ELECTRICAL ACTIVITY OF THE CEREBRAL CORTEX IN MEN HAVING HIGH OR LOW OUTPUT ALPHA-FREQUENCIES WHILE PERFORMING USUAL MANUAL MOVEMENTS IN RESPONSE TO SENSORY SIGNALS

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Summary: A test group consisting of 104 healthy men from the ages of 19 to 21 was divided into two groups according to the magnitude of their individual α- frequency (IAF) median—groups with high (n = 53, IA ≥ 10,04 Hz) and low (n = 51, IAF ≤ 10,03 Hz) levels of IAF. Changes in power and coherence of the EEG oscillations during the usual manual movements as well as intergroup differences were evaluated. The higher level of the background tone of the cortex activation in men with a high IAF (individual alpha-frequency) was found as correlative with a significant selection of the relevant sensory information and a nonspecific input afferentation and its weakening under the performance of habitual manual movements. A functional state of the cortex is relatively lower in men with a low IAF and compensated by the tension of brain processes associated with a low level of the selective attention and the increase of the reticular influences and their significance during the finger movements. Men with a high IAF are characterized by the greater locality and asymmetry of processes of the cortical excitation under the dominant role of the left hemisphere. Activation changes are more diffuse in nature in subjects having a low frequency.

Key words: electroencephalogram, individual alpha-frequency, usual manual motion.

Introduction

The modern world is characterized by the growth of occupations with critical individual functional potentials of the sensory and motor systems and the brain activity of the person involved. A direct reflection of the individual characteristics of the brain is its background electrical activity активність (Begleiter, Porjesz 2006, van Beijsterveldt, van Baal 2002). The α-rhythm maximum peak frequency has the most information value among its other parameters (Anokhin et al. 2006, Christian et al. 1996, Hooper 2005). It is believed that various α-subbands are differed by the specific brain generators, functional significance, and varying degrees related to the major systems of the brain activation (Klimesch et al. 2007). A low or high range of the α-rhythm superiority in the background encephalogram of the person can cause his/ her psychomotor and cognitive abilities (Doppelmayr et al. 2005, Hyde 2005).

In view of this, the main goal of our research is to elucidate issues answering the question how the function of the cerebral cortex is changed in men with a different output individual α-frequency under the influence of habitual movements in response to special signals compared to the determined in a quiescent state. This issue is urgent and has not only the theoretical importance but also obvious practical application as it concerns fundamental matters affecting the neuro-physiological purposeful human hand movements. The alternative clench and unclench of fingers under the pincer prehension type and used in our study as a motor load are the most commonly using manual movements by a person and playing a significant role in the person's day-to-day life, training, operator performance and production activities. The implementation of such movements in response to acoustic signals is a prerequisite for the sensory motor coordination process. Its successful realization has become increasingly important for the context and the complexity and diversity of the modernizer's information environment, the dissemination of the practical implementation of the manual remote control carried out by electronic technical devices.

The aim

To identify the cerebral cortex electrical activity in men with a high or low output α-frequencies during the habitual manual movements in response to sensory signals.

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Materials and methods

The participants in our study were 104 male volunteers from the ages of 19 to 21. Biomedical ethics rules in accordance with the Helsinki Declaration of the World Medical Association on the Ethical Principles of Scientific and Medical Research involving Human Subjects were adhered to during the experiment. All the testees were healthy with regard to the judgment and advisory conclusions of their medical professionals, and had normal hearing in their own estimation, as well as a suitable profile of manual and auditory asymmetries. It determined by the nature of responses in the survey, execution of the motor and psychoacoustic tests and counting the individual ratio of the manual and auditory asymmetries (K skew) (form. 1) (Zhavoronkova 2009).

Formula 1

$$K_{skew} = \frac{\Sigma_{right} - \Sigma_{left}}{\Sigma_{right} + \Sigma_{left}} \times 100\%$$

where Σ right – the amount of tasks where a right hand (right ear) is dominating during their execution,
and Σ left – the amount of tasks under which the left hand (left ear) is dominant.

This coefficient had a positive skew being higher than 50% in each man.

All examinations were performed in the morning. The profile of the asymmetry was evaluated 30 minutes before the EEG recording registration.

The testees were in a quiescent state with their eyes closed and in a reclining position with their limbs relaxed and not crossed during the EEG and EMG testing. The experiment was carried out in a room which was sound-proof and light-proof. The whole experimental procedure consistently included the following steps for each testee:

Step 1.The EEG recording in the functional balance (background)

Step 2.The EEG recording during the clench of the right hand fingers

Each step lasted 40 s. To exclude the edge effects, the EEG recording registration was started at 15 s after the beginning and had been stopped at 5 s by its completion.

The execution of each movement of the finger clench and unclench (without any force) was carried out in response to the sound signal. The electronic version of the drum battle (the software of Finale 2006) was used for this purpose.

Binaural stimuli were produced by four speakers placed in different corners of the room at the distance of 1.2 m from the testee's right or left ear. The stimulus duration was 130 ms; the playback sound volume did not exceed 55-60 dB at outlet from the speakers under the measurements carried out by the sound level meter of the 'DE-3301'type. Additionally, the sound loudness was individually regulated for each tested to achieve the necessary level. The rate of the sound stimuli delivery was 2 Hz (120bpm / Min.).

Active electrodes were placed in accordance with the international system 10/20 in nineteen points on the scalp of the head during the electroencephalogram (EEG "Neurocom", and the Certificate of State registration # 6038/2007 from 26 January 2007) recording. The performance of the EEG recording was monopolar, with the use of ear electrodes as a reference. The Fourier analysis era was 4 s with a 50% overlap. ICA-procedure analysis was used for the rejection of EEG anomalies.

Both the power (mkV^2) and the coherence of the brain electrical activity in the θ-, α-, β- and γ-frequency intervals were also evaluated. Taking into consideration the functional heterogeneity of different sub-bands of the EEG α- and β-rhythms, the changes in the power and coherence of each of them were considered, and coefficients of coherence (Coh) above 0.5 were analyzed as well.

The maximum frequency peak of the α-rhythm was determined for each testee in each EEG lead at a functional balance (Klimesch et al. 2007). Its value was averaged for all leads and the obtained values were considered as the testee's individual α-frequency (the individual alpha-frequency of EEG, IAF, and Hz). The IAF median was also determined and calculated for the group of men. It was 10.04 Hz. Thus, there were formed subgroups of testees in according to the value of the median:

- groups with a high IAF ($n = 53$, IAF ≥ 10.04 Hz);
- groups with low IAF ($n = 51$, IAF < 10.04 Hz).

The EEG frequency interval limits were determined individually, relying on the value of the testee's IAF. The following algorithm (Klimesch et al. 2007) was used and the truth of which was that the upper limit of α3-subband was set to the right side of the IAF in increments of 2 Hz. It corresponded to the lower limit of the β1-band. The upper limit of the β1-sub-band was defined according to the standard concepts as 25 Hz. The lower limit of the α2-band was determined in steps of 2 Hz to the left of the peak, and the α1- band in 4-Hz steps, as well as θ-frequencies – in 6 Hz. Limits of β2- and γ-bands were recognized as standard, properly, 26 – 35 Hz and 36 – 45 Hz.

The resulting individual values of the power and coherence of EEG oscillations within the selected groups of men were averaged for each lead.

A statistical data analysis was performed by using the package ‘STATISTICA 6.0’ (Stat-Soft, 2001). Any normalcy of the data distribution in testees’ subgroups was evaluated by means of the Shapiro - Wilk test (indicator SW). Based on test results, it was found that all of our studied samples had a normal data distribution. To estimate the significance of differences existing in testees’ subgroups, the Student’s t-test (index t) was used between steps of testing both for independent equal samples and for dependent samples. Significant differences between testees’ subgroups and among steps of testing were statistically considered at $p \le 0.05$ and $p \le 0.001$. After the result examination, a qualitative evaluation of dynamic processes occurring in the cerebral cortex under the test conditions was given by us too.

Results

Changes in electrical activity of the cortex during habitual manual movements executed by men with high or low IAF baselines were present. EEG power reductions in a wide frequency range in the cortex, particularly, in the posterior cortical areas compared to the background, were seen in men with a high IAF. Such changes in θ-, α1- and α2-frequency ranges have been localized in the posterior temporal and pariental areas of the cortex left hemisphere ($p \le 0.05$), γ-rhythm – in its left posterior frontal, central and parietal areas ($p \le 0.05$, $p \le 0.001$). They had a generalized character in the cortex ($p \le 0.05$, $p \le 0.001$) in α3- and β1-bands. However, the capacity increase on θ-, α1- and β2-waves was present in the frontal leads ($p \le 0.05$). These changes in power comes amid a comparable reduction of θ- and α1-EEG coherent oscillations, particularly, in the frontal, central, pariental and left temporal lobe cortex areas, and α3-, β- and γ-waves – in the left temporo-parietal parts ($p \le 0.05$, $p \le 0.001$). Moreover, the spatial synchronization of α2-activity is fixed in the central frontal and right anterior temporal areas ($p \le 0.05$, $p \le 0.001$), and β2-rhythm – in the frontal lobes of the cortex in both hemispheres ($p \le 0.05$). Changes in power and coherence of EEG oscillations in the cortex of men with a high IAF during the usual manual movements are given in Fig.1.

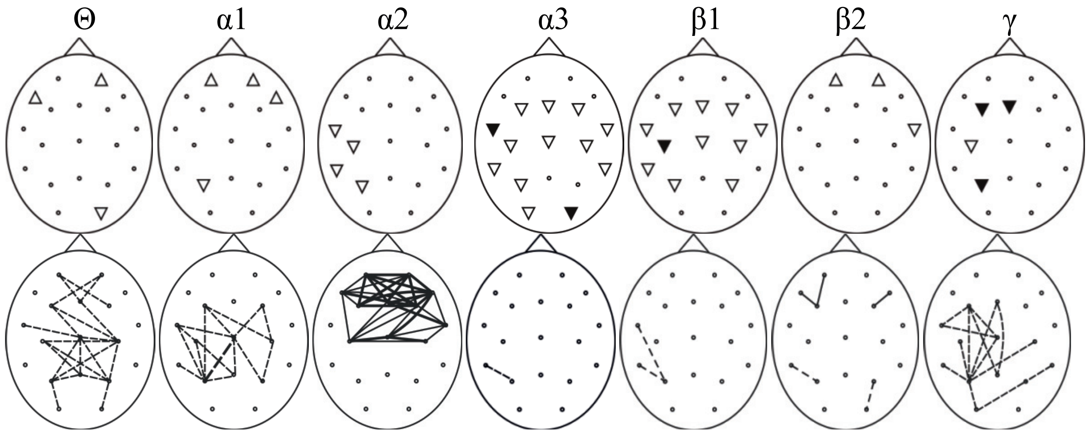

Figure 1. Changes in power and coherence of EEG oscillations in men having a high level of IAF during the habitual manual movements
Source: own study

Notes to Fig.1-2:

1) △▽▲▼ increase (decrease) of power, $p \le 0.05$, $p \le 0.001$,

2) ═ (╌╌) increase (decrease) of coherence, $p \le 0.05$, $p \le 0.001$.

The more generalized capacity reduction of α- and β1-EEG oscillations ($p \le 0.05$, $p \le 0.001$) is in the cortex of men at a low IAF level than in men at rest. Such regularity is fixed in the γ-band in frontal and central lobes of the cortex ($p \le 0.05$, $p \le 0.001$). A relative increase of indices, particularly, in frontal areas ($p \le 0.05$) is in the θ- and β2-bands. The decrease of coherence values of θ-, α1-, α3-, β1- and γ-waves of the EEG in the cortex ($p \le 0.05$, $p \le 0.001$) is present as well. Such changes in the θ-sub-range are fixed in the right hemisphere as they are located in the left posterior cortical areas in α3- and γ-bands of the EEG and generally distributed in the cortex at α1- and β1-frequency. A comparable growth of the α2-frequency of the EEG coherent oscillations can be traced throughout the neocortex having a higher significance in the frontal, anterior temporal and central structures ($p \le 0.05$, $p \le 0.001$), in the β1-lane – in the back of the frontal areas ($p \le 0.05$), and β2-activity - in the posterior frontal and central zones ($p \le 0.05$). Changes in power and coherence of EEG oscillations in the cortex of men having a low IAF during habitual manual movements are shown in Fig. 2.

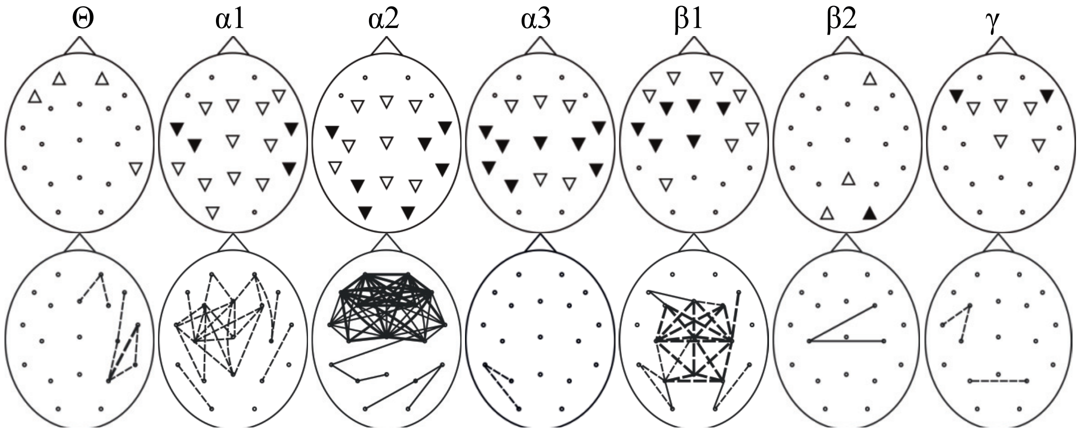

Figure 2. Changes in power and coherence of EEG oscillations in men having low levels of IAF during the habitual manual movements
Source: own study

Differences in power and coherence of EEG oscillations between male subgroups are also present. Testees with a high IAF are characterized by the lower power of θ-, α1-, α2- and β1-EEG oscillations and higher power in the α3-, β2- and γ-bands in a quiescent state than individuals having a low frequency ($p \le 0.05$, $p \le 0.001$). Men with a low IAF are characterized by higher coherent EEG oscillations, particularly, in the frontal, temporal and central lobes ($p \le 0.05$, $p \le 0.001$). Such differences in power and coherence between male subgroups are traced during the execution of movements. Moreover, men with a low frequency have the power predominance of the β2-activity in comparison with those who have a high IAF ($p \le 0.05$). Differences between power and coherence of EEG oscillations between male subgroups are shown in Fig.3 and Fig.4.

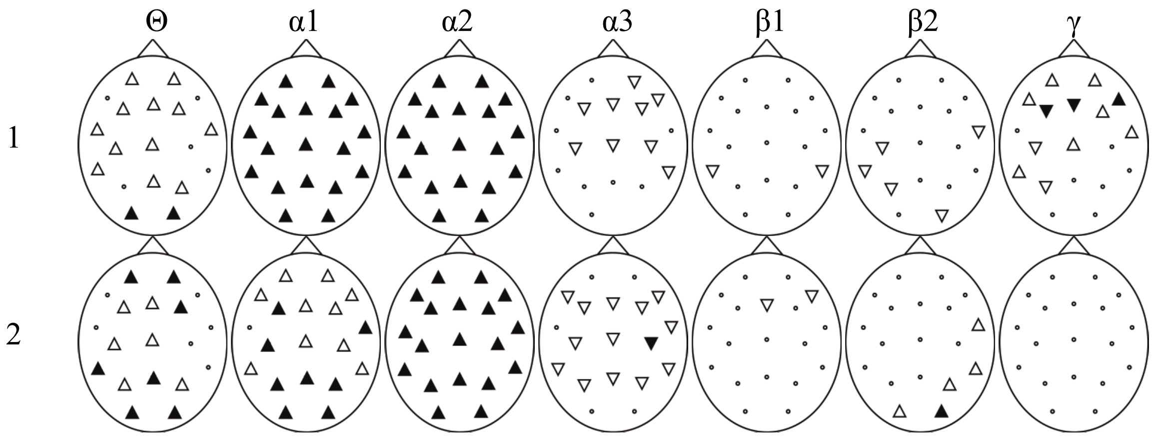

Figure 3. Differences in the EEG frequency power between male subgroups in a quiescent state and during habitual manual movements
Source: own study

Notes to Fig.3-4:
1) 1 - a functional balance, 2 – the execution of habitual manual movements.
2) △▽▲▼ higher (lower) rates in men with a low IAF level, $p \le 0.05$, $p \le 0.001$,
3) ═ (‑ ‑ ‑) higher (lower) rates in men with a low IAF level, $p \le 0.05$, $p \le 0.001$.

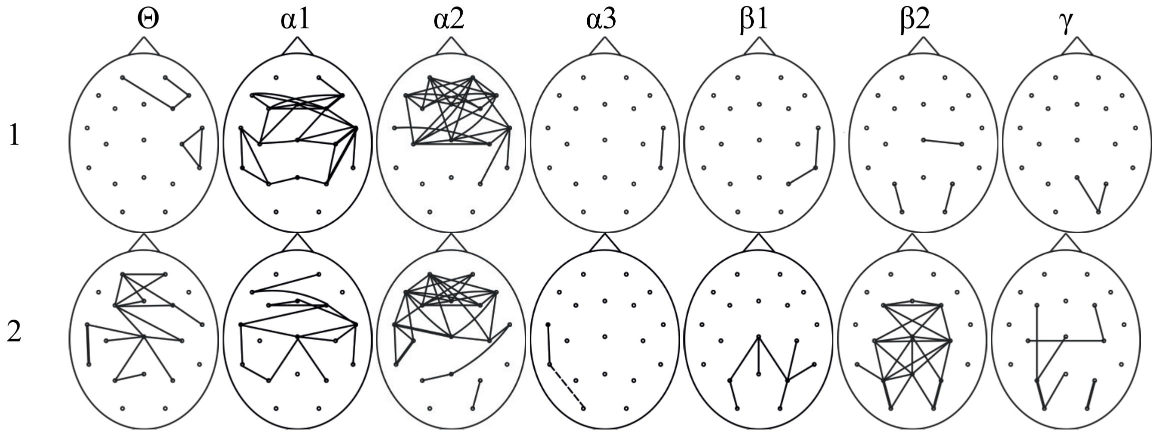

Figure 4. Differences of the EEG coherence oscillations in subgroups of men in a quiescent state and during habitual manual movements
Source: own study

Discussion

Performing habitual manual movements as any other activities takes place against the backdrop of a functional state of the nervous system, which can be evaluated by EEG parameters. The nature and results of operations depend on the background of the bioelectrical activity. Therefore, it is important to take into account the features of the background in testees' groups. According to Cherminskyi (Cherninskyi et al., 2010), this approach prevents an incorrect interpretation and "masking" of some reactions having the inverse orientation in different testees. The information content of changes in the functional state of the cerebral cortex increases during its activity.

According to literature references (Klimesch et al. 2,007, Pulvermuller et al. 1997), the reduced θ-power as well as low α-activity elicited in our studies may be associated with the state of ability and attention retaining whilst the expression of α3-, β-and γ-oscillations may be coincided with the organization of specific forms of attention necessary for higher cognitive functions. Thus, defined differences in the power level of EEG frequency bands in male subgroups may indicate the status of the relatively high activation tone of the cortex and its ability for any activity and monitoring of information and thought processes in individuals with a high IAF. Those cortex functional features became an evidence of modeling systems of brain activity (Danilova 1985). Neuropsychological research works (Korsakova, Moskvichyute 1995) showed that the thalamus and neocortex interactions provide the process of attention, level of activity and orientation as the best backgrounds for the mental processes and their occurrence as well as they may indicate a predominance role of the thalamocortical ties in patients with a high α-rate under the quiescent state observance.

A relatively lower activation tone of the cortex in groups of subjects having a low IAF is accompanied by low coherent EEG oscillations, particularly, in the frontal, temporal and central lobes. Thus, conditions for compensatory relief of the propagation of the excitation among different nodes of structural and functional systems of any perception (Gavoronkova 2009) under these conditions are created. The functional meaning of this spatial synchronization type is associated with a higher level of encephalic stresses (Knipst et al. 1982) and with the mobilization of all elements of the system as well as with the inclusion of additional units. The research (Knipst et al. 1982) showed that this increase in spatial synchronization of cortical potentials was modulated by tonic effects of nonspecific brain systems: the limbic system in the low-frequency range and the reticular formation in the high frequency band of the EEG.

An important component of brain mechanisms of any information processing during habitual movements of finger clenching and unclenching in men from both subgroups is any blocking of the cortical electrical activity. According to literature references, a unidirectional power reduction over a wide frequency range of the EEG is a reflection of the processes of the active information processing and the increased level of attention (Bastiaansen et al. 2005). The increase diffusivity of the changes in high-frequency bands (α3-, β1- and γ-) may be due to the influence of the reticular formation of the brain stem as the modulator of the electrical activity in the cortex at these frequencies. Moreover, the left hemisphere activity is predominant and relatively contralateral to the working limb. Men with a low IAF are characterized by the propagation of the excitation in the cortex. Such changes in each man can be primarily evidence of the sensory stimuli processing, sensory-spatial attention, and completed motor program running instead of its creating. We assume that the function of the motor cortex under these conditions is the actualization of the long-term memory and the motor program startup of the nervous automatisms corresponding to the usual movements of manual process of the finger clench and unclench. The correction of these movements may be largely due to the internal tonic control by local feedbacks (Bernshtein 2008, Kazennikov 2009).

The increase performance in the frontal zone of θ-, α1- and β2-subbands is fixed along with blocking processes in men with a high IAF and in the θ-and β2-EEG bands in men with a low IAF. This capacity increase in θ-, α1-frequencies may indicate the heightened selective attention inhibiting any irrelevant information (Klimesch et al. 2007), as well as updating of memory traces (Kiroj et al. 2010) and β2 –activity. It facilitates the close interaction between widely distributed neural networks involved in the sensomotor integration (Pulvermuller et al. 1997).

A reducing coherence in θ-, α1-, β- and γ-frequency bands may be generally a reflection on the reduced functional activity of the cortex (Klimash et al. 2010) apparently caused by a decrease in non-specific activating influences on the reticular formation in the cortex or in the septum generating low-frequency EEG oscillations (Klimash et al. 2010). Thalamocortical interactions may greatly provide the necessary level of any attention and selection of any relevant information concerning the first touch afferentiation based on a nonspecific tone reduction in the cortex. A spatial synchronization (the coherence increase) in α2-band and the expression of θ- and α1-activity in the frontal zone became evidence of this phenomenon. A local synchronization (the capacity increase) of α1-oscillations in the frontal zone indicates a relatively high degree of any attention selectivity in men with the high α-frequency. Both the diffuse activation and EEG spatial synchronization as well as the synchronization of β1-front oscillations may indicate a relative key role of any reticulocortical influence on men having a low frequency. The significance of β2-activity in this process for each man is apparently promote better integration elements of the information processing in the sensomotor coordination under the literature resources (Wróbel 2000).

Differences in power and coherence of EEG oscillations between male subgroups during the finger clenching and unclenching generally implement the likes of the detected in the functional balance. However, the implementation of the manual movements imposes additional requirements for the information processing. Men with a low IAF are characterized by a leading role of power and coherence of high β-frequency oscillations in the EEG than those who have a high α-frequency. This is apparently a correlate of the comparative increased level of the nonspecific tone in the cortex at a strengthening role of the reticular activation effect on the cortex of men with a low frequency (Pulvermuller et al. 1997, Wróbel 2000).

Thus, the higher level of the background activation tone in the cortex, any ability to carry out activities dealing with the control of information and thought processes in men with a high IAF arises from the significant role of the thalamo-frontal interactions. These characteristics determined the source of a sensory-spatial attention and its high selectivity as well as reduced a nonspecific input afferentiation subject to the usual manual movements. Relatively lower functional states of the cortex in men with a low IAF and offset by an increased tension in regulator mechanisms cause lower levels of the selective attention and increased role of reticular influences on testees during the finger movements. Each man uses nervous automatisms as motor programs already ready-to-use and stored in memory. Men with a high IAF have a greater locality and asymmetry of the excitation in the cortex with a dominated significance of the left hemisphere, which is relatively contra-lateral to the working hands. Activation changes in subjects having a low frequency are more diffuse in nature.

Conclusions

1. Habitual movements executed by a right hand are associated with any blocking, particularly, in posterior cortical areas of EEG oscillations over a wide frequency range in comparison with the background. However, the capacity increase is locally fixed on θ-, α1- and β2-waves in the frontal leads. These changes are followed by decreased coherent values of θ-, α1-, α3-, β- and γ-EEG oscillations in the cortex, particularly, in the left hemisphere, and the increased – in α2-sub-range in the frontal, anterior temporal and central areas, as well as β-frequencies – in the frontal areas of the cortex.
2. Men with a low IAF in a quiescent state and during movements are characterized by a higher power of θ-, α1-and α2-EEG oscillations and lower – in the α3-, β2- and γ-bands than testees with a high frequency. Men with a low IAF relatively differ by higher values of the EEG coherent oscillations, particularly, in the frontal, temporal and central lobes of the cortex.
3. Men having a high IAF are characterized by the greater locality and asymmetry of phenomena called the blocking of the electrical activity of the cortex in a wide frequency range whilst men with a low α-frequency – by a high diffusivity of such changes.

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References:

1. Anokhin A., Muller V., Lindenberger U., Heath A, Myers E. (2006) *Genetic influences on dynamic complexity of brain oscillations.* "Neuroscience Letters", Elsevier Science Ireland Ltd., Netherlands, vol. 397, № 1–2, p. 93–98.
1. Bastiaansen M., van der Linden M., ter Keurs M., Dijkstra T., Hag P. (2005) *Theta responses are involved in lexical-semantic retrieval during language processing.* "Journal of Cognitive Neuroscience", Mit Press, Kambridge, USA, vol. 17, p. 530–541.
2. Begleiter H., Porjesz B. (2006) *Genetics of human brain oscillations.* "International Journal of Psychophysiology", Elsevier, Netherlands, vol. 60, № 2, p. 162–171.
3. Bernshtein N. (2008) *Biomechanics and physiology of movement*: Selected psychological works. Moscow Psychological and Social Institute Press, Moscow, Russia Press "Modek", Voronezh, Russia 688 p. (in Russia)
4. Cherninskyi A., Kryzhanovskyi S., Tukajev S., Piskorska N., Zyma I., Mak***a***rchuk M. (2010) *Relations between human resting and reactive EEG during activity with different information richness.* "Physics of the Alive", Kyiv National Naras Shevchenko University Press, Kyiv, Ukraine, vol. 18 (2), p. 85 – 91. (in ukrainian)
5. Christian J., Morzorati S., Norton J., Williams C. J., O'Connor S., Li T. (1996) *Genetic analysis of the resting electroencephalographic power spectrum in humans twins.* "Journal of Psychophysiology". Official publication of the Federation of European Psychophysiology Societies, vol. 33, p. 584–591.
6. Danilova N. (1985), *Functional Status: Mechanisms and Diagnosis*, Moscow University Publishing, Moskow, Russia, p. 287. (in Russia)
7. Doppelmayr M., Klimesch W., Hodlmoser K., Sauseng P., Gruber W. (2005) *Intelligence related upper alpha desynchronization in a semantic memory task*. "Brain Research Bulletin", Elsevier, Netherlands, vol. 66, p. 171–177.
8. Gavoronkova L. (2009) *Right-handed, Left-handed. Biopotentials Hemispheric Asymmetry of the Human Brain*, Press "Ekoinvest", Krasnodar, Russia, p. 240. (in Russia)
9. Hooper G. (2005) *Comparison of the distributions of classical and adaptively aligned EEG power spectra.* "International Journal of Psychophysiology", Elsevier, Netherlands, vol. V. 55, № 2, p. 179–189.
10. Hyde J. (2005) *The gender similarities hypothesis.* "American Psychologist", Official publication of the American Psychological Assocition, Washington, USA . – 2005. – V. 60, № 6. – P. 581.
11. Kazennikov O. (2009) *Cortico-spinal influence on the distal muscles of the arms at innertsionnoy load.* "Journal of Higher Nervous Activity", Russian Academy of sciences Press, Moscow, Russia, vol. V. 59, № 3, p. 288–295. (in Russia)
12. Kiroj V.. Vladimirskij B., Aslanjan E., Bakhtin O., Minjajeva N. (2010) *Electrographic correlates of actual and mental movements: a spectral analysis.* "Journal of Higher Nervous Activity", Russian Academy of sciences Press, Moscow, Russia, vol. 60, № 5, p. 525–533. (in Russia)
13. Klimesch W., Sauseng P., Hanslmayr S. (2007) *EEG alpha oscillations: the inhibition–timing hypothesis*. "Brain Research Reviews", Elsevier, Netherlands, vol. 53, p. 63–88.
14. Klimash A., Tsytseroshyn M., Shepovalnikov A., Zajtseva L., Kondakov E., Borovikova V. (2010) *Violations of the spatial organization of the bioelectrical activity of the cerebral cortex in boldnyh with severe traumatic brain injury at a different intensity of oppression consciousness*. //Human Physiology, Russian Academy of sciences Press, Moscow, Russia, vol. 36, № 5, p. 49–65. (in Russia)
15. Korsakova H., Moskovichute L. (1995) *Subcortical Brain Structures and Mental Processes*, Moscow University Publishing, Moscow, Russia, p. 119. (in Russia)
16. Knipst I., Kurova N., Korinevsky A. (1982) *Dynamics of the Topography of Potentials and Functional State of the Cerebral Cortex*, Press "Science", Moskow, Russia, p. 166. (in Russia)
17. Pulvermuller F., Birbaumer N., Lutzenberger W., Mohr B. (1997) *High-frequency brain activity: its possible role in attention, perception and language processing*. "Progress in Neurobiology", Pergamon Press Ltd., London, United Kingdom, vol. 52, № 5, p. 427–445.
18. Van Beijsterveldt C., van Baal G. (2002) *Twin and family studies of the human electroencephalogram: a review and a meta-analysis* "Biological Psychology", Elsevier, Netherlands, vol. 61, № 1–2, p. 111–138.
19. Wrobel A. (2000) *Beta activity: a carrier for visual attention.* "Acta Neurobiologiae Experimentalis", Nensky institute of Experimental Biology Press, Warshawa, Poland, vol. 60, p.247.