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PSYCHOPHYSIOLOGICAL FORMATION OF BRAIN ACTIVITY RHYTHM

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Abstract: *Changes in psychophysiological responses with periodic stimuli presentation were studied. Was established that the period of visual and verbal stimuli presentation during conducting various types of questionnaires coincides with the physiological responses of a person to the presented stimuli. A model of psychophysiological regulation, including the conscious regulation of physiological processes, is proposed. The natural human psychophysiological rhythm and brain activity period (BAP) are determined in very low frequency (VLF) range (30–60 seconds period).*
Keywords: *vibraimage, physiology of consciousness, psychophysiology, stimuli, chronobiology, brain activity period (BAP), VLF.*

Based on the chronome theory, created by Franz Halberg [Halberg, 1987, Blank MA, Blank OA, 2010], it can be assumed that endogenous rhythms of the human brain can occur in all frequency zones of biological rhythms — ultradianne (< 20 h), circadian and infraradian (> 28 h) [Khetagurova, 2010]. Known that with the help of external influences, for example, rhythmic photo stimulation during electroencephalography, it is possible to diagnose certain diseases of the brain [Trenité, 1999, 2012]. Another well-known method of periodically influencing a person's subconscious mind is the ambiguously interpreted technology of 25 frames [Loftus, Klinger, 1992]. However, the conscious formation of physiological rhythms under the influence of the presented stimuli still remains a little studied phenomenon, despite the theoretical and practical relevance of this problem when studying consciousness or conducting an interview. The work on the physiology of consciousness [Boring, 1933] known for a long time, and the term itself was introduced in the 30 s of the last century, before the appearance of chronobiology, as an independent scientific direction. Heart rate variability studies are also widely represented [Baevsky et al., 2001; Shaffer, Ginsberg, 2017] as medical and chronobiological research. Researchers of heart rate variability (HRV) proved the complexity of the mechanism of regulation of cardiac activity [Bayevsky et al., 2001, Chibisov, 2018], including various physiological processes and a two-level model of regulation, one of whose components is brain activity [Baevsky et al., 2001 , Fleischman, 1999, 2014]. However, most studies of HRV are focused on the internal regulation of physiological processes without taking into account the work of consciousness.

The aim of this work is an experimental study of psychophysiological and chronobiological factors affecting the period of human brain activity in the VLF frequency range.

The first objective of this work was the external formation of the period of brain activity upon presentation of stimuli close to the period of presentation to the natural period of brain activity in the VLF frequency range.

Another objective of this work was to identify the natural period of brain activity in the VLF frequency range using vibraimage technology.

Materials and methods

As an example of psychophysiological rhythm formation, we consider the results of testing groups of 825 high school students and students (aged 15–25 years) using the VibraMI program with the Gardner12T questionnaire [Minkin, Nikolaenko, 2017; VibraMI, 2019] and a group of 210 high school students (age 15–17 years) of St. Petersburg schools for PsyAccent programs with the T12 questionnaire [PsyAccent, 2019], conducted in 2017–2018. Testing was conducted on computers with an IntelCore I7 processor, with a Microsoft LifeCam Studio webcam with an image format of 640×480. The illuminance of the test subjects was within (500–700) lux, the horizontally testee head size was at least 200 elements, the image quality indicator in the VibraMI and PsyAccent programs exceeded 80%. The duration of each test was approximately 380 seconds.

As an example of the natural physiological rhythm formation, the results of 100 tests in the course of work of 5 photolithography operators (20 tests of each operator), as the responses for asynchronously generated stimuli are presented. Operators were monitored by the VibraMed10 program [VibraMed10, 2019], operators aged 30–59 years, testing was conducted in 2019. Testing was conducted on computers with an IntelCore I7 processor, with a Microsoft LifeCam Studio webcam with an image format of 640×480. The illuminance of the test subjects was within (500–700) lux, the head of the test horizontally was at least 200 elements, the image quality indicator in VibraMed programs exceeded 60%. The duration of each test was approximately 380 seconds.

VibraMI, PsyAccent and VibraMed10 programs measure psychophysiological state (PPS) time dependences during whole testing time.

Testing results

In the process of testing with VibraMI and PsyAccent programs, test subjects are presented with a stimulus image and textual information, to which they (during the presentation time) should answer in the Yes / No format or ignore the answer to the presented question. The time of each question presentations was approximately 16 seconds and has slight fluctuations from question to question, since the duration of the presented textual information is slightly different (from 5 words to a minimum question, to 10 words to a maximum question). VibraMI and PsyAccent programs differ in the semantic content of the questions [VibraMI, 2019; PsyAccent, 2019], however, the period of change in physiological parameters identified by these programs and presented in Figures 1 and 2 was approximately the same (34 seconds for VibraMI, 30 seconds for PsyAccent) and approximately equal to the time of presentation of two questions (32 seconds). The averaging of the data of spectrograms of FFT processing was carried out by the mean (Avg) and median (Median) values obtained during each testing.

According to the available data in the maximum range, the discreteness of determining period samples by the FFT was approximately 4 s, therefore it should be considered that the maximum in graph 1, which is 34, is the closest reading to the period of stimulus presentation, including the presentation of 2 questions — 32 s [Minkin, Myasnikova, 2018].

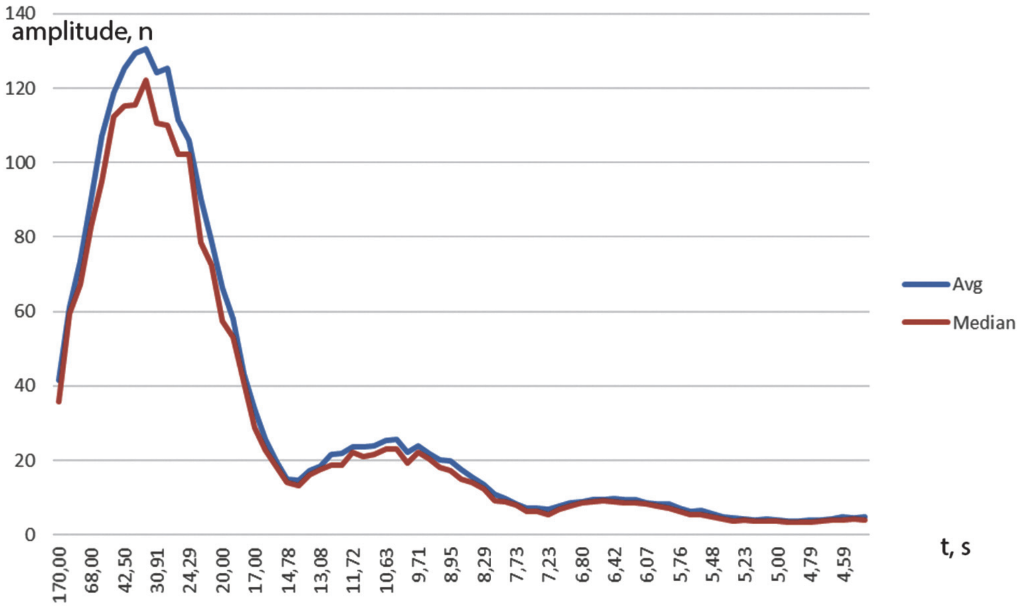

Fig. 1. PPS spectrogram calculated by FFT for 825 tests conducted by VibraMI program

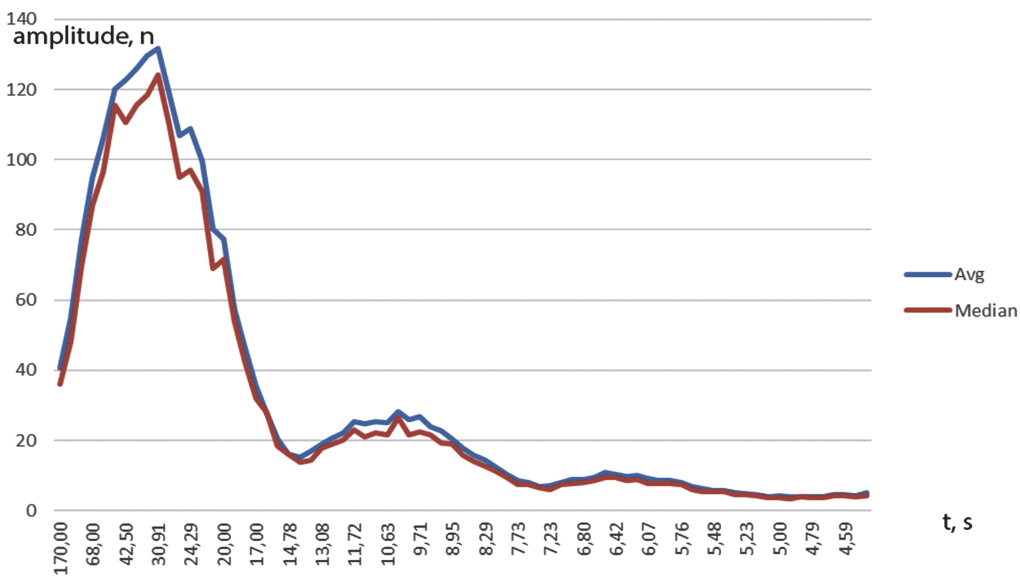

Fig. 2. PPS spectrogram calculated by FFT for 210 tests conducted by PsyAccent program

The maximum on figure 2 corresponds to a period of 30.91 seconds, the next period countdown is 34 seconds. Thus, with an accuracy within one discrete, both maximums on the graphs coincided with the stimuli presentation period and, therefore, when conducting surveys with programs with different content of questions, the period of changing the PPS of the testee does not depend on the content of the questions, but is determined by the external rhythm of presentation of incentives. Figure 3 shows FFT spectrogram, obtained by monitoring the operators with the VibraMed program for the same time of 380 seconds. The work of the operator provides for the emergence of unsynchronized (without a specific presentation period) stimuli, i. e. a response to stimuli can occur at arbitrary points in time.

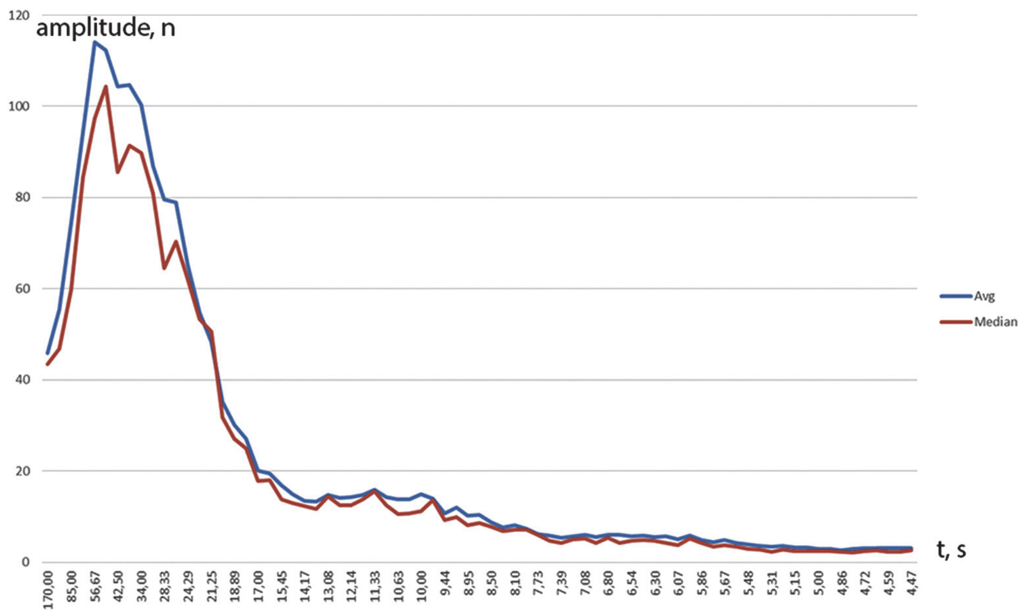

Fig. 3. PPS spectrogram calculated by FFT for 100 tests conducted by VibraMed program

It is interesting to note that when testing photolithography operators in the process of working with arbitrary stimuli, there was a clear shift of the maximum of the period towards lower frequencies compared to the tested ones, which were presented with stimuli with a period of 32 seconds. The maximum value of the FFT spectrogram in graph 3 corresponds to a period of 56.67 seconds for averaging values and 48.57 for median reading.

Discussion

In this research, the analysis of changes in the physiological state of the subjects was processed by the vibraimage technology [Minkin, Shtam, 2008; Minkin, 2007; 2018, Blank et al., 2012]. The testee was in a quasi-stationary state, practically did not make any movements, only watched the questions and stimuli appearing on the monitor screen. Consequently, the physical activity of the subjects was close to zero, the physiological activity can be conditionally considered as a constant, having periodic fluctuations associated with the flow of natural physiological processes in the human body (respiration, heartbeat, etc.). The unstable value (affecting metabolism) was only brain activity, which responds to the presentation (and disappearance) of new stimuli and questions to the subject. It is logical to assume that the presentation of the new stimulus to the subject should cause an increase in the processes of perception and information processing in the human brain and an increase in the energy consumed by the person. After answering the question posed, there should be a slowdown in conscious thinking processes and a decrease in the energy consumed. Since the human brain is the main consumer of oxygen [Tamar, 1976], the increase in the intensity of the brain activity should be noticeable by the increase in energy consumption of the whole organism. Based on these considerations, it was possible to assume that the period of change in the physiological state of a person should coincide with the time of presentation of one question and stimulus to the subject.

However, from the figures 1 and 2, we see that this is not the case. Earlier studies [Minkin, Myasnikova, 2018] showed that the presentation of each individual stimulus shifts a person's PPS away from the natural equilibrium psychophysiological state, and the presentation of the next stimulus shifts the PPS in the opposite direction. If we consider the change in the PPS in the axes of information-energy (information efficiency of the physiological systems functioning — the energy consumed by man), then upon presentation of significant questions an inverse correlation was established between the information and energy parameters of person [Minkin, 2018]. This mechanism of psychophysiological regulation leads to the fact that the period of changing PPS is the time of presentation of two questions-stimuli, and the adjustment of physiological mechanisms to the external rhythm occurs almost instantly after the presentation of the first question-stimulus.

It is interesting to note that the natural physiological processes (heart rate, breathing) are almost imperceptible against the background of the work of consciousness, which imposes its rhythm on the work of all physiological systems. It turns out that it is the processes of consciousness (psyche) that are in this case the conductor of the work of physiological systems, i. e. nature gave the brain the right to dispose of the resources of the body at its discretion. In previous studies of HRV, Professor Fleischmann found a noticeable maximum on Fourier spectrograms in the VLF (very low frequency) band with a period in the range of 30–60 seconds [Fleishman et al., 2014 *a*, *b*]. Moreover, Fleischman connects this maximum with the work of the brain and the psychoemotional state, and analysis was carried out for medical diagnostics of the studied patients depending on their functional state.

In this paper, we analyzed not the medical indicators of the testee, but their conscious and psychophysiological responses to various semantic stimuli, which allows us to put forward a number of new hypotheses. The different shape and magnitude of the maximum in the spectrograms for a free and imposed rhythm shows that the human brain can adapt to the frequency of external stimuli, if the stimuli presentation period is less than the natural period of regulation of brain activity, which usually does not exceed 60 seconds.

With the active work of the brain, there is a natural psychophysiological regulation of the work of the brain, which does not allow brain activation for more than half a period — 30 seconds. The human body has something similar to graphite rods that do not allow overheating of a nuclear reactor, the physiological causes of this phenomenon can be quite complex, but the phenomenon of periodic brain activity should be considered proven. It is possible that this process has an acquired character, is determined by dynamic connections in the human brain and does not have rigid double-circuit regulatory mechanisms proposed by researchers of HRV [Bayevsky et al., 2001, Fleishman, 1999, 2014]. The study of brain activity dynamics by vibraimage technology can establish the mechanism of rhythmic brain activity, since the technology vibraimage does not influence the brain load of testee. Naturally, the BAP has a certain variability (as heart rate) for each person and depends on many factors. In this study, we see the period in the range of 35–60 seconds for natural rhythm and 30–35 seconds for the imposed rhythm.

The presentation of external stimuli (imposed rhythm) can slightly change the BAP, but most likely, it will be in the VLF range from 30 to 60 seconds. The study of BAP dependence on various factors may be the subject of further research. We believe that, in contrast to the heart rate (HR), a lower-frequency process of brain activity better characterized by period (time) parameters, than frequency, therefore we suggest introducing the term “brain activity period” or “BAP”. The history of the study of pulse activity has more than 5000 years, the history of the study of brain periodic activity is just beginning. Moreover, the use of the term BAP allows you to distance yourself from the traditional frequency EEG ranges of 1–50 Hz (delta, theta, alpha, betta, gamma) [Tatum, 2014], which characterize the current brain activity, rather than its chronobiological activity. Perhaps this technology will allow the dream of many managers to come true and will allow remotely and contactless controlling the mental labor process of workers. It is logical to assume that, just as exercise causes an increase in pulse rate, mental load should cause a decrease in the period of brain activity. Experimental confirmation of this dependence was obtained in the work devoted to the study of BAP under various brain loads of the subject [Minkin, Kachalin, 2019].

Conclusions

Given data of almost instantaneous adjustment of person’s physiological parameters to an external imposed rhythm with the help of processes of consciousness are of particular interest, since they reveal the adaptive capabilities of a person from external influencing factors. Data of brain activity period obtained by two independent technologies (HRV and vibraimage) confirm the indisputability of this phenomenon, despite the fact that BAP is not widely known to date. It is interesting to pay attention to the lack of attention to the VLF range from the rather widespread and long-studied electroencephalographic studies, which are focusing on the higher frequency ranges, showing not chronobiological processes, but current brain activity.

The heightened sensitivity and informational content of the vestibular system, as an integral characteristic of the PPS [Minkin, 2018] allows visualizing PPS integral changes synchronously with the changes of external factors and autonomous chronobiological processes. The measurement of blood flow in the brain is too difficult to collect reliable statistics on a large number of subjects and identify brain pulse activity [Butler, 2017], and the study of HRV and ECG is usually performed on electrodes that reflect the general blood flow, rather than brain activity. At the same time, subjects (patients) in conducting medical studies (EEG and ECG) are usually in a relaxed state and do not have significant brain activity, which also prevented the establishment of the effect of BAP previously. Thus, it can be established that the objectives of this study should be considered completed, and the revealed period of brain activity is one of the basic psychophysiological characteristics of a person.

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