Electroencephalographic Evidence on the Strategies of Adaptation to the Factors of Monotony

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In a series of studies, in which 19 apparently healthy male volunteers participated, on the basis of a comparative analysis of the bioelectric brain activity and work performance, it is shown that two strategies of adaptation to the factors of monotony are possible. One of them is based on the maintenance of a high quality of activity even at the price of a considerable reduction in the functional state of the brain; the second is based on the maintenance of the functional status of the brain even at the expense of the short-term loss of control over realizable performance. The factor conditioning the long term inability to support continual high quality of performance under the conditions of monotony is a high lability in nervous processes. The resistance to the effects of the factors of monotony is connected, on the other hand, with the low lability of nervous processes with a certain predominance of excitatory processes over inhibiting processes. The electrographic correlates of the development of the state of monotony represent an increase in the EEG of an alert person of the slow spectra (theta and alpha), and also beta-2 waves, as well as a reduction in the intrahemispheric coherence of alpha-waves. These results can be used for the development of control systems for the state of the operators who work in conditions of monotony (pilots, the operators of electric trains, the operators of power plants, including atomic power plants, and others), as well as in the occupational selection of individuals for jobs involving work under such conditions.
Keywords: electroencephalography, monotony, power spectra, coherence spectra

Sobre la base de un análisis comparativo de la actividad bioeléctrica del cerebro y del rendimiento en el trabajo, se mostró en una serie de estudios en los que participaaron voluntarios masculinos aparentemente sanos que es posible tener dos estrategias de adaptación a los factores de la monotonía. Una de ellas se basa en el mantenimiento de una alta calidad de la actividad, incluso a costa de una considerable reducción en el estado funciónal del cerebro; la segunda. se basa en el mantenimiento del estado funcional del cerebro, incluso a costa de una pérdida de control a corto plazo del rendimiento posible. El factor que condiciona la incapacidad a largo plazo de soportar la alta calidad continua del rendimiento bajo condiciones de monotonía es una alta labilidad en los procesos nerviosos. La resistencia a los efectos de la monotonía se relaciona, por otro lado, con la baja labilidad de los procesos nerviosos con cierto predominio de procesos excitatorios sobre los procesos de inhibición. Los correlatos electrográficos del desarrollo del estado de monotonía representan un aumento en el EEG de una persona alerta de las ondas lentas (zeta y alfa), y también las ondas beta-2, además de la reducción en la coherencia intrahemisférica de las ondas-alfa. Estos resultados pueden utilizarse para el desarrollo de sistemas de control para el estado de operadores que trabajen en condiciones de monotonía (pilotos, conductores de trenes eléctricos, operadores de centrales eléctricas, incluyendo centrales nucleares, y otros), además de en la selección de individuos para puestos de trabajo en dichas condiciones.
Palabras clave: electroencefalografía, monotonía, espectro de potencia, espectro de coherencia

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The question about the relation between stable individual traits and characteristics of human performance is urgent both in the theoretical and in the practical aspects. Interest in this grew substantially in the middle of the 20th century in connection with the massive expansion of the profession of the operators for management and control systems monitoring, which is currently one of the most common occupations. The improvement in the technical sector of control systems created a situation in which the human element became its most vulnerable link, determining the stability and reliability of the functioning of the system as a whole; and the so-called human factor becames a source of mistakes, the consequences of which are often large-scale technogenic catastrophes with massive loss of human life. The reason for such errors, as a rule, lies in the decline of the functional state of the working person, caused, in particular, by the influence of surrounding factors, including the conditions of the activity being performed.

Since it is often necessary for the operator to work in a standby or monitoring mode and in the context of the scarcity of information and the presence of pronounced monotony of the performed activity, this leads to the development in the individual of the state of decreased wakefulness or monotony, which affects his or her work performance. It is shown that the resistance of operators to the operative factors of monotony varies significantly and is determined, first of all, by their individual-typology characteristics. The ones who suffer from the influence of the factors of the monotony to the greatest degree are those who possess significant power spectra and a high level of EEG coherence (above all, in the frontal lobes), which indicates the strength of nervous processes, and at the psychological level, correlates with extraversion and low anxiety (Asvaduryan, 1991; Malakhov, 1988; Rozhdestvenskaya, 1980; Rusalov, Rusalova, Kalashnikova, Stepanov, & Strel´nikova, 1993). On the other hand, an important factor which influences work performance is the functional state of the brain, a decline of which under the conditions of the operative factors of monotony, can even lead to "failures" in the performance of the operators (Dikaya, Shapkin, & Gusev, 1992). And finally, the individuals with high levels of motivation, even though they may essentially differ in their specific traits, can function effectively for a long time under conditions of the operative factors of monotony (Bodnar, Zarakovsky, & Chainova, 1999).

Therefore, in spite of a sufficiently large number of works dedicated to the study of different aspects of the state of monotony, the mechanisms of its formation, the strategies of adaptation to the operative factors of monotony and their interrelation with the individual-typological character traits remain understudied to this day, which hampers the development of methods of control and prediction of this state, or the professional selection of individuals who may be resistant to the influence of these factors.

The purpose of this work was the study of the interrelation of stable individual characteristics of properties of the nervous system, which are manifested in special features of time-spatial organization of the bioelectric brain activity, and the adaptive strategies of the operators to the influences of the factors of monotony.

Procedure

Nineteen male volunteers (average age of 22 years, all right-handers) participated in the study, each of whom performed a monotonous activity, by its very nature, connected to the recognition of visual and auditory signals for 3.5 - 4 hr. Psychological testing was conducted prior to the start and at the conclusion of the study, directed towards the estimation of the functional state of those being investigated. The diagnostic method of operative estimation HAM (H – health, A – activity, M- mood), Spielberg-Hanin diagnostic method of self-rating of situation anexity were used as well as 7 number scale on the determination of the subjective level of activity. The high level of motivation to perform effectively was determined by the condition that the quality of the accomplishment affected the amount of payment being provided for the participation in the study

Flashes of light-emitting diodes (red and orange) were used as visual stimuli, located at a distance of 80 cm from the eyes of the participants, while as auditory stimuli tones were used, with a frequency of 220 and 250 Hz supplied binaurally through head sets. The number of stimuli presented for each modality was 100 (50 stimuli were differentiated by individual characteristics), the duration of each stimulus was 100 ms, the luminous intensity was 25 mcd, and the intensity of sound was 60 dB. Stimuli were presented in a random order with an interval of 7 - 18 s.

According to their instructions, upon the appearance of a red flash or a higher tone (250 Hz) a participant had to push a button in his right hand as fast as possible, and upon the appearance of an orange flash or a deeper bass tone (220 Hz), push the button in his left hand. The modeling was done on a personal computer; the time of presentation and the type of stimulus, as well as the characteristics of the response reactions of the participants were recorded and stored in its memory.

Individual chronograms were constructed for each participant at the end of the study, in which the reaction times (RT) to the produced stimuli were calculated together with the probability of the appearance of errors. If no less than 80% of the response reactions of a participant during a consecutive 2 min period had a RT lower than the total average RT for the entire study, then this time period was identified as the stage of optimal working capability (OWC); if the RT was greater, then this time period was identified as the stage of decreased or pessimal working capability (PWC); see Figure 1. The first 15 min of work, because of variability, and due to a warming-up period, were not analyzed.
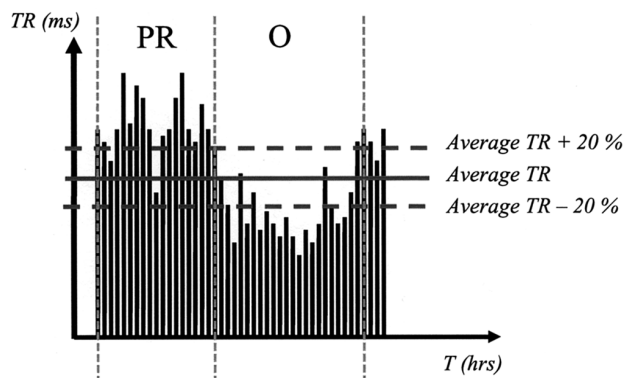
Figure 1. Diagram of the isolation of the sections of the pessimal (PWC) and optimal (OWC) working capabilities on the chronograms of the inspections.
Designations: T – the duration of the trial (in the hours), TR – times of response reactions (in ms).

EEG was recorded continuously during the entire study using unipole placement on 10 regions of the cortex: symmetrical frontal (F3, F4), temporal (T3, T4), central (C3, C4), parietal (P3, P4) and occipital (O1, O2), using the 10 x 20 system, relative to the combined referential electrodes, which were located on the mastoidal bones of the skull. An oculogram was recorded for the purposes of quality control of the electrograms.

The participants worked with open eyes. Before the work was activated, a test on the opening and closing of eyes was carried out and repeated upon command of the experimenter five to six times (the duration of each state was 30 s).

For the analysis of each of 4 states, that is, steady state with open eyes (OE) and closed eyes (CE) before the work, OWC, and PWC, they were selected from 30 - 40 artifact-free EEG-epochs with a duration of 1.28 s each (Kaplan, 1998). In the process of activity, for analytical purposes, the epochs which preceded the error-free reactions of the participants were selected, and were not less than 20% longer (state of PWC) or shorter (state of OWC) than the mean RT for the entire study as a whole.

The following characteristics were calculated for each assignment and state:
1. Prevailing frequency of the alpha wave.
2. Total power spectra (SSpM) of the EEG.
3. Averaged power spectra ([SpM]) of the EEG in the frequency ranges, which correspond to delta- (0.78-3.12 Hz), theta- (3.90-7.02 Hz), alpha-1- (7.80-10.14 Hz), alpha-2- (10.92-13.26 Hz), beta-1- (14.04-17.94 Hz), and beta-2-waves (18.72-30.42 Hz).
4. Averaged coherence spectra ([KoG]) in the frequency ranges for 45 pairs of the indicated electrodes, which were consolidated into blocks: symmetrical (5 pairs), intra-hemispheric and interhemispheric (each with 20 pairs).

Multivariate analysis of variance was used for the evaluation of the obtained results, and implemented using the multifactor analysis of variance (MANOVA). The ANOVA design for dependent sampling included the following factors:
1. State (S, gauge levels: OE, CE, OWR and PWR).
2. Frequency (R, gauge levels: delta-, theta-, alpha-1-, alpha-2-, beta-1-, beta-2-waves).
3. Abduction (L, gauge levels: F3, F4, T3, T4, C3, C4, P3, P4, O1, O2), for the averaged power spectra.
4. Pairs of abduction (Lc: the levels: 5 symmetrical pairs [Sym], 20 intra-hemispheric pairs [Vn], and 20 interhemispheric pairs [Mp]), for the coherence spectra.

For independent samples the major factor reported was the Group factor (G, gauge levels: 1, 2, and 3 groups of the participants).

The comparison of the results of psychological testing and indices of quality of performance of the participants was carried out according to a similar scheme. The following factors were identified:
1. Time (T, gauge levels: before and after studies).
2. Modality (M, gauge levels: visual, auditory stimuli).
3. Parameters (P, gauge levels: the scale values of the HAM questionnaire, the indices of subjective activity and level of situational anxiety, the average values of the reaction time at the stages of optimal and pessimal working capability).

With the value of $r \leq .05$, the differentials were considered to be statistically reliable, with $.05 < r \leq .08$ they became significant (the presence of a strong trend was stated) (Falkenstein, Hohnsbein, & Hoormann, 1994). For the best approximation of standard distribution the values of the power spectra underwent a log-transformation, while those of the coherence spectra underwent a Z-transformation (Kiroy, Warsawskaya, & Voynov, 1996).

Results

Dynamics of the Indices of Performance Quality and Psychological Testing

Individual chronograms. The analysis of individual chronograms showed that all the participants more or less exhibited fluctuations in the quality of performance during the time period between 2 and 30 min. The total duration of the periods of OWC capability on the average was about 41% of the time of the study, while that of the periods of PWC was about 28%. During the progress of the study the duration of the first decreased, and the second increased.

Even according to the results of a visual analysis of the chronograms, all of the participants were distinctly divided into groups. Two indices were used as the criteria for their

formal separation: (a) an increase in RT, and (b) quantity of errors towards the end of the study.

In terms of the first criterion all participants were divided into two groups. In one of them a considerable increase in RT was not observed during the progress of the study (4 people), while in the second group a considerable increase occurred (15 people). In all the participants of the first group and part of the second (8 people) the quantity of errors toward the end of work did not substantially change. However, in a segment of the participants of the second group (7 people) an increase in RT towards the end of the study was accompanied by periods of complete omission of signals.

Thus, on the basis of an analysis of the individual chronograms, three types of performance quality dynamics (Figure 2) were isolated, and accordingly, into three respective groups of participants. In the first category there were four people who were characterized relative to their stable working capability ("monotony-proof"). Towards the end of work (in comparison with its beginning) the individuals in this group were not observed to have any significant increase in RT. However, for them the duration of the periods of optimal working capability decreased by 15% on the average, and the duration of the periods of the pessimal working capability increased by 2.5% on the average.
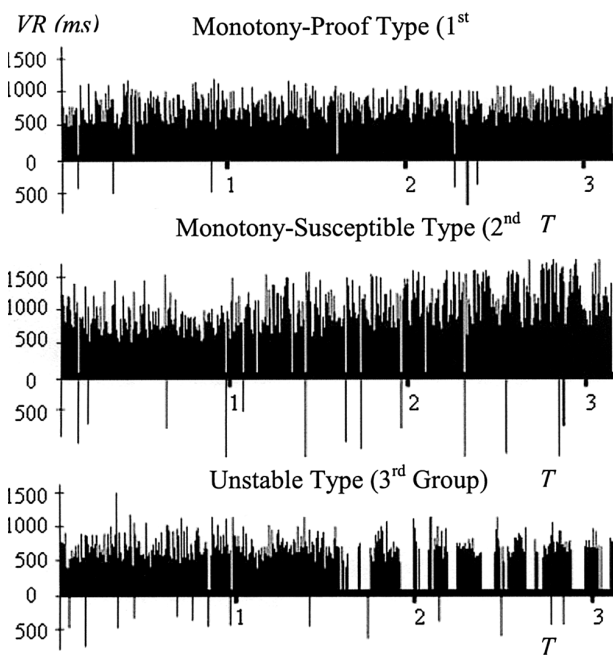

Figure 2. Individual chronograms of the typical representatives of three groups of the participants
Designations: deviation upward - correct answers, deviation below - the answers made by the wrong hand (error), gaps – omission of signals. Axes are designated as in Fig. 1.

The second group was composed of eight participants, in which a progressive reduction in the quality of performance ("monotony-susceptible") was observed. The mean RT to stimuli of both modalities toward the end of the study grew reliably, $F (1, 7) = 7.50$, $r = .029$, the duration of PWC periods was increased by almost 3 times, and the duration of OWC periods was reduced by half.

The third group was composed of seven people, in which there was also observed an increase in RT towards the end of work, although not so pronounced as with the representatives of the second group. Furthermore, in this group there appeared periods of total loss of control over realizable activity, during which they responded to none of the presented stimuli ("unstable"). The frequency of the appearance of these periods and their duration grew over the course of time. At times, the probability of missing stimuli at the stage of pessimal working capability reached 36% of the total number. It should be noted that the participants of this group also had the shortest reaction time to stimuli of both modalities.

As a whole, all participants made two types of errors. On one side, the response was made using the wrong hand, with latent reaction response periods that were both short (less than the average for the study) and long (longer than the average), and on the other side, an omission of the response. The number of the erroneous reactions toward the end of the study increased in all the participating groups; however, the variance on the whole was unreliable.

The most frequently observed type of error was the omission of the response. By this indicator the participants of the third group, wherein such errors were more prevalent, clearly differed from both other groups, from the first, $F_{1-3}(1, 9) = 3.99$, $r = .076$, and from the second, $F_{2-3}(1, 14) = 7.24$, $r = .017$. The number of short-term latent erroneous reactions as a whole was reduced at the stage of the pessimal working capability; however, these changes were reliable only in the participants of 2 groups, $F_2(1, 7) = 15.85$, $r = .004$. The fraction number of long-term latent responses increased, but not reliably.

Reliable differences between the quantity of errors to stimuli of different modalities were not revealed, although the representatives of the first group, as a whole, more successfully managed the visual stimuli, while the second and the third groups were more successful with the auditory stimuli, the differentiation of which (according to the reports) was a more complex problem subjectively.

Psychological testing. The analysis of the results of psychological testing showed that all individual appraisals of personal anxiety corresponded to an average level. Differences between the groups were absent. The level of situational anxiety of the participants did not practically change during the work dynamics.

Changes in well-being, alertness and disposition were, on the whole, of a similar nature in all the participant groups (Figure 3). They were most significant in those of the second

group, $F_2(1, 7) = 24.23$, r = .001, in which the indicators changed significantly statistically for well-being, $F_S(1, 7) = 68.60$, r = .000, disposition, $F_N(1, 7) = 6.17$, r = .042, and alertness, $F_A(1, 7) = 16.52$, r =.004). Qualitatively similar, but quantitatively less significant changes occurred in the individuals of the third group: $F_S(1, 6) = 25.15$, r= .002, $F_N(1, 6) = 8.11$, r = .029, and $F_A(1, 6) = 5.54$, r = .056), respectively. In the participants of the first group the changes were the least significant.
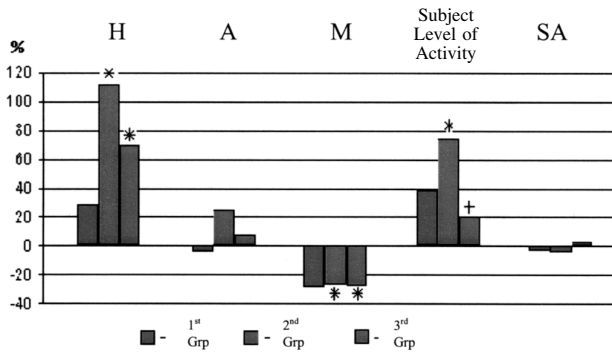

Figure 3. Changes (in %) in the indices of the psychological testing of the three investigated groups
Designations: * - significant differences, + - trend, S - health, A - activity, N - mood (scales of questionnaire HAM), SA - situational anxiety test (Spielberger-Hanin).

EEG Spectra Characteristics of the Participants During Rest and During Work Performance

In the steady state with open eyes (OE), in comparison with the similar state but with closed eyes (CE), the EEG of all of the participants showed a reduction in total power spectra (SSpM), $F_1(1, 3) = 14.46$, r = .032, $F_2(1, 7) = 137.53$, r = .000, $F_3(1, 6) = 65.21$, r = .000, which was most significant with the individuals of the third group (Table 1).

At the stage of OWC (in comparison with the state of steady wakefulness with OE) in the participants of the second and third groups, a reliable increase in SSpM was observed, $F_2(1, 7) = 14.77$, r = .009 and $F_3(1, 6) = 8.86$, r = .028), respectively.

In the state of PWC (in comparison with OWC) a further increase in SSpM was observed in the EEG of the participants of the second group, $F_2(1, 7) = 9.66$, r = .023.

The prevailing frequency of alpha activity as a whole was observed at a maximum in the EEGs of the first group, and at a minimum in the third group of participants (Table 2). In the OE state (in comparison with CE), in the representatives of the second and third groups, the alpha activity was reliably reduced, $F_2(1, 7) = 13.19$, r = .008, and $F_3(1, 6) = 7.99$, r = .030, respectively. With the development of the state of monotony, a further decrease in the alpha activity was observed, which was most significant in the EEGs of the participants of the second group, $F_2(1, 7) = 7.48$, r = .029.

Table 1
Total EEG power spectra (SSpM in mkV²) and its changes (in %) in the different groups participating in the trial

Group	SSpM				% changed SSpM		
	CE	OE	OWC	PWC	CE-OE	OE-OWC	OWC-PWC
1	725.07	318.58	425.42	416.03	**−56.1**	33.5	−2.2
2	1212.96	443.67	524.39	597.29	**−63.4**	**18.2**	**13.9**
3	1082.49	381.02	578.30	608.42	**−64.8**	**51.8**	5.2

Designations: significant differences are highlighted in **boldface,** they will <u>emphasize</u> (r ≤ 0.05), trend (0.05 < r ≤ 0.08). CE – steady state with closed eyes, OE – steady state with the open eyes, OWC – optimal working capability, PWC – pessimal working capability.

Table 2
Results of the analysis of the prevailing frequency of alpha-waves in the EEG of three groups investigated

Group	Predominant frequency (GHz)				% changed		
	CE	OE	OWC	PWC	CE-OE	OE-OWC	OWC-PWC
1	10.44	10.53	10.16	9.79	0.86	−3.51	−3.64
2	10.45	9.40	9.71	9.55	**−10.05**	**3.30**	−1.65
3	9.69	9.16	8.97	8.91	**−5.47**	−2.07	−0.67

Designation from Table 1.

The three-factor ANOVA of the magnitude of the frequency ranges in the average power spectra (SpM) showed the significant presence of L-, R-factors and L_R-interactions (Table 3). They reflect the presence of known frequency and regional differences, which are sufficiently described in the literature.

With the analysis of the EEG spectra characteristics of the participants of the first group, significant C effects were discovered only with the comparison between the steady wakefulness states with the eyes open and closed. In the EEGs of the participants of the second group, reliable differences were observed with the comparison of all states. The most substantial changes in the EEG spectra characteristics of the participants of the third group were revealed with the opening of eyes and the forming of the state of PWC (in comparison with OWC).

The results of the specification implemented with the use of the "simple design" procedure during the sequential fixation of the levels R- and L- factors are given in Table 4 (R-const) and in Figure 4 (L- const). They attest to the fact that in the persons of the second and third groups the opening of eyes led to the reduction of SpM of the frequencies of all wave types. In the EEGs of the participants of the first group, the changes were less significant. They did not affect theta-waves, or the electrodes at F4 and T4.

An increase in the SpM of the frequencies of the alpha-wave was observed in the stage of OWC (in comparison with the steady wakefulness state with OE) in all participating groups (but was most significant in the second). At the same time, in persons of the third group the SpM of theta-waves increased reliably. In this regard, the adjustments affected the examined individuals in the second and third groups in all areas of the cortex (except the temporal), while in the first group only the central area was affected (Figure 4).

In the state of PWC (in comparison with the optimal) in the EEGs of the second and third groups of participants, there was a further increase in SpM observed. In this regard, in the EEGs of individuals in the second group, there was observed a parallel increase in SpM, both of slow (theta and alpha-1) and faster (beta-1 and beta-2) waves. In the EEGs of persons in the third group the changes were more significant in the area of the right hemisphere.

Table 3

Results of three-factor analysis of the averaged EEG power spectra that were registered in the participating three groups

Group	Principal Varience	df	CE-OE		OE-OWC		OWC-PWC	
			F	R	F	R	F	R
	C	1, 3	**13.37**	**0.041**	2.52	0.213	6.12	**0.088**
	L	9, 27	**4.46**	**0.000**	**5.35**	**0.000**	**6.03**	**0.000**
	R	5, 15	**40.47**	**0.000**	**32.73**	**0.000**	**41.39**	**0.000**
1	C × L	9, 27	**8.22**	**0.000**	**2.46**	**0.032**	1.46	0.210
	C × R	5, 15	**8.75**	**0.000**	**5.54**	**0.000**	0.38	0.865
	L × R	45, 135	**2.42**	**0.000**	**2.38**	**0.000**	**2.77**	**0.000**
	C × L × R	45, 135	**3.29**	**0.000**	<u>1.38</u>	<u>0.078</u>	**1.79**	**0.011**
	C	1, 7	**153.85**	**0.000**	**8.73**	**0.022**	**8.66**	**0.021**
	L	9, 63	**14.79**	**0.000**	**18.21**	**0.000**	**13.66**	**0.000**
	R	5, 35	**35.27**	**0.000**	**57.69**	**0.000**	**64.16**	**0.000**
2	C × L	9, 63	**13.77**	**0.000**	**2.10**	**0.039**	0.88	0.551
	C × R	5, 35	**17.68**	**0.000**	**9.14**	**0.000**	1.67	0.170
	L × R	45, 315	**9.93**	**0.000**	**10.05**	**0.000**	**10.87**	**0.000**
	C × L × R	45, 315	**4.14**	**0.000**	0.89	0.674	<u>1.33</u>	<u>0.077</u>
	C	1, 6	**69.69**	**0.000**	4.84	0.089	**10.98**	**0.030**
	L	9, 54	**10.76**	**0.000**	**6.60**	**0.000**	**8.23**	**0.000**
	R	5, 30	**51.20**	**0.000**	**37.03**	**0.000**	**30.72**	**0.000**
3	C × L	9, 54	**10.17**	**0.000**	1.69	0.133	0.83	0.592
	C × R	5, 30	**14.92**	**0.000**	2.85	**0.041**	0.67	0.654
	L × R	45, 270	**4.36**	**0.000**	**5.74**	**0.000**	**4.33**	**0.000**
	C × L × R	45, 270	**1.57**	**0.020**	0.90	0.560	0.64	0.957

Designations: F - Fischer's criterion, r - the R-level of significance, df - number of degrees of freedom, remaining designations as in table 1

Table 4

Results of the two-factor (R-const.) analysis of the indices of the power spectra of the EEG waves of the three groups investigated (only S- effects)

| Group	Principal Varience	df	CE-OE		OE-OWC		OWC-PWC	
			F	R	F	R	F	R
1	delta	1, 3	7.66	0.071	0.27	0.640	6.51	0.078
	theta		3.55	0.161	0.29	0.638	2.26	0.230
	alpha-1		8.36	0.057	6.50	0.078	0.40	0.574
	alpha-2		**24.89**	**0.020**	6.65	0.077	3.60	0.151
	beta-1		**9.77**	**0.046**	1.16	0.361	1.06	0.380
	beta-2		**12.61**	**0.038**	0.69	0.473	0.68	0.469
2	delta	1, 7	**21.44**	**0.000**	0.63	0.452	0.36	0.571
	theta		**77.48**	**0.000**	1.22	0.310	**37.85**	**0.000**
	alpha-1		**184.02**	**0.000**	**64.79**	**0.000**	**9.70**	**0.023**
	alpha-2		**30.88**	**0.000**	**59.19**	**0.000**	0.70	0.430
	beta-1		**31.10**	**0.000**	3.29	0.111	4.26	0.077
	beta-2		**49.68**	**0.000**	0.17	0.693	**5.53**	**0.046**
3	delta	1, 6	**11.89**	**0.018**	2.22	0.200	0.01	0.930
	theta		**39.59**	**0.000**	**6.32**	**0.046**	4.25	0.088
	alpha-1		**40.57**	**0.000**	**13.22**	**0.011**	3.60	0.121
	alpha-2		**79.42**	**0.000**	**24.17**	**0.000**	3.26	0.133
	beta-1		**70.15**	**0.000**	2.78	0.162	1.30	0.310
	beta-2		**59.50**	**0.000**	0.01	0.940	1.23	0.328

Designations as in table 1 and 3.
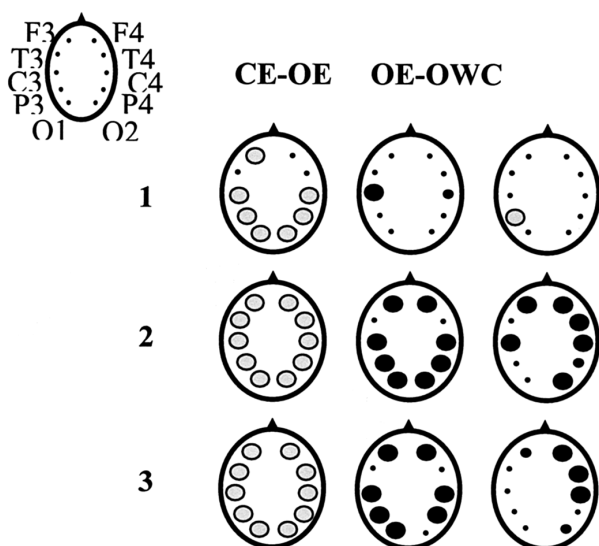
Figure 4. Results of two-factor ANOVA- analysis (L- const) of the indices of the power spectra (SpM) of EEG waves of the three investigated groups.
Designations: gray circles - reduction of SpM, black - an increase in SpM; large circles - the significant differences, small - trend, point - absence of reliable differences. CE – steady state with closed eyes, OE – steady state with open eyes, OWC – Optimal working capability PWC – Pessimal working capability (the first state in the pair was taken as the background, relative to which the changes of the index in the second state were calculated).

Comparative analysis showed that EEG SSpM was at a maximum in the participants of the second group, and at a minimum in the first (Table 1). In CE the differences were revealed between the individuals of the first group, on one side, and the other two groups, on the other side, which did not differ from each other. In this regard, in EEG's of the participants of the second group (in comparison with the first), theta and beta-waves were more significant, and in the third group delta-, theta-, and beta-1-waves (Table 5).

The EEG characteristics registered, in different groups of participants, in terms of the steady wakefulness state with OE and OWC, were not significantly different from each other.

In the stage of the pessimal working capability, the total power spectra of the EEGs of the participants of the first group differed on the trend level compared to that recorded in the persons of the second and third groups, $F_{1-2}(1, 10) = 4.56$, r = .058, and $F_{1-3}(1, 9) = 4.58$, r = .066, respectively. In this regard, in comparison with the individuals of the second group, the EEG's of the participants of the first group had less significant frequencies of delta-, theta- and beta-waves (especially in the parietal regions), in comparison with the third group, which had theta- as well as both beta-sub-waves (especially in the occipital regions). The participants of the second and third groups were not reliably different from each other.

Table 5

Differences (in %) in the characteristics of the power spectra (SpM) of EEG waves in the participating three groups in different states

Group	Rhythm	Variance SpM (in %)			
		CE	OE	OWC	PWC
1-2	delta	149.24	133.42	40.16	**49.60**
	theta	**87.58**	50.29	37.31	<u>66.90</u>
	alpha-1	49.06	20.47	39.95	68.45
	alpha-2	54.70	−1.50	3.24	20.34
	beta-1	**98.80**	17.59	27.83	**52.16**
	beta-2	71.63	50.26	58.47	101.84
1-3	delta	**221.12**	42.03	<u>114.23</u>	128.49
	theta	**386.18**	112.59	<u>341.06</u>	**450.57**
	alpha-1	262.92	266.59	271.87	295.01
	alpha-2	8.34	−11.94	−14.09	34.46
	beta-1	<u>260.13</u>	106.02	140.20	**179.31**
	beta-2	250.03	175.35	72.47	<u>194.05</u>
2-3	delta	−28.67	-48.93	0.40	−3.92
	theta	20.23	−9.45	47.61	40.45
	alpha-1	25.26	48.88	31.22	15.46
	alpha-2	−32.07	−7.41	−9.36	−9.76
	beta-1	−5.29	16.80	15.81	7.56
	beta-2	11.78	13.55	−4.9	−1.30

Designations as in table 1 and 3.

As was noted above, in the chronograms of the participants of the third group periods of total omission of responses were noted. The time segments, which preceded the moments of the presentation of stimuli during such periods, were separated into a special state of omissions of signal (P), and were compared with other states. The results of analysis are given in Table 6.

As follows, from the results given in this table, in its spectral characteristics the periods of the total omission of responses did not differ substantially from the state of activity, but it differed from the steady wakefulness states both with eyes closed and open. In the stage of the omission of responses the strength of alpha-waves, $F_{A1}(1, 6) = 42.77$, $r = .000$, $F_{A2}(1, 6) = 42.21$, $r = .000$, the strength of beta-1-waves, $F_{B1}(1, 6) = 29.25$, $r = .000$, in all areas of the cortex, and also the strength of beta-2-waves, $F_{B2}(1, 6) = 6.59$, $r = .046$, recorded in the central, parietal and occipital regions, were lower than in the steady wakefulness state with CE. From the steady wakefulness state with OE, the periods of the omission of responses were differentiated by the considerably greater manifestation of theta-waves, $F_T(1, 6) = 12.26$, $r = .020$, in the EEGs of all regions, and alpha-1-waves, $F_{A1}(1, 6) = 4.60$, $r = .078$, in the EEGs of the parietal and occipital regions.

Table 6

Results of the comparative estimation of the indices of the power spectra of the EEG waves of those participating in the third group in the stages of the omission of signals (df = 1, 6) only S- effects

Comparison State	F	T	%
CE-P	**30.02**	**0.000**	**−39.50**
OE-P	<u>4.76</u>	<u>0.078</u>	<u>43.78</u>
OWC-P	0.33	0.801	3.15
PWC-P	0.75	0.420	−4.73

Designations: P = the state of the omission of signals. Remaining designations as in Table 1 and Table 3.

Changes of the Indices of the Coherence of EEGs During Rest and During Work Performance

Analysis has shown that the coherence (KoG) of the electrograms registered from the symmetrical frontal and parieto-occipital electrodes was higher than the average, while that of the symmetrical temporal, fronto-temporal and frontal-occipital electrodes was lower than the average range. Intra-hemispheric coherence as a whole was higher than between the electrodes from the different hemispheres. All this was characteristically similar for the EEGs of all participating groups for all states.

Substantial changes in the level of coherence in the dynamics of the study occurred in the representatives of the second, and the least changes in the first group. With the opening of eyes (in comparison with the stable state with CE) reliable changes in the level of coherence were noted only in the EEG of participants of the third group and only for the intra-hemispheric and interhemispheric nodes (Table 7). With the forming of the state of OWC (in comparison with the steady wakeful state with CE) reliable differences were observed both in the EEG of the participants of the third and the second groups. In this regard, in the participants of the third group they affected only interhemispheric connections, and with the second - all groups of connections. With the forming of the state of the PWC (in comparison with the optimal) substantial changes in the coherence were not noted, with the exception of interhemispheric connections in the participants of the third group, where the level of coherence was reduced.

Double- (Figure 5) and single-factor (Figure 6) analysis showed that with the opening of eyes of all participants there occurred a significant reduction in the coherence of alpha-2-waves in EEG and also in the connections of all groups. In the participants of the second and third groups

similar changes occurred in the region of alpha-1-waves. Together with all these, in the individuals of the first and third groups there occurred a decrease in the level of coherence of beta-1-waves and in the second group there was an increase in the coherence of theta and beta-2-waves.
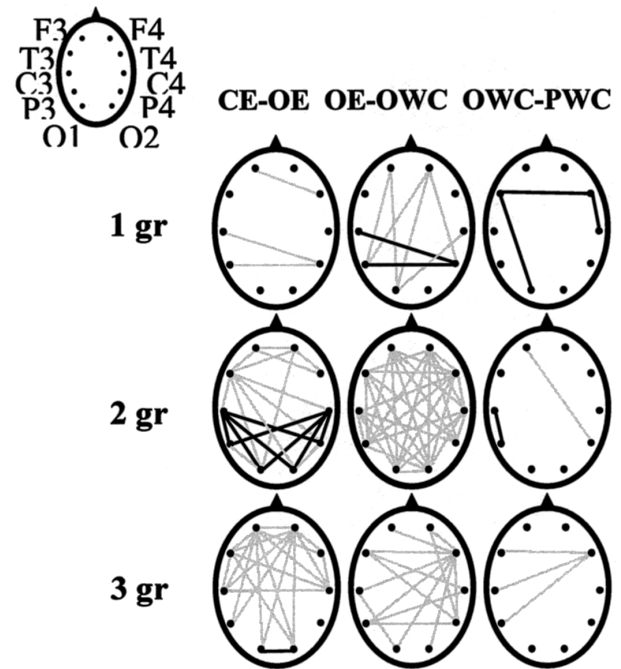

Figure 5. Results of the two-factor analysis (LC- const) of the level of EEG coherence (KoG) of the EEG of the three investigated groups.
Designations: black lines - increase, gray - reduction in KoG (reliable differences and trends are united and shown by one color). Remaining designations as in Fig. 4

Table 7
Results of the two-factor (R-const.) analysis of the indices of the power spectra of the EEG waves of the three groups investigated (only S- effects)

Group	Group Signal	df	CE-OE		OE-OWC		OWC-PWC	
			F	R	F	R	F	R
1	Sim	1, 3	3.43	0.161	0.00	0.970	0.01	0.970
	Vp		0.55	0.511	1.91	0.261	0.12	0.746
	Mp		1.48	0.310	2.15	0.238	0.15	0.719
2	Sim	1, 7	2.79	0.133	**7.15**	**0.028**	0.02	0.880
	Vp		0.98	0.360	**9.96**	**0.013**	0.01	0.910
	Mp		0.46	0.515	**10.36**	**0.012**	0.09	0.764
3	Sim	1, 6	4.10	0.089	3.06	0.131	2.66	0.154
	Vp		**9.25**	**0.023**	3.61	0.106	3.97	0.093
	Mp		**6.51**	**0.043**	**6.46**	**0.044**	<u>4.73</u>	<u>0.073</u>

Designations: Sim- block of the symmetrical pairs of electrodes, [Vp] - the block of the intra-hemispheric pairs of electrodes, [Mp] - interhemispheric pairs of the electrodes. Remaining designations as in tables 1 and 3.
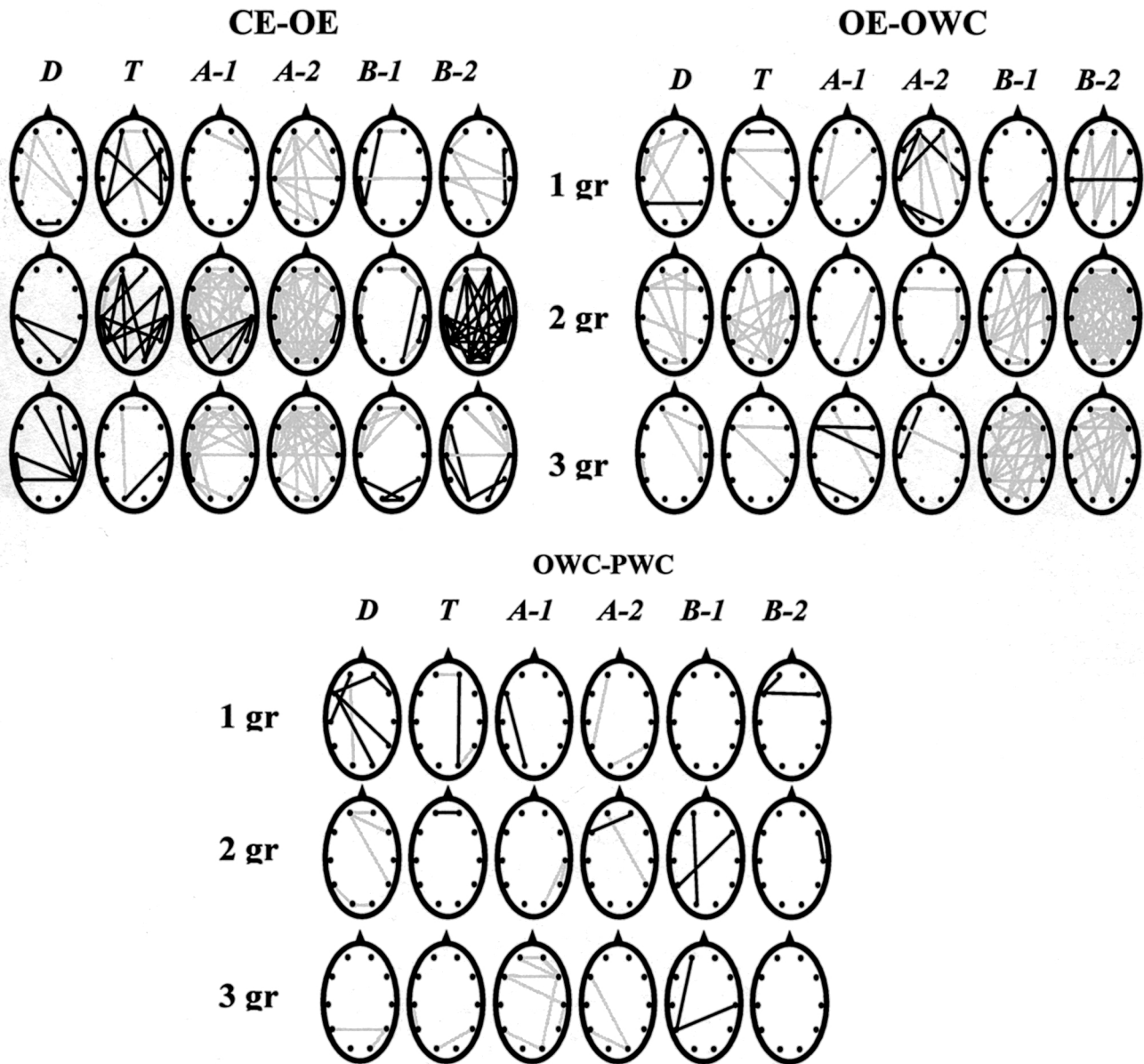
Figure 5. Results of the two-factor analysis (LC- const) of the level of EEG coherence (KoG) of the EEG of the three investigated groups. Designations: black lines - increase, gray - reduction in KoG (reliable differences and trends are united and shown by one color). Remaining designations as in Fig. 4

The analysis of regional characteristics showed that the level of coherence was most substantially reduced between the electrograms of front (frontal and temporal) and rear (parieto-occipital) regions. Changes were most essential in the EEGs of the participants of the third group. The coherence of the activity in the central and parieto-occipital lobes, on the contrary, rose, especially in the representatives of the second group.

With the forming of the state of OWC further reductions occurred in the coherence of slow (delta and theta) and rapid (beta) waves. In this regard, in EEG's of the participants of the first and second groups a reduction in coherence to the larger degree affected the area of the beta-2-waves, while

the third group saw a reduction in the coherence of the beta-1-waves. A maximum decrease in the level of the coherence of slow frequencies was observed in the EEG's of the participants of the second group.

Comparative analysis showed that statistically significant differences are observed in the group of interhemispheric connections. The level of coherence in the participants of the second group was reliably higher than in the first, $F_{1-2}(1, 10) = 10.80$, r = .007, and $F_{1-2}(1, 10) = 3.69$, r = .079, respectively, for the steady wakeful states with CE and OE, and also reliably higher than in the third group, $F_{2-3}(1, 13) = 5.48$, r = .034, with OE. The participants of the third group differed from the first in terms of a higher level of coherence

Table 8

Results of the comparative estimation of the indices of the level of EEG coherence with participants of the third group at the stages of the omission of signals (P) ((df = 1, 6) only S- effects given)

Comparison State	Group Comm.	F	R	%
CE-P	Sim	**11.55**	**0.015**	**–3.92**
	Vp	**10.66**	**0.017**	**–4.66**
	Mp	**9.48**	**0.022**	**–6.45**
OE-P	Sim	2.73	0.149	–2.70
	Vp	1.25	0.307	–2.13
	Mp	4.04	0.091	–3.86
OWC-P	Sim	0.67	0.442	–0.92
	Vp	0.17	0.696	–0.70
	Mp	0.82	0.401	–1.53
PWC-P	Sim	0.14	0.713	–0.24
	Bπ	0.08	0.778	0.30
	Mπ	0.02	0.914	0.25

Designations as in table 1, 3, and 7.

of their EEGs for the frontal lobes (frontal and temporal, especially under the conditions of work), and from the second – by a lower level of coherence of EEG for rear (parietal and occipital) regions, moreover both between each other and the latter - with other lobes (especially in the steady wakefulness state with open eyes and the pessimal working capability).

In terms of the level of coherence, the EEG, recorded before the omission of responses (in the participants of the third group), differed significantly only from the steady wakeful state with closed eyes, furthermore, differences were observed in all groups of connections (Table 8); in the first case the coherence in the EEGs of the front (frontal and temporal) regions between each other and with other regions was lower, it was the most significantly marked in the alpha-band (from 4.7 - 10.6%) and beta-band (from 5.1- 9.7%).

Discussion

First of all, we would like to note that all the states analyzed are related to the versions either of steady wakefulness or operational rest, because in the states of OWC and PWC the analysis selected the EEG epochs, which correspond to the state of the expectation of stimulus. All this makes it possible to assert that the observed EEG-phenomena were, first of all, connected with the dynamics of a functional state of the CNS, but not with information processing itself, which in recent years has been more frequently associated with the effects in the area of gamma-waves (e.g., Kiroy & Belova, 2000; Kiroy & Chorayan, 2000; Muller, Junghofer, Elbert, & Rochstroh, 1997; Rodriguez et al., 1999; Tallon-Baudry & Bertrand, 1997).

We separated the participants into groups according to the indicators of the quality of their performance, reaction time and number of errors. By the indices of well-being, alertness, and disposition, the level of situational and personal anxiety the participants were not essentially different and, falling within the region of average values, they could be characterized as a group of sufficiently successful performing operators (Shevyakov, 2005). Nevertheless, as it turned out, they are essentially distinguished by their EEG characteristics.

Those participants with the minimum total power spectra EEG entered the group of those who work most stably under the conditions of monotony. They also were characterized by the predominantly high-frequency alpha-wave, the minimum level of the dimensional synchronization of the biopotentials of the front regions of cortex. The low total power with the predominance in the EEG of the higher-frequency alpha wave usually indicates a weakness of the processes of alertness and inhibition, which is characteristic of introverts (Ivashchenko, Berus, Zhuravlev, & Myamlin, 1999), and the absence of any substantial changes in the EEGs power point to the low lability of nervous processes. A certain predominance of alertness with the low lability of nervous processes will, apparently, provide the participants with a longer time to successfully resist the influence of monotony and to support the functional state of the brain at the level adequate for qualitative work performance under these conditions. However, since the tendency toward EEG signal-change in the participants of this group coincides with the changes observed in the other two groups, it can

be assumed that their resistance to the action of the factors of monotony is not absolute, and that during the prolongation of work under these conditions it is unavoidable that a reduction in the functional state of central nervous system and quality of work will occur.

The most explicit reduction in the indices of quality of activity and mental condition was observed in the persons with the maximum total power spectra and a high level of EEG coherence at rest, which were substantially changed in the dynamics of the study. As has been shown by Rusalov et al. (1993), the characteristics indicated testify to the strength of nervous processes, and on the mental level, to extraversion and low anxiety. Analogous data were provided in other works (Asvaduryan, 1991; Malakhov, 1988; Rozhdestvenskaya, 1980). A significant increase in the EEG of these persons in the strength of the alpha-waves against the backdrop of a decrease in the level of coherence in both slow (delta and theta) and rapid (beta) waves characteristic for the state of OWC, testify to a decreased "starting" level of brain activation as a condition of the formation of the optimal state for effective performance under the conditions of monotony. A subsequent decrease in the level of wakefulness, evidence of which is an increase in the EEG power of the theta- and alpha-1-waves, was partly compensated by a parallel increase in the power of the beta-1-waves and by a reduction in the coherence of the alpha-2-waves, which apparently ensured performance. Nevertheless, the presence of significant differences in the EEG- characteristics, recorded in the individuals of this group in the state of OWC and PWC, testifies to the forming of the state of monotony in them.

According to EEG indices of the total power spectra while at rest, the individuals working unstably in the conditions of monotony in practice do not differ from the persons of the previous group. However, they have a below average prevailing frequency of alpha-waves, and have theta and beta-2-waves more marked, above average level of coherence of EEG in the frontal, and below average in the rear regions of the cortex. Some authors indicate the presence of a positive correlation between the manifestation of theta-waves in EEG while at rest and the extraversion of personality, and its negative correlation with the level of anxiety (Mizuki, 1982). The high level of EEG coherence of the frontal regions of the cortex positively correlates with the strength of nervous processes (Rusalov et al., 1993). The above combination of electrographic characteristics attests to the fact that the individuals of this group have a strong and labile (well marked beta-2-waves) type of nervous system (Yatsenko & Kaigorodova, 1998). This also attests to a high total energy of alpha-waves (Makarenko, Voronovskaya, Kovtun, & Panshenko, 1992), more substantial changes in the spectral characteristics of EEG with the change of states, and the presence of the most short-latency reactions to the stimuli of both modalities (Makarenko, 1989). Under the influence of the factors of

monotony, an increase in the strength of alpha- and theta-waves was observed in the EEG of these persons already at the stage of optimal working capability, which was then further strengthened in the stage of pessimal working capability (and especially significantly marked in the frontal regions of the cortex). All this testifies to the fact that the essential inhibition of the cortex and cortico-subcortical managers of impulses (Gulyakov, 2000) apparently lead to a decrease in the level of attention and the total omission of responses.

It is well-known that the omission of responses by operators is often connected with the forming of a dream state (Dikaya et al., 1992). However, as we have shown, in its electrographic characteristics, the state which corresponds to the omission of responses in the condition of motivated monotonic activity, statistically does not significantly differ from the states of operational rest and OWC. Only the functional state of the frontal regions of the cortex is substantially reduced, which could lead to a decrease in the level of arbitrary alertness (Khomskaya, 1972; Luriya, 1973; Ryabchikova, Podyacheva, & Ghulgovsky, 2001).

As the obtained results demonstrate, qualitatively identical changes in the characteristics of activity were observed in practically all the participants. However, the rate of development and the depth of these changes in people with different EEG-characteristics differ significantly. However, the so-called monotony-phobic persons are distinctly divided into two subgroups. In one of them the reduction in the effectiveness of work performance takes place gradually. With its preservation only some characteristics and overall quality of work deteriorate. The individuals in the second subgroup are characterized by the spontaneous appearance of periods of complete "precipitation" from work, which, from one side, is fraught with the loss of control, and from the other side, hampers the resolution of the control problem and the prediction of their state. Despite the fact that under the conditions of the factors of monotony a significant decrease in the level of structural activation in the CNS is not observed in the performance of these participants, they cannot concentrate their attention on the implemented activity for a long period of time and are inclined to transfer their attention, which leads to the loss of control. Specifically, this testifies that the periods of total omission of responses can occur against a backdrop of sufficiently high levels of brain activation. Such a strategy of adaptation to the operative factors of monotony makes it possible to support the current alertness at a relatively high level, and leads to significant changes in the quality of work.

Thus, individual resistance to the action of the factors of monotony is connected to the predominance in the CNS of the processes of excitation in combination with the low lability of nervous processes as a whole. The low lability of nervous processes ensures the stability of the functional state of the brain, the sufficiently prolonged maintenance

of the corresponding level of working capacity and performance effectiveness. The high lability of nervous processes is a factor that is unfavorable towards work performance under the conditions of monotony, since it makes the prolonged concentration of attention impossible even with the presence of a sufficiently high level of motivation towards its fulfillment. The latter leads to the appearance of periods of total omission of responses against the backdrop of a relatively high level of wakefulness.

As a whole, the two strategies of adaptation to the operative factors of monotony should be separated. The first is reduced to the maintenance of a high quality of activity, at the expense of a reduction in the functional state of the central nervous system. It is characteristic in persons with individually high levels of activation in combination with low levels of lability of the nervous processes. The second strategy is connected with the maintenance of a high level of activation of the central nervous system, at the expense of a reduction in the quality of work performance. This strategy is characteristic for individuals with a high lability of the nervous processes. The maintenance of a high level of activation is achieved either by the switching of arbitrary attention or by the activation of involuntary attention. It is possible to assume that for those who use the first strategy, an increase in the initial level of activation (for example, due to additional motivation) or its correction in the process of work can reduce the rate of the forming of the state of monotony. For those who use the second strategy of adaptation, it is possible to attain a similar effect by enriching their working environment with additional information (thus, removing the effect of one of the major factors of monotony -the factor of monotony/scarcity of new information) or organizing additional short-term interruptions during work.

Conclusions

1. It has been experimentally shown that the forming of a state of OWC under monotonic conditions of activity is connected with the increase (in comparison with the state of steady wakefulness) in EEG of the power spectra of predominantly slow (theta and alpha) and beta-1-waves, which can testify to the need for an initial reduction in the excessively high level of brain activation needed for the effective realization of this form of activity. These changes are accompanied by a considerable decrease in the level of coherence of both the slow (delta and theta) as well as rapid (beta) EEG-frequencies, which can be considered to be a reflection of the functioning of the compensating mechanism, which ensures the maintenance of a high quality of activity.

2. The long-term effect of the factors of monotony in combination with the need for effective work performance leads towards an increase in the EEG of the power of slow (theta and alpha-1) waves, which is compensated by an increase in the power of rapid (beta) waves in the absence

of significant changes in the level of coherence. The observed changes in the different groups of operators are qualitatively similar, but are quantitatively differentiated.

3. Resistance against the influence of the factors of monotony depends significantly on the specific features and properties of the CNS, which are reflected in the time-spatial organization of the bioelectric brain activity of the person, in particular, from the initial activation level of the cortex and the lability of nervous processes. The most optimum for the realization of monotonic activity is the certain predominance in the CNS of the processes of excitation over the processes of inhibition in combination with the relatively low lability of nervous processes (especially excitation).

References

Asvaduryan, A. A. (1991). Issledovanie vzaimosviazi psikhologicheskikh, nadezhnykh i elektroentsefalograficheskikh kharakteristik cheloveka-operatora [Study of the relations between psychological, reliable and electroencephalographical characteristics of the operators]. Avtoreferat dissertatsiy kandidata biologicheskikh nauk, Rostov-na-Donu.

Bodnar, E. L., Zarakovsky, G. M., & Chaynova, L. D. (1999). Motivatsiya kak faktor formirovaniya funktsional'nogo sostoianiya napriazhennosti operatora [Motivation as a factor of functional state formation of an operator's intensity]. *Fiziologiya cheloveka, 25*(3), 71-78.

Dikaya, L. G., Shapkin, S. A., & Gusev, A. N. (1992). Osobennosti adaptatsiy operatorov k asomniy: analiz dinamiki biopotentsialov mozga i povedencheskikh pokazateley [Peculiarities of operators' adaptation to asomnia: analysis of the dynamics of the brain's vitality and behavioral indicators]. *Fiziologiya cheloveka, 18*(1), 42-50.

Falkenstein, M., Hohnsbein, J., & Hoormann, J. (1994). Effects of choice complexity on different subcomponents of the late positive complex of the event-related potential. *Electroencephalography and Clinical Neurophisiology, 92, 2,* 148-160.

Gulyakov, M. B. (2000). Korkovo-podkorkov'e mekhanizmy priniatiya resheniya i korrektsiya ikh funktsional'nogo narusheniya [Cortex-subcortical mechanisms of decision-making and correction of their functional disorder]. XXX Vserossiyskoe soveshchianie po problemam vysshey nervnoy deyatel'nosti. Tezisy dokladov, t. 1, Sankt-Peterburg.

Ivashchenko, I. O., Berus, A. V., Zhuravlev, A. B., & Myamlin, V. V. (1999). Individual'no-tipologicheskie osobennosti bazovykh svoystv lichnosti v norme i ikh EEG-korreliatsiy [Individual and typological peculiarities of basic characteristics of personality in the norm and their EEG-correlation]. *Fiziologiya cheloveka, 25*(2), 46-55.

Kaplan, A. Ia. (1998). Nestatsionarnost EEG: metodicheskiy i experimental'niy analiz [Non-steady EEG: methodical and experimental analysis]. *Uspekhi fiziologicheskikh nauk, 29*(3), 35-55.

Khomskaya, E. D. (1972). Mozg i aktivatsiya [Brain and activation]. Moskva: Izdatel'stvo MGU.

Kiroy, V. N., & Aslanyan, E. V. (2006). Individual'naya ustoychivost' k deystviyu factorov monotoniy i ee otrazhenie v EEG [Individual resistance to the exposure to the factors of monotony reflected in the EEG]. *Zhurnal vysshey nervnoy deiatel'nosti, 56, 1, 5, 38-46.*

Kiroy, V. N., & Belova, E. I. (2000) Mekhanizmy formirovaniya i rol' ostsiliatornoy aktivnosti neronnykh populiatsiy v sistemnoy deiatel'nosti mozga [Mechanisms of formation and the role of oscillatory activity of neuronal populations in brain's systemic activity]. *Zhurnal vysshey nervnoy deiatel'nosti, 50*(2), 179-191.

Kiroy, V. N., & Chorayan, O. G. (2000) K teorii neyronnykh ansambley mozga [To theory of brain's neuronal ensembles]. *Uspehi fiziologicheskikh nauk, 31*(2), 23-39.

Kiroy, V.N., Warsawskaya, L. V., & Voynov, V. B. (1996). EEG after prolonged mental activity. *International Journal of Neuroscience, 85,* 31-40.

Luriya, A. R. (1973). Osnovy neyropsikhologiy [Neurophysiology's basics]. Moskva: Izdatel'stvo MGU.

Makarenko, N. V. (1989). Vremia slozhnoy sensomotornoy reaktsiy vybora u lits s razlichnoy funktsional'noy podvizhnost'iu nervnykh protsessov [Time of complex sensomotoric choice reaction of people with different functional mobility of neural processes]. *Zhurnal vysshey nervnoy deiatel'nosti, 34*(5), 813-818.

Makarenko, N. V., Voronovskaya, V .I., Kovtun, T. V., & Panshenko, V. M. (1992). Elektroentsefalograficheskie korreliatsiy vremennykh kharakteristik prostykh sensornykh reaktsyi u liudey s raznym urovnem funktsional'noy podvizhnosti nervnykh protsessov [Electroencephalographic correlations of temporary characteristics of simple sensomotoric reactions with the people with different levels of functional mobility of neural processes]. *Fiziologiya cheloveka, 18*(3), 33-41.

Malakhov, N. S. (1988). Znachenie svoystv lichnosti v fiziologicheskom normirovaniy trudovoy deiatel'nosti [The significance of personal characteristics in the physiological control of the labour activity]. V sbornike: Fiziologicheskoe normirovanie trudovoy deiatel'nosti, Leningrad: Nauka.

Mizuki, Y. (1982) Frontal midline theta activity during performance of mental tasks. *Electroencephalography and Clinical Neurophysiology, 54*(3), 25-30.

Muller, M. M., Junghofer, M., Elbert, T., & Rochstroh, B. (1997) Visually induced gamma-band responses to coherent and incoherent motion: a replication study. *NeuroReport, 8*(11), 2575-2579.

Ryabchikova, N. A., Podyacheva, E. V., & Ghulgovsky, V. V. (2001). Psikhofiziologicheskie osobennosti ispytuemykh s raznoy effektivnost'iu veroiatnostno-prognosticheskoy deiatel'nosti [Psycophysiological characteristics of tested people with different eficiency of probabilistic-forecasting activity]. *Zhurnal vysshey nervnoy deiatel'nosti, 51*(5), 552-557.

Rodriguez, E., George. N., Lachaux, J.-Ph., Martinerie, J., Renault, B., & Varela F.J. (1999). Perception's shadow: long-distance synchronization of human brain activity. *Nature, 397, 430-433.*

Rozhdestvenskaya, V. I. (1980). Individual'nye razlichiya rabotosposobnosti: psikhofiziologicheskie issledovaniya rabotosposobnosti v usloviyakh monotonnoy deiatel'nosti [Individual diversities of work performance: psychophysiological research of work performance under the conditions of monotonous activity] Moskva: Pedagogika.

Rusalov, V. M., Rusalova, M. N., Kalashnikova, I. G., Stepanov, V. G., & Strel'nikova, T. N. (1993). Bioelektricheskaya aktivnost' mozga cheloveka u predstaviteley razlichnykh tipov temperamenta [Bioelectrical activity of the human brain of people with different types of temperament]. *Zhurnal vysshey nervnoy deiatel'nosti, 43*(3), 530-542.

Tallon-Baudry, C., & Bertrand, O. (1997). Oscillatory _ – band (30 – 70 Hz) activity induced by visual seach task in humans. *Journal of Neuroscience, 17*(2), 722-734.

Shevyakov, A. V. (2005) Psikhofiziologicheskie kharakteristiki deiatel'nosti operatorov AES kak factor avariynosti [Psychophysiological characteristics of nuclear power station operators as a factor in accident rate]. *Fiziologiya cheloveka, 31*(5), 135-141.

Yatsenko, M. V., & Kaigorodova, N. Z. (1998). EEG-korreliatsiy individual'no-tipologicheskikh osobennostey cheloveka [EEG-correlations of individual-typological characteristics of a person]. Materialy XVII s'iezda fiziologov Rossiy, Rostov-na-Donu.