cortical regions [47]. According to the data of magnetoencephalography, however, the primary auditory cortex localized in the temporal cerebral lobes is the primary generator of the above-mentioned component [48]. It was also noted that cerebral structures, such as the brainstem reticular formation (RF), medial and dorsal thalamus, and limbic system, contribute also to generation of the N1 [49]. The genesis of the N1 of auditory EPs was interpreted as related to activation of the apical dendrites via axon collaterals of activated neurons of cortical layers III and IV and to somatofugal spreading of excitation via the dendrites of nerve cells of the above layers [27]. The N1 and P2 oscillations were frequently considered a combined component, namely the N1-P2 complex or the "vertex potential." In this case, the relation of this complex to the arrival of impulsation from nonspecific thalamic and mesencephalic structures was emphasized [3].

A few researchers differentiated three N1-like components in the temporal region (latencies of the maxima 75 and 130 msec) and the vertex zone (100 msec) [50]. Naatanen and Picton [51], when analyzing all the three components, supposed that the early temporal and vertex components reflect mostly "pure sensory" physical properties of the stimuli (intensity, spatial localization, and moment of presentation with respect to other stimuli). At the same time, the late temporal component is less specific and reflects, to a considerable extent, a general current level of cerebral activation [51]. The amplitude of the auditory N1 was found to increase under conditions of increased concentration of attention to the stimuli [36] and expanded interstimulus intervals [52].

The N1 component in the case of visual stimulations is usually elicited with a 110- to 160-msec-long latency and reaches the maximum amplitude in the occipital [53] or inferior temporal [54] cortical regions. Similarly to the auditory N1, the visual N1 includes at least two different subcomponents. One of them (in central leads) crosses the isoline in 100 msec, while another one (in posterior regions of the brain) attains the zero line in about 165 msec [44]. A few researchers interpreted the N1 recorded from the central leads as related to the processes of preparation for a behavioral response because this oscillation disappears when there is no necessity for a motor reaction. Using a combination of the techniques of positron emission and functional magnetonuclear tomography with recording of EPs, Hopf et al., [53]

located the sources of visual N1 in the inferior occipital lobe and occipito-temporal conjunction. In addition, other researchers using low-resolution electromagnetic tomography identified additional sources of the visual N1 component in the inferior temporal region [54].

An increase in the amplitude of the visual N1 was noticed in the performance of a task related to discrimination of the stimuli [44]; when stimuli were presented with short interstimulus intervals, the N1 amplitude decreased. Correlation with the processes of attention was demonstrated for component N1 of visual EPs, similarly to the respective situation with the analogous component of auditory EPs [30]. Dependences of the parameters of components N1 and P1 on the level of selective attention were found; these dependences were direct for the amplitude and opposite for the latency [55]. As was reported, the N1 amplitude increased with intensification of attention to localization of the stimuli in space [34]. In these cases, such an effect cannot be related to a greater general activation of the brain because the development of higher-amplitude N1 potentials was observed under conditions of the experimental task, which did not require accentuation of attention of the subject on the most rapid realization of the response [44]. At the same time, this phenomenon probably cannot be related to the action of inhibition, because there are no differences between the amplitudes of the N1 in responses recorded under conditions of the go/no-go paradigm [54].

Component P2, similarly to the earlier P1 and N1 components, is characterized, according to the published data, by relatively low individual variability and rather good reproduction in different experimental tasks [56]. There are several interpretations of the functional role of the P2 component. According to some authors [57, 58], component P2 reflects the process of inhibition in the irrelevant informational channels “competing” for the attention resources and possibility for further processing of information. Other researchers believe that the P2 is an indicator of the level of differentiation and classification of the stimuli [59] and also of modulation of attention with respect to standard (routine, non-target) stimuli [60].

The P2 component in responses to presentation of the stimuli of auditory modality frequently develops together (is “merged”) with the preceding N1 component and is rather similar to that in its functional significance. This is why the modulus of the sum of the peaks N1 and P2 is frequently designated in the literature as the N1-P2 complex [61]. The maximum

amplitude of the P2 is observed within a wider range of the latencies than that of the N1 component (150 to 275 msec) [62]. Two maxima can be present in the P2 wave [63]. The greatest P2 amplitudes were found in the central regions of the neocortex [64]; because of this, the entire N1-P2 complex is frequently called the vertex potential. Characteristics of the auditory P2 are sensitive to physical parameters of the stimulus, such as the height of the sound tone [60] and its intensity [67]. The amplitude of component P2, similarly to that of the N1, increases with increase in the intensity of the stimulus.

Polich and a few other researchers [47] considered the characteristics of the vertex potential as a direct index of the efficacy of processing of different types of sensory information by the subject. As was believed, these indices can be used for estimation of the threshold of perception of an extensive set of variations of a sound signal, i.e., localization of the source of the sound, its loudness, and height [65]. The dipole analysis of generation of auditory EPs demonstrated the presence of a clear dependence of the N1-P2 amplitude on the stimulus intensity [66]. The cited authors believed that manifestations of such dependences correlate with the existence of rather dense serotonergic (ST-) innervation of the primary auditory cortex. Such innervation provides modulation of processing of incoming information and restricts the level of activation of this neocortical region. It was supposed that the dependence “stimulus intensity vs amplitude of auditory EPs” is one of the indicators of the activity of the ST system [67]. In more details, the P2 component of auditory EPs was described in the review by Crowley and Colrain [61].

The P2 component in the responses to presentation of the visual stimuli appears as a positive wave developing with the latency of 150 to 200 msec and reaching the maximum amplitude in the frontal cortical regions [68]. As was found, the amplitude of the visual P2 increases with increase in the stimulus complexity [69]. It was also mentioned that the amplitude of the P2 wave noticeably depends on the activity of the nonspecific cerebral systems (in particular, on the functional state of the RF). This amplitude increases with age (within a certain range); this phenomenon can reflect the level of maturity of the reticulo-cortical connections [33, 70]. There are data on correlation of the characteristics of component P2 with the phase synchronization of the field electrical activity of the brain within the theta frequency range. As is believed [71], the synchronized theta rhythm reflecting descending regulatory processes is, at least partially,

involved in modulation of the P2 component.

Component N2 at present is considered to be a complex of subcomponents differing from each other from a few aspects and depending on the stimulus modality [72] and parameters of their presentation [73]. The N2 oscillation is characterized by a high individual variability [74]. According to the published data, a general concept on its psychophysiological interpretation has not been formed. The stage of recognition of the stimulus is begun, as is supposed, from the moment of initiation of the N2 component [75]. It is also assumed that the characteristics of the N2 reflect, in some way, the parameters of the orientation reflex [76], the successfulness of discrimination of the stimuli [77], and selection of the stimuli from the train containing both target and standard (non-target) stimuli [72]. It was shown that the N2 component is especially pronounced in the case of presentation of novel (unusual or unexpected) stimuli and reflects "switching on of curiosity" and recognition of the complicate and extraordinary stimuli [78]. The amplitude and latency of component N2 decrease, as compared with their mean values, upon application of the stimuli with short interstimulus intervals [79].

The N2 component upon auditory stimulations is elicited with a delay of 200-350 msec after presentation of the stimulus. The maximum amplitude of the N2 is recorded in the central and parietal regions of the cortex [80]. The amplitude and latency of component N2 positively correlate with each other, and the correlation coefficients reach the greatest values also in the central and parietal neocortical zones [47]. The supratemporal auditory cortex is thought to be involved in generation of the auditory N2 component [81].

Under conditions of visual stimulation, component N2 has the highest amplitude in the preoccipital region [80]. The amplitudes and latencies of the N2 vary considerably depending on peculiarities of the experimental task [77] and patterns of the stimulus, i.e., texts (written words), images of the objects, or human faces. Using recording with intracranial electrodes localized immediately in the cortex (i.e., recording of electrocorticogram, ECoG), Allison et al. [82] showed that visual presentation of a few written/typed words elicits the N2 component in the occipital gyrus in the vicinity of the occipito-temporal sulcus. It was also found that presentation of the images of complicated objects results in the development of higher-amplitude N2, as compared with the effects of presentation of meaningless and distorted images. The use of portraits of human faces as the stimuli resulted in generation of

the maximum N2 components in the fusiform gyrus. These data show that generation of the N2 probably correlates with category-specific processing of the stimulus [82]. Other researchers also mentioned the relation of the development of the above component to the processes of categorization. In particular, Oades [58] hypothesized that the amplitude of component N2 shows a certain correlation with categorization of the stimuli; this parameter decreases with age and with decrease in the level of concentration of attention.

Some researchers classified a separate component of visual EPs, the N170, which is specifically related to visual processing of immediate perception of human faces or perception of their images. According to their opinion, the N170 component is a member of the N2 component family. It develops with a 155 to 190 msec latency, and its amplitude is the maximum in the occipital/temporal regions of the cortex [83, 84]. It was shown that component N170 is characterized by a significantly higher amplitude in the case of presentation of the face images but not of other objects; it is not generated at all in subjects suffering from prosopagnosia (inability to recognize faces) [85]. According to the data of magnetic resonance tomography (MRT) [86] and intracranial recording of EPs [82], the fusiform gyrus is the neuroanatomic substrate responsible for generation of the N170 component. At the same time, additional sources of generation of this oscillation could be detected in the lateral occipital/temporal region outside the fusiform gyrus [87].

Component P3 (P300) develops within a time interval of about 250 to 500 msec after presentation of a target stimulus against the background of standard stimulations [88]. This EP oscillation is characterized by a rather diffuse topographic distribution, and its amplitude reaches the maximum in the central/parietal and parietal cortices; higher values of the amplitude of the P3 wave are observed in the left hemisphere. When standard (targetless) stimuli are presented, the P3 also can develop, but, in this case, its amplitude is considerably lower, and interhemisphere topographic differences are absent [89].

As is supposed, the P3 wave is a conglomerate of several oscillations having different topography and dissimilar latencies. If such oscillations of the potential overlap completely each other, an integral P3 wave is formed. In other case, where the latencies of these oscillations somewhat diverge, two to three waves can be differentiated in the P3, and it is possible to call the latter the P3 complex [90]. In addition, at least two independent oscillations generated in dissimilar

cortical regions within time intervals close to each other are described as the P3 complex. Under conditions of passive attention, when no active behavioral response to presentation of the target stimulus is needed from the subject, a version of the P3 component known as the P3a is elicited [91]. In the case of visual stimulation, the P3a is characterized by a shorter latency, as compared with that of the corresponding component in auditory [93] and somatosensory [94] EPs; the P3a is maximally manifested in the frontal cortical regions. The “frontal” P3a is probably recorded under conditions of involuntary attention, and its peculiarities are to a significant extent determined by the context of the experiment [95, 96]. In the case of active attention to the stimulus, especially when it is necessary to realize a motor response to the latter, the P3b component is generated. It is characterized by a longer latency, as compared with that of the P3a, and is better expressed in the central/parietal regions [2, 88]. As was supposed, generation of the P3a component is related to the influences incoming via the frontal dopaminergic (DA) projections to the cortex, while generation of the P3b is determined by the activity of the parietal noradrenergic (NA) pathways [97].

The opinions of different researchers about the effects of the stimulus modality on the amplitude/temporal characteristics of the P3 are to a considerable extent contradictory. It was reported [98] that the amplitudes and latencies of the P3 component of visual EPs are higher than the respective parameters of auditory EPs. Nevertheless, most authors believe that the modality of the stimulus exerts no significant influence on both the amplitude and latency of the P3 [80] and topographic distribution of this oscillation [89].

Sources of generation of the P3 have still not been entirely identified. There are, nonetheless, indications that the medial temporal cortical lobe [99], hippocampal region [100], and parahippocampal gyrus together with the amygdala and thalamus [101] are related to the genesis of this component. These data are supported by clinical observations of neurological patients with the impairments of the parietotemporal regions of the cortex, allowing one to suppose that the temporal structures play an important role in generation of the P3 complex [102]. Results of examination of relations between the parameters of component P3 with the characteristics of memorization and reproduction of the semantic material led to the supposition that the P3 reflects modulatory inhibitory influences coming from the temporal cortical structures and increasing the thresholds for excitation of cortical neuronal

networks [103]. As was demonstrated in experiments on animals, some loci of the parietal cortex participate in generation of the P3 wave [104]. The brainstem structures are probably also involved in generation of the P3 oscillation and N2-P3 complex [105]; the prefrontal cortex plays a role of the modulator of the above wave [106]. As is believed, the associative temporal/parietal cortex is of key importance for the development of the P3b upon presentation of the target stimuli, while the frontal/lateral cortex is related mostly to generation of the P3a in the case of action of the novel stimuli [94]. It was shown in experiments on animals (cats) that the cholinergic system plays an important role in generation and modulation of a positive wave in EPs, which is believed to be an analog of the P3 in humans [107]. Activation of NA-ergic neurons is a necessary prerequisite for the development of the P3 [108, 109]. As was thought, the P3 reflects the arrival of phasic activity from the NA-ergic system of the *locus coeruleus* and the influence of potentiation of the NA system on information processing and formation of the decisions [110].

Despite the fact that the P3 wave at present is one of the EP components examined in detail, the problem of its probable functional significance remains unresolved and urgent. It should be recognized that the P3 (P300) is a complex of a few waves, and the measured amplitudes of this complex in general or amplitudes of its subcomponents do not necessarily correlate with a single definite type of cognitive activity. It was supposed that generation of the P3 component is related to the formulation of a decision, level of subjective confidence, significance of the stimulus, transition from one stage of behavior to another, and characteristics of short-time memory [1, 3, 12, 111]. There were also suppositions that the P3 plays the role of an indicator of memory innovation, i.e., the process of replenishment of memory with novel information [112]. According to some concepts, the P3 component is related to estimation of the stimulus significance and correction of the memory-stored information, in agreement with the new data obtained [57, 58]. The P3 was also interpreted as a phenomenon related to the mechanisms underlying formation of a decision based on the comparison of the incoming signal with a model of some stimulus present in the memory store [113]. As is believed, stabilization of the parameters of the P3 is an indicator of the cognitive maturity of the brain [2]; the final formation of this component reflects termination of the processes of myelination of nerve fibers and synaptogenesis in various CNS regions (first of all, in frontal regions of the neocortex) [114]. In the

case of retardation of mental development typical of children whose parents suffered from alcoholism, the P3 component appears reduced [115]. Generation of the P3 probably correlates with the recognition of a perceptive decision on identification of the relevant signal and corresponds to the final stage of information processing in higher CNS structures [116].

The P3 is considered, from a definite aspect, an electrographic manifestation of the orientation reflex. Similarly to the phenomenon of the orientation reflex itself, a well-expressed P3 wave is elicited upon presentation of unexpected and task-relevant stimuli, and its development is related to disagreement between the trained behavioral scheme and the realized event. The P3 parameters, as was believed [117], reflect the extent of such disagreement and correlate to a greater extent with encoding and evaluation of the stimulus than with producing an effector reaction.

It was demonstrated that the amplitude of component P3 depends on the level of attention [118], on the probability of presentation of the target stimuli within a train of the standard ones (the less frequently the target stimuli is presented, the higher the P3 amplitude), and also on the subjective value and motivational significance of the stimuli [70]. It is known that the highest amplitude of the P3 is observed in those subjects who perform an experimental task best and are characterized by greater cognitive maturity [70]. As was shown [119], the duration of the interstimulus interval influences the amplitude of the P3 independently of the probability of presentation of the stimulus; the shorter the interval, the higher the P3 amplitude.

The latency of the P3 component varies depending on the complexity of the stimulus [120], the successfulness of differentiation between the target and background stimuli [121], and the maintenance of sufficiently high level of attention [122]. It was also found that the latency of the P3 reflects the duration of the process of evaluation of the stimuli [112] and also correlates with the cognitive abilities of an individual. In this case, shorter latencies of initiation of the P3 are associated with more successful cognitive activities [123].

Changes in the characteristics of component P3 are in close correlation with various disorders of cognitive functions. Due to this peculiarity, recording and analysis of this wave are extensively used in clinical examinations, e.g., in Alzheimer's disease, schizophrenia, and other pathologies [2]. Abnormally long latencies of the P3 were observed in patients suffering from non-demented Parkinson's

disease [124] and also in patients with panic disorders [125]. Taking into account that the parameters of the P3 closely correlate with the characteristics of attention, researchers extensively studied subjects with attention-deficit hyperactivity disorder (ADHD). In these individuals, reduction of the P3 wave is observed [126, 127]. There are indications that subjects with asocial behavior are distinguished by a higher P3 amplitude upon presentation of a warning stimulus [128]. In a situation where differentiation of the rare target stimuli is necessary, such subjects demonstrated a relative increase in the P3 duration. The cited authors interpreted these results as related to the ability for especially intense short-term mobilization of cognitive resources, which is frequently noticed in psychopathies.

Studies carried out in recent years have shown that the main characteristics of the P3 are inherited to a considerable extent. Such inheritance is related to definite loci in the human genome; these loci also determine stable properties of personality. A decreased amplitude of the P3 is a significant marker of predisposition to alcoholism and drug addiction [129]. Noticeable correlations between the P3 parameters and the peculiarities of the temperament and character of individuals were also found [130-132].

After the P3 component, one more late positive wave develops. Most frequently, it is mentioned in publications as the slow wave, SW, and its latency varies approximately between 400 and 1,000 msec. In some cases, a long-lasting oscillation with similar characteristics is called the late positive potential, LPP (latency 400 to 700 msec) [133]. Characteristics of such electrophysiological phenomena considerably vary depending on requires of the experimental stimulation and correlate with operations performed by working memory [134, 135].

The P600 component that is also considered to be related to the memory processes has been sometimes distinguished within the same time range. This component develops in about 400 msec after presentation of the stimulus and lasts from 400 msec to 600 msec or more [136]. There is an opinion that the P600 correlates with the process of recognition of the stimulus [136]. When the stimuli that were presented to the tested subject earlier are used, the P600 components are characterized by a higher amplitude than those observed in situations with novel (never used earlier) stimuli [137].

In general, the number of studies of the late EP components and their functional significance remains at present relatively limited, and interpretation of their

results and the conclusions proposed are frequently contradictory.

ELECTROENCEPHALOGRAPHIC EPs UPON PRESENTATION OF EMOTIOGENIC STIMULI

As was noticed in the early studies dealing with the influence of emotions on the EP characteristics, the amplitude of component P3 increases when the emotiogenic stimuli are applied, and this effect shows no dependence on the sign of emotions [138, 139]. Further studies showed that the emotional "tint" of the stimulus affects stages of informational processing beginning from rather early time intervals (70-100 msec). The most expressed differences are, however, observed in long-latency EP components, such as the P3 and the potential following the latter (LPP). With perception of emotiogenic signals of both positive and negative valency, the amplitudes of these components are significantly higher than in the case of perception of emotionally neutral signals [133, 140-142].

Distinguishing the two main measures of emotions, their valency (pleasure/displeasure), and the level of emotional activation (quiet/agitation) is the generally accepted mode of classification of changes in the emotional state [143]. It was found that both emotional valency of the presented stimuli and level of existing emotional activation exert modulatory influences upon the EP parameters. The stimulus valency affects mostly relatively early (100-250 msec) EP components, while the level of emotional activation influences late components [141, 144]. It should, however, be noted that such changes were mostly attributed to the amplitude characteristics of EP components, while the latencies of these components in the case of presentation of emotiogenic stimuli changed, according to the published data [7], insignificantly.

A few studies showed that the amplitude of component P1 depends on the emotional valency of an image presented as the stimulus. In the case of negative stimuli, it was higher than the analogous P1 parameter upon presentation of positive and neutral stimuli [145-147]. This effect was observed in the occipital [145, 147] and temporal [147] cortical areas. It was noticed that the amplitude of the late P1 subcomponent (latency 160 msec) in the frontal regions is higher in the case of action of negative stimuli [148]. Comparable data were obtained with respect to the N1 oscillation; its

amplitude in the occipital/temporal cortical regions was found to be higher under conditions of perception of the emotiogenic stimuli (with no dependence on the sign of emotions) [149, 150]. It is interesting that habituation of the N1 (progressive decrease in its amplitude in the frontal cortical regions in the course of repeated stimulation) in the case of a negative tint of the stimuli was considerably less expressed than the similar process upon presentation of other categories of the stimuli [151]. According to some researchers, an increase in the amplitudes of the early EP components (latency 100 to 250 msec) under the influence of negative stimuli agrees with the hypothesis on a higher sensitivity of the cerebral information-processing systems to negative emotiogenic stimulation. Negative stimuli in the first turn attract selective attention and more intensely activate the corresponding cortical zones [152, 153].

The EP components developing within a 200-300 msec range of the latencies are also subjected to modulation determined by an emotional content of the received information; the opinions of different authors on the pattern of these influences are, however, rather contradictory. It was mentioned that the amplitude of component P2 increased upon perception of both positive and negative stimuli, but the amplitude of the next (N2) component under conditions of presentation of positive stimuli was higher than in the case of negative and neutral ones [145]. At the same time, it was shown that the N2 amplitude was higher under conditions of presentation of the stimuli of all valencies [154], while the amplitude of the N2-P3 complex in the parietal regions of the right hemisphere was higher upon the action of negative stimuli [155]. According to the opinion of the cited authors, this fact supports the hypothesis on a leading role of the right hemisphere in the processing of emotionally negative information. There are data on increases in the amplitude of component P2 and decreases in its latency upon presentation of emotionally negative stimuli. Considering that correlation of the amplitude/temporal characteristics of the P2 with the state of the attention sphere has been demonstrated many times, the authors [156] concluded that negative signals attract relatively greater attention and, correspondingly, determine the formation of a faster and more expressed EP response, as compared with those related to neutral and positive signals.

An extensive series of studies showed that the emotional significance of stimuli noticeably influences the amplitude of the late EP components (latency 300-800 msec). Interesting results were obtained by

Begleiter et al. [138, 139] who studied cortical EPs elicited by presentation of emotionally significant visual “verbal” information, i.e., textual images of pleasant, unpleasant, and neutral words. The EPs were recorded under conditions of presentation of either verbal stimuli themselves [138] or after training of a conditioned relation between an abstract visual signal (image of an arrow or a geometric figure in a definite position) and one word or another [139]. In the case of the use of unpleasant words, the amplitude of late EP components (wave P3 and the preceding negative oscillation) was higher than that upon presentation of neutral words. The same was observed in the case of combination of a visual signal with an emotionally significant word when correlation between the conditioning stimulus and the emotion was recognized by the subject.

In the study carried out by Johnston et al. [157], the effect of the emotional content of an image on three EP components with the maxima within a 300 to 920 msec range was demonstrated. When portraits of normal faces (neutral stimuli) and faces of subjects suffering from various dermatopathologies (emotionally negative stimuli) were used as the stimuli, the emotional content influenced late EP components with peak latencies of 285, 380, and more than 500 msec [155].

Many authors mentioned that the amplitude of wave P3 was higher under conditions of perception of emotiogenic signals, as compared with the effects of neutral signals [97, 140, 142, 158]; a negative emotion-related increase in the amplitude of the LPP was also noticed. In this case, on-modulation of the LPP amplitude was preserved even under conditions where one and the same image was repeated many times [141]. Increments in the amplitude were most clearly manifested in the occipital and posterior temporal regions, predominantly in the right hemisphere [133]. Bilateral changes in the P3 and LPP were, however, also found, and left-side asymmetry of processing of the affective information within earlier stages (corresponding to components P1 and N2) was observed [159]. A higher amplitude of the P3b subcomponent (latency 460 msec) was noticed in healthy subjects in the case of presentation of negative stimuli, as compared with the effects of neutral ones; this phenomenon was most clearly expressed in the right parietal region. In subjects suffering from depression, a smaller amplitude of the P3b combined with a higher amplitude of the P3a wave (latency 330 msec) was observed under conditions of negative stimuli used. According to the authors [160], this fact

can indicate that “late” estimation of the emotional content of the stimuli is disordered in these subjects; such estimation is related to selective inhibition of the right parietal cortex, which plays an important role in the perception and estimation of the emotionally tinted signals. Results of examination of processing of the emotional information in representatives of different national cultures showed that early EP components do not differ from each other in Frenchmen and Japanese; at the same time, the late components in the occipital/parietal regions had considerably lower amplitudes in Japanese than in Frenchmen [161]. The authors concluded that the well-known phenomenon of more restricted emotional behavior of the main massive of Japanese can be related to a somewhat “suppressed” functioning of the parietal neocortical regions, as compared with what observed in Europeans.

At the same time, studies of Kostandov [162] showed that the emotionally determined dependence of characteristics of the late cortical response is typical of the occipital region but is completely absent in the associative cortical zones. It was noted that the P3 wave related to visual presentation of emotionally significant words developed in the cortical regions with a significantly shorter latency than the respective responses to neutral words. Shortening of the latencies related to the action of emotionally tinted stimuli was expressed considerably more intensely in the left hemisphere than in the right one. Simultaneously, the amplitude of wave P3 at the action of emotiogenic stimuli was higher in the occipital zones of both hemispheres, but the difference was noticeably greater in the right hemisphere than in the left one [163]. According to the author's opinion, these data showed that changes in the wave P3 related to the action of emotionally significant visual stimuli were mostly observed only in the occipital cortex, i.e., were limited by the zone of the corresponding (visual) cortical analyzer.

It is interesting to note that emotiogenic stimuli are selectively processed by the brain even in the case of their presentation within an extremely short time interval insufficient for complete recognition of their meaning. As was shown [159], adjectives with an emotional tint, when visually presented during a time sufficient (40 msec) or insufficient (1 msec) for their recognition, led in both cases to the formation of higher amplitudes of components P1, P2, P3, and LPP than words with a positive emotional tint.

In general, the published data are in agreement with the statement that the emotional significance of the stimuli is reflected in a definite manner

mostly in the characteristics of late EP components (latencies greater than 200 msec), and the respective manifestations are, in most cases, maximal in the right hemisphere.

CORRELATION OF THE CHARACTERISTICS OF EEG EPs WITH PECULIARITIES OF THE PERSONALITY

According to the accessible publications, the amplitude/temporal parameters of different EP components reflect rather significantly (but, of course, not absolutely) individual peculiarities of temperament and specificities of personality. Techniques for detection of these peculiarities (mostly using the corresponding questionnaires) have been developed in detail, and their validity has been demonstrated. Correlation of the parameters of EP components (mostly those of wave P3) with such a general personality index as extraversion/introversion has been mentioned many times. It should, however, be emphasized that the opinions of different researchers on the pattern of such relations are in many cases contradictory. Observations of a few authors indicated that the amplitude of the P3 in introverts is higher than that in extraverts [164], and the most clearly expressed (significant) differences were observed in the central/parietal/occipital regions [130]. As was supposed [165], the greater P3 component in introverts is related to the greater level of voluntary attention in these subjects and also to the higher level of general cerebral activation [166]. Negative correlation between the level of extraversion and the latency of component P3 was also found, i.e., the P3 wave develops in extroverts with a shorter latency than in introverts [167].

At the same time, other rather numerous studies have shown that the P3 component in subjects with high indices on the extraversion scale has a higher amplitude than in subjects with low estimates when using this scale [132, 164, 169]. It was, however, found that extroverts are characterized by more intense habituation to stimulation than introverts. Therefore, the averaged P3 potential can be characterized by a lower amplitude [170]. It was supposed that a higher amplitude of the P3 in introverts can be related to more intense habituation in extraverts because this wave is probably recorded in most cases under conditions of presentation of a great number of similar stimuli. To check the correctness of such a supposition, Cahill and Polich [171] carried out a

study with minimization of the effect of habituation and found that, under such conditions, the P3 amplitude in the situation with differentiation of the target stimuli was higher in extraverts than that in introverts. At the same time, the latencies of this component were approximately the same in both above groups. Under conditions of an increase in the probability of presentation of the target stimulus, the P3 amplitude dropped, and this decrease was more rapid in extraverts than in introverts; i.e., introverts maintained the responsiveness for such stimuli for a longer time [171]. It was also shown that extraverts were characterized by a relatively higher amplitude of the P3 under conditions of short presentations of the stimuli and also in the cases where the experimental paradigm required cognitive efforts and did not require responses to presentation of standard-type monotonic stimuli [172]. It was also found [173] that negative correlations between the extraversion level and P3 amplitude under conditions of varied intensities of stimulation were replaced by positive correlations when the tested subjects were additionally subjected to the action of white noise (loudness 60 dB above the hearing threshold) in the task for visual vigilance. Such an effect can be correlated with inhibition that is initiated in introverts at lower stimulation intensities [174]. In a task requiring calculation of repeated acoustic signals, the amplitude and latency of component N1 in introverts were significantly smaller than those in extraverts. Under conditions of a sensorimotor task, a different dependence was observed. Introverts were characterized by greater amplitudes and latencies of the N1 component, as compared with the respective indices in extraverts. In this case, the P3 amplitude within the framework of both tasks was higher in extraverts [168].

Individuals with higher indices based on the extraversion scale demonstrated more intense responses to presentation of emotionally tinted verbal stimuli when positive-valency stimuli were used. This was expressed in the formation of higher-amplitude P3 waves in the frontal and parietal regions of the left hemisphere [132]. Other researchers observed in introverts higher amplitudes of the P3 upon the action of neutral stimuli, while in extraverts the P3 wave was greater under conditions of presentation of both positive and negative stimuli [131]. The authors supposed that more intense activation of neuronal systems in the frontal cortical regions of extraverts develops independently of the emotional valency of the stimulus.

It was also mentioned that persons characterized by higher estimates by the “search for novelty” scale demonstrate a trend toward higher values of the peak amplitude of wave P1-N1 under conditions of both auditory and visual stimulation in the course of increase in of the stimulation intensity (the so-called augmentation phenomenon). At the same time, individuals with low indices by this scale demonstrated the maximum amplitude at lower intensities of stimulation (the reduction phenomenon) [175]. Such observations indicate that subjects with a drive for “search for novelty” need, as a rule, higher levels of stimulation. It was also noted that the index “search for novelty” positively correlated with the latency values of the N1 component of auditory EPs in both the left and right hemispheres [176]. At the same time, the P3 latency showed negative correlation with estimates by the “search for novelty” scale, and positive correlation of the latter index was found with estimates by the “persistence” subscale [177].

The amplitude of the P3 component positively correlated with the estimates of frankness, readiness for cooperation, and conscientiousness, while negative correlation was found for the neuroticism level [178]. Positive correlation of the P3 amplitude was also revealed with the indices “dependence on a reward” of the Cloninger’s questionnaire [177]. The latter feature of personality, as is supposed, correlates significantly with the level of activity of the cerebral NA system [179]; this system, in turn, influences the amplitude/temporal parameters of the P3 wave [108, 109]. Persons with a higher level of the activity of the NA system showed shorter latencies of the P3 component [180]. Other authors, when comparing subjects with high and low levels of neuroticism, found greater amplitudes of all EP components, relative shortening of the latencies of early EP components, and prolongation of the late components in the occipital regions of highly neurotic subjects; these dissimilarities were most pronounced in the right hemisphere. At the same time, relative decreases in the amplitude and increases in the latency of all EP components mostly expressed in the left hemisphere were noticed in the left hemisphere [181].

Tested subjects characterized by a high anxiety level showed higher amplitudes of the N1 component in the frontal cortical regions after presentation of tonal auditory stimuli [182]. In the course of the studies of the cognitive P3 component of auditory EPs in subjects with a high anxiety level, lower amplitudes of the P3 and distortion of the habituation process

(dishabituation) of this wave were observed in both hemispheres [183].

In a few studies, correlation of the spatiotemporal characteristics of EPs with an individual level of aggressiveness was found [184, 185]. Such correlations were found for all EP components, beginning from the shortest-latency ones (in particular, having mostly the brainstem genesis). It was also mentioned that brainstem auditory EPs were elicited with longer delays in high-aggressive subjects than in persons with lower aggressiveness [186].

Both the amplitude and latency of mid- and long-latency EP components probably also correlate with the aggressiveness and level of psychoticism of the individual. Information on these relations is, however, rather contradictory. It was found that the amplitudes of components N1 and P2 of auditory EPs in healthy subjects negatively correlated with the level of psychoticism [187] and a number of the indices of aggressiveness [188]. At the same time, among teenagers with psychotic deviations, individuals inclined to impulse aggressive behavior demonstrated a higher amplitude of the P1 component when light flashes and reversion of images were used as the stimuli [189]. Examination of healthy young subjects (students) gave somewhat different results [190]. As was found, individuals with a drive to impulsive aggression were characterized by smaller amplitudes of component P1 and higher amplitudes of the N1; the latencies of the P1, N1, and P2 components in EPs initiated by light flashes were shorter in these individuals. In addition, such tested subjects showed a clearer increase in the amplitude of the P1-N1 complex with increase in the stimulation intensity, as compared with what was observed in the control group. In other words, individuals with inclination to impulsive aggression belong to the so-called augmenters; in these subjects, cerebral activation develops with nearly no limitations or with insufficient limitation from the side of “superlimit” inhibition.

In the course of a computer game with the aggressive content, the amplitude of the N2 component in the frontal cortical regions of teenagers with a high background level of aggressiveness increased, while in the temporal regions this parameter decreased. At the same time, a decrease in the N2 amplitude in the frontal zones and an increase of this index in the temporal regions were observed under the above conditions in teenagers with a low initial level of aggressiveness [191].

The specificities of the amplitude and latency of

the P3 component as a prominent feature of EPs recorded within the odd-ball paradigm (with the use of frequent and rare acoustic tonal stimuli) were found in the frontal leads of impulsive aggressive healthy persons [192]. Positive correlation of the latency values of the P3 component with the estimates of aggressiveness was also found in such situation in healthy tested subjects [193]. Results of a similar study with presentation of frequent and rare visual stimuli demonstrated the simultaneous existence of negative correlation of the amplitude of this wave and positive correlation of its latency with the level of aggressiveness [194]. Reduction of the P3 was found in aggressive alcoholics, and this feature differed them from non-aggressive ones [195]. Longer latencies of the above-mentioned wave were demonstrated by imprisoned subjects characterized by inclination to aggression [196]. The higher the impulsivity as the personality feature of criminals, the lower the values of the P3 amplitude in these aggressive subjects [197]; at the same time, no significant differences were found between the latencies of this EP component [198]. The use of the odd-ball paradigm allowed researchers to find a positive correlation between the P3 amplitude in parietal leads with the motor impulsivity [199].

In situations where the P3 component was elicited by presentation of a feedback signal informing the tested subject about the successfulness/failure of the performance of the experimental task, the difference between the amplitudes of the P3 in the cases of presentation of positive and negative signals positively correlated with the level of psychoticism of the individual [200]. The tested subjects with high estimates based on the psychoticism scale demonstrated significantly higher-amplitude P3 components after presentation of positive signals, as compared with those developed after the arrival of negative signals. This observation agrees with the characterization of such individuals as subjects ignoring warnings on possible mistakes and danger but aiming at a reward [201]. Subjects with low estimates of psychoticism were characterized by higher amplitudes of the P3 related to presentation of positive and neutral stimuli than persons with high indices of psychoticism [132]. According to the cited authors, this fact supports the hypothesis that subjects with low levels of psychoticism are more sensitive to stimuli associated with positive emotions; it also agrees with the earlier obtained data on the existence of negative correlation of the psychoticism level with the magnitude of positive affects [202].

ROLE OF AMINERGIC CEREBRAL NEURONAL SYSTEMS IN THE FORMATION OF INDIVIDUAL FEATURES OF THE PERSONALITY, EMOTIONAL STATES, AND THE PATTERN OF EEG EPs

We believe that correlation between the features of the personality, peculiarities of perception of emotionally tinted stimuli, and characteristics of EPs can, to a significant extent, be explained by specificities of the functioning of a few brain neurochemical systems. At present, when analyzing biological factors determining the formation of the human personality, researchers do not consider the brain as some homogeneous (nevertheless extremely complicate) giant neuronal network or as a simple totality of different morphological structures. The brain is interpreted as a complex of definite structural/functional neuronal systems, and each of them is characterized by a unique neurochemical nature. As is supposed, the inheritance of the personality features is, in this case, due to complicated interaction of the peculiarities of gene control of the development of cerebral neuronal systems possessing a definite transmitter/mediator nature, control of the receptors of one neurotransmitter and mediator or another, and effects of biologically active compounds, which are directly involved in the metabolism of the above transmitters or modulate this metabolism [179, 203, 204].

Interaction of such neuronal systems should inevitably "tint," in one way or another, the entire behavior of a person, influence the learning processes, mediate the effects of reward and punishment, and determine a concrete mode of behavioral activity. To provide the influence of a definite separate neuronal system on general informational processing, the structural/functional organization of this system should satisfy the following requirements analogous to those formulated for the neuronal systems controlling learning [205]. Such a neuronal system should possess projections distributed across the entire cerebral cortex (or, at least, should project to sufficiently extensive regions), should control synaptic intracortical neuron-to-neuron connections, and should exert long-term effects on the efficacy of these connections. Systems related to reward and punishment should exert opposite influences on cortical synapses, and intracortical terminals of the pathways from these systems should release different transmitters absent in the neocortical neurons.

Aminergic systems formed by neurons situated in relatively local brainstem regions meet these

requirements. Synapses of the corresponding chemical nature are not presented among the synapses typical of cortico-cortical connections. Terminals of the axons of aminergic neurons form varicosities containing vesicles with a neurotransmitter; these varicosities are, in fact, presynaptic structures with no postsynaptic compartments. Their transmitters are frequently released into the intracellular space and possess, in such a way, access to numerous cortical neurons and their synapses (the so-called volume neurotransmission).

In other words, we can suppose that definite factors of the biological substructure of a personality (temperament) are, to a considerable extent, controlled by extensively ramified cerebral neuronal systems using different transmitters. These are, first of all, DA, NA, and ST systems; their effects are capable of modulating various types and manifestations of behavior.

Findings made in numerous studies showed that the DA system is undoubtedly involved in the organization of motivation behavior. As is believed, the DA system belongs to a group of the cerebral systems forming the reward-related system [206, 207]. Processes of learning, memory, the level of attention, the development of research activity, anxiety, melancholy, and "social emotions" related to parting events are interpreted as being realized with the involvement of the NA system [206, 208].

Activation of the ST system restricts informational processing in the CNS; the ST system is actively involved in the organization of social behavior. Clinical symptoms of exhaustion of the ST-ergic transmission in humans are frequently accompanied by mental disorders manifested not only in intensification of anxiety but also in increases in the level of aggressiveness and the probability of suicidal attempts [206, 209, 210].

How does the aminergic systems influence the psychodynamics in humans? According to Gray [211], such a category as the temperament reflects individual specificities of the personality from the aspect of predisposition for certain types of emotions and general intensity of the latter. For example, the emotion of gladness predominates in sanguinic persons, anger is the clearest emotion in choleric, sadness is typical of melancholics, while all emotions are relatively "wiped off" in phlegmatics. Gray believes that all types of emotions are in general determined by the following three integral systems:

(i) Emotional system of the "bringing nearer" behavior includes the basal ganglia, prefrontal and

motor cortices, thalamus, and brainstem DA system. These structures form the cortical-subcortical loop of positive feedback. The system is activated by stimuli related to reward or absence (missing) of punishment.

(ii) Emotional system "struggle/escape" includes the amygdala, medial hypothalamus, and central grey. This system is responsible for the reactions induced by presentation of undoubtedly dangerous stimuli. The responses elicited (defensive aggression or flight) are related to the emotions of fury and horror.

(iii) Emotional system of behavioral inhibition is formed by the hippocampus, septal region, circle of Papez, and ST and NA systems. This system is responsible for perception of "frightening" aspects of the reality. Depending on the balance of activity between the ST and NA systems, activation of this integral system leads to behavioral inhibition, "standing still," and development of the subordinated behavior (domination of the influences of the ST system) or, vice versa, to intensification of the research activity and dominating behavior (greater activity of the NA system). Activation of the system of behavioral inhibition is accompanied by the development of anxiety.

The above-mentioned emotional systems, which include neuronal populations of the aminergic systems, influence behavior mostly by interacting with each other and not in an isolated manner. The final result of interaction determines the emotional tint of behavior. The individual specificity of interaction of these systems and level of their activities determines the personality's temperament. Cloninger [179, 212] postulates even a more important role of the systems of aminergic neurons in the formation of the structure of a personality. Based on the results of clinical observations and phylogenetic analysis of the learning processes, he proposed a hypothesis according to which neurons of the aminergic systems provide regulation of the neuroadaptation systems, modulation of the processes of central activation, and the maintenance of behavioral responses at the adequate level and their inhibition. Each of the mentioned neuroadaptation systems is represented by a complex including a few cerebral regions; their activity is realized with the involvement of many transmitters, co-modulators, regulatory neuropeptides, and hormones. Nevertheless, each definite monoamine plays the main neuromodulatory role provided by a single system. The DA release is related to behavioral activation and search for sensations, that of ST correlates with behavioral inhibition and avoidance from failures,

while the NA release is related to the maintenance of current behavior and dependence on a reward. These principles of organization allow one to explain the existence of at least three of the four existing typical patterns of temperament. In turn, the activity of aminergic systems is determined by an individual set of the genes (one allele or another) and interaction of the levels of their expression. The individual number of aminergic neurons, peculiarities of spatial distribution of their axons, polymorphism of receptors and transport of transmitters, and also interaction between the genotype-determined phenomena and social environment are rather significant factors.

Therefore, both individual peculiarities of emotional reactions and the pattern of EEG EPs noticeably depend on the development and state of the aminergic cerebral systems. It is logical to suppose that a reverse relation exists: The levels of expression of biologically predetermined features of the personality, spectrum of emotions, and peculiarities of the characteristics of definite components of EEG EPs allow researchers to discover, to a greater or smaller extent, the peculiarities of functioning of the aminergic systems.

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