

THE APPLICATION OF NEUROTECHNOLOGIES TO IMPROVE THE WORK EFFICIENCY OF PROJECT TEAM MEMBERS

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Abstract: In this article the experiment on the use of neurotechnologies among project team members was described and conducted using brain-computer interface with functional biofeedback technology. The results of the experiment showed that it was extremely difficult for young people to regulate psycho-emotional state and the technology of neurofeedback can be regarded as “physiological mirror” which helps to train the physiological and mental states by tracking their brain activity in a real time mode. It was found out as well that the teamwork contributes to increased involvement, self-confidence, concentration and relaxation of the participant, if necessary. In conclusion some recommendations for project managers were given. The results of the practical part can be useful for further study of brain activity, receptivity to information, various psycho-emotional states of employees of organizations, as well as for the practical application of neurofeedback technologies in the activities of companies and project teams.

Keywords: Brain; Neuro Project Management; Project team members; Neurofeedback; Neurotechnologies; Electrical signals; Brain computer interface; Psycho-emotional state.

1. INTRODUCTION

In the modern world, most discoveries are made at the junction of various sciences. Neuroscience, as a complex of sciences combining psychophysiology, behavioral physiology and genetics, is now widely studied by scientists from different countries. The development of neuroscience permeates and covers many scientific areas including medicine, engineering and most of social sciences, creating opportunities for research and new scientific branches. Such interdisciplinary areas as neuroeconomics, neuromanagement, neuromarketing, neuro project management and others are rapidly developing today.

Management is closely related to the basic economic sciences, as well as to such general sciences as psychology, sociology. In modern

companies it is not enough for a manager to use classical management functions. The activity of a manager is increasingly related to emotional intelligence, behavioral psychology, knowledge management and the development of cognitive abilities. Competent management of an organization or project requires systematic management of processes through which knowledge from the external environment is identified, accumulated, distributed and applied in the organization to improve its performance. The cognitive abilities of the head and the specialists of the organization become the key to the development of the organization, not survival.

2. RELATED WORKS

Many authors in their scientific works described the technologies of the fourth industrial revolution. Such technologies of digitalization

and robotization of production permeate all spheres of human activity: work, everyday life, leisure. They help a modern person in making decisions, but not making decisions for him (Fernández et al., 2021; Hassoun et al., 2023; Love et al., 2022). At the same time, scientific works describing the technologies of the fifth industrial revolution are already appearing. They focus on the creation of cyber-physical systems and bio-technologies that stand at the intersection of such sciences as medicine, genetic engineering, psychophysiology, neuroscience, engineering (Gumbo et al., 2023; Muddassir, 2020; Noble et al., 2022). The creation and implementation of such systems is supposed to be in all spheres of activity with the possibility of decision-making without human participation (Nayeri et al., 2023).

Project management has also been investigated by many authors for the possibility of using neurotechnologies (Khalimon et al., 2020; Khalimon, 2020; Kemp, & Baker, 2022; Neuro Project Management, 2020; Vargas, 2015).

It should be noted that it is incorrect to consider neurotechnologies as technologies aimed only at using neural networks when analyzing a large amount of data and helping the project manager make decisions (Mossalam, & Arafa, 2017; Vargas, 2015). Neuro project management, as a scientific approach, reveals the specific patterns of the formation of project thinking, as well as the features of neural processes in the professional activities of project managers (Khalimon et al., 2020; Khalimon, 2020; Kemp, & Baker, 2022). And it is already possible to explore the possibilities of using neural networks in the field of project management (Neuro Project Management, 2020).

It was noted by the authors that it is impossible to use neural networks at the level of tactical management in the company (Tronto et al., 2008; Wang, & Bu, 2023) or at the project level. This is due to the fact that a small limited time horizon does not allow to accumulate a large amount of data (Vargas, 2015).

At the same time, at the level of program and portfolio management, where the planning horizon can be 10-15 years (Barro et al., 2022; Geraldi et al., 2022), or when working with megaprojects, such a need arises and a neural

network can help in data analysis and processing (Cottafava et al., 2023; Jiang et al., 2023).

Exploring the question of the impact of project activity on human thinking, on the brain, on the course of decision-making, it will be important to note that project activity is characterized by a number of factors (Liedtka, & Locatelli, 2023; Mortati et al., 2023):

- team interaction;
- the ability to communicate with external participants and within the team;
- the ability to solve problems;
- the desire to achieve the goals;
- analytical mindset and systemic thinking.

These factors form the phenomenon of project thinking (Gawarikar, 2023; Knai et al., 2023; Kiyakbay et al., 2023; Müller et al., 2015; Sisamud et al., 2023), which is different from technical or executive thinking.

Separately, it is necessary to note the rapid development of such a direction as neuromarketing (Bhardwaj et al., 2023; Ouzir et al., 2024). It is known that marketing is one of the most important components of project management (Obradović et al., 2016), since marketing research permeates the work on the project from the beginning to the end (Lehtimäki et al., 2009). Neuromarketing is now actively used in marketing projects for planning advertising campaigns, brand creation, and city development strategies (Schauerte et al., 2023; Toukola et al., 2023).

In this regard, it is considered important to conduct more research in order to better understand:

- the brain technology of specialists engaged in project activities working in a team;
- what are effective ways to activate their brain activity and involve them in work;
- what techniques can a project manager use to increase the effectiveness of the team and their activities.

3. METHOD AND MATERIAL

3.1 Neurofeedback technology

Neurofeedback is a kind of biofeedback technique that helps individuals consciously regulate their brain activity. During neurofeedback sessions, predominantly electroencephalography (EEG) data is recorded, and then the components of EEG signal are presented to participants through an online feedback loop using audio, video, or both. Through neurofeedback training, individuals learn to recognize and modify their automatic responses. Like any habit, establishing a new pattern requires repeated practice over time.

The human brain operates with electrical signals (Steinhardt et al., 2020). It constantly generates electrical impulses, which are called brain waves (or brain rhythms, brain waves, brain activity). Various patterns of the electrical activity of the brain can be identified by their amplitudes and frequencies. Frequency describes the speed at which these waves oscillate, measured in hertz (Hz), or cycles per second, while amplitude indicates the strength of these waves, measured in microvolts (μV). Different frequency components are classified into delta (below 4 Hz), theta (4-8 Hz), alpha (8-13 Hz), beta (13-30 Hz), and gamma (30-100 Hz), each associated with a specific physiological function (Hossain et al., 2023; Yousefi, & Kolivand, 2023).

EEG sensors placed on the scalp to detect brain waves, which are then converted into video games or moving images, allowing the brain to 'track' its activity. The training focuses on adjusting the amplitude of specific frequency bands at designated scalp locations to higher or lower levels. Additionally, the frequency bands and training directions (increasing or decreasing amplitudes) may vary depending on the training objectives. As the game progresses, sounds increase, and images move, the brain adjusts its wave patterns for improved functioning.

The neurofeedback technique is suitable in treatment and mental state training of both adults and the elderly, as well as with school-age children (Betts, & Froehlich-Grobe, 2017). This innovative technology can help adults improve their concentration, reduce stress levels,

and improve work efficiency. It can be used to develop self-regulation skills, improve cognitive function, and enhance overall well-being. It functions as a feedback system that delivers real-time updates on brain wave pattern changes, enabling targeted adjustments to optimize brain function.

3.2 Experimental procedure

The described study is a part of a larger experiment. In the experiment, the brain computer interface (BCI) NeuroPlay-6C (Neuro Assistive Technology Ltd) was used as a neurofeedback device for mastering the relaxation and concentration of attention skills.

NeuroPlay-6C consists of 6 surface dry, active, replaceable, coated with Ag/AgCl electrodes, placed in standard recording channels in the frontal, temporal, and occipital lobes. In our cases the monopolar montage is used in the neurofeedback training: the active electrode is placed on the skull and the recorded signal by the active electrode is compared to the second electrode entitled as the reference electrode. The activity of the active electrode minus the activity of the reference electrode represents the brain activity at the active electrode.

In our experiment the frequency/ power neurofeedback trainings were used. There are several neurofeedback treatments protocols i.e. alpha, beta, alpha/theta, delta, gamma, and theta (Marzbani et al., 2016).

We applied alpha and beta protocols. The alpha wave of the brain is usually associated with alert relaxation (Evans, & Abarbanel, 2000). The alpha condition reflects the brain's creative functions, which are utilized during relaxation (easing muscle tension) and ultimately facilitate sleep. These waves appear and spread quickly across the skin. Research indicates that alpha waves intensify during meditation. The typical frequency range for alpha therapy lies between 7-10 Hz, which is beneficial for meditation, sleep, and alleviating stress and anxiety. Additionally, a frequency of 10 Hz promotes deep muscle relaxation, pain relief, regulates breathing, and lowers heart rate (Dempster, 2012; Vernon, 2005).

Beta activity serves as a strong indicator of cognitive performance. Beta training is employed to enhance concentration and attention (simulating increased beta at 12-14 Hz), improve reading skills (simulating 7-9 Hz), and foster positive academic outcomes. It also boosts computational abilities and cognitive processing (simulating 14-22 Hz and 12-15 Hz).

As an example, the Figures 2-3 show the results of measuring the indicators of one of the participants.

The BCI interacts with several ready-made neural games used for team building. The BCI starts the video and the higher the selected indicator (concentration or relaxation), the faster and better the image is reproduced. At the beginning a brief introduction to neurofeedback technology, experimental procedure and short practice trials were provided to each subject. This experiment lasted 20 minutes.

The procedure includes several stages:

Stage 0 “Beginning”: at the zero stage, experimental tasks are prepared, equipment is selected and tested, the initial state of the group of subjects and their characteristics (number, age, gender, general physical, emotional state, readiness for the experiment) is recorded. Participants are explained the general tasks and the course of the experiment.

Stage 1 “Work at the level of introspection”: it is necessary to conduct in-depth research and cognition by the participants of the experiment of acts of their own activity in the process of team interaction within the framework of solving project issues. There is a fixation of individual thoughts, images, feelings, experiences by each participant separately. Then the presenter collects and summarizes the data.

Stage 2 “Formation of an experimental task”. Tasks involve several stages:

1. providing information to participants in the form of pictures and audio accompaniment, analysis and evaluation of the

perception of the same information by different participants.

2. interactive teamwork with NeuroPlay-6C for learning meditation and concentration methods by using ready-made neural games.
3. competition of teams in achieving the best group result in meditation and concentration.
4. Stage 3 “Experiment stage”. Participants used BCI for neurofeedback. They were given the list of task to perform and timing for each subject in a team. The obtained results depending on the participant's brain activity, stress level, and the ability to concentrate or relax were recorded.
5. Stage 4 “Evaluation of the result”: analysis of the results obtained according to the following criteria.
6. Stage 5 “Adding the results to the number of factors”: if the data collected are relevant for further analysis, then as a result, the answers to the 10 questions posed above can be achieved.

3.3 Participants

Thirty-four Master's degree students of the State University of Management (Moscow, Russian Federation) aged 22-25 participated in the study. Participants gave an informed consent to take part in the study. The study was approved by the Ethics Commission of Psychological Institute of Russian Academy of Education, 2023/02-3.

3.4 Heuristic modeling

The essence of the method is that a model of an object or process is created based on a hypothesis about its structure and functions (Zou et al., 2023). At the same time, the data available in the scientific literature are used and, based on a qualitative hypothesis, the missing ones are added by checking the assumptions.

In our case, the algorithm for using heuristic modeling looks like this (Fig.1).

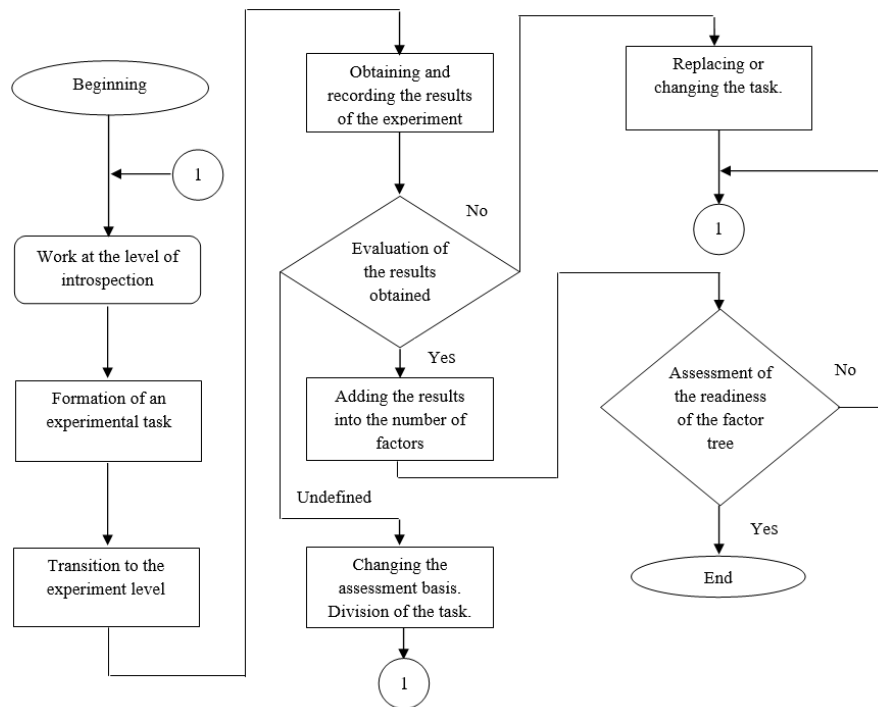


Figure 1: Heuristic modeling scheme

The process of using heuristic modeling is a single continuous process that has a beginning and an end, but contains cyclic processes. In our case, cycles are implemented by going to the beginning of the entire process with a revision of the original task (circle number 1). Also, in the scheme of heuristic modeling there are variables of transitions through a stage or stages.

The formation of the task for the experiment involves getting answers to the following questions:

Task 1 involves getting answers to questions:

- 1) Do different participants react to audio and video information in the same way or in different ways?
- 2) Can participants control their stress and mood levels?
- 3) How long is the participant's brain under stress and at rest during team interaction when engaged in project activities?

Task 2 involves getting answers to questions:

- 4) Can participants manage their concentration and relax, if necessary, while being in a team?

- 5) Do the techniques used by the participants to control the state of concentration and relaxation work the same for different participants or not?
- 6) Which subjects do better: concentration or relaxation?

Task 3 involves getting answers to questions:

- 7) Can team support help to increase the effectiveness of exercises on NeuroPlay 6-C?
- 8) What techniques are used by team members to create the conditions necessary to increase the effectiveness of exercises on NeuroPlay 6-C for the subject?
- 9) How does the performance of team tasks affect the psycho-emotional state of team members?
- 10) What conclusions do the participants draw based on the results of the tasks?

4. RESULTS

EEG data was processed and analyzed with a special software NeuroplayPro (Neuroassistive Technology Ltd). The frequency bands were analyzed in the experiment. As we applied alpha and beta protocols during neurofeedback trainings, we calculated the amplitudes of a certain frequency band on a defined location on

the scalp during each neural games in every subject of the team.

Figure 2 shows the level of alpha-rhythm of one of the participants during neurofeedback trainings. As it can be seen from the graph:

- the largest amplitude of the α -rhythm is observed in a state of calm wakefulness from the 2nd to the 5th minute with open eyes and deep breathing;
- the smallest amplitude - with mental activity (from the 6th to the 8th minute) and with closed eyes (from the 0th to the 2nd minute).

Based on this, it can be concluded that the alpha-rhythm of the neural activity of the brain

under cognitive load and with the closed eyes of the subject is similar. (It should also be noted that the jump at 01.30 and 06.20 was recorded due to the movement of the subject's and the loss of the signal from the sensors.)

Figure 3 shows the amplitude of the beta waves are high when new unexpected stimuli are presented (from the 2nd to the 3rd minute the eyes were open), as well as with mental stress (from the 6th to the 7th minute there was a cognitive load). When performing the task "deep breathing" and with eyes closed, the amplitude of the waves is not high.

The obtained values for the rhythms of the neurons of the participants' brains can be summarized and presented in the form of Table 1.

Table 1: Changes in brain rhythms when performing tasks

minutes rhythms	00.00- 02.00	02.00- 04.00	04.00- 06.00	06.00- 08.00	Comments
α -rhythm (\downarrow)	\downarrow	\uparrow	\uparrow	\downarrow	In order to be able to compare the data obtained for this rhythm, it is necessary to take into account that in a state of calmness of a person, the amplitude for this rhythm is the greatest.
β -rhythm (\uparrow)	\downarrow	\uparrow	\downarrow	\uparrow	

It can be seen from the table that reliable data suitable for analysis can be obtained when using the equipment. There was also a correlation between high activity of neurons when performing a cognitive task and when opening the

eyes of the participants, which can be used and studied more deeply in subsequent studies.

The following results were obtained during the second experiment (Table 2):

Table 2: The results of the second experiment

Research question	Answer	Comments
Task 1		
1) Do different participants react to audio and video information in the same way or in different ways?	97% of participants had the same reaction to audio and video information	When pictures and sounds depicting nature and animals appeared, causing a sense of harmony, tranquility, and enjoyment, the participants recorded a decrease in stress levels. When pictures and sounds with aggressive animals, factories, garbage, aggression appeared, the participants had a feeling of anxiety and stress. Small deviations of 3% were associated with personal memories of the subjects, distorting the result: the mountains in one participant caused a feeling of anxiety due to his experience of hiking in the mountains.

2) Can participants control their stress and mood levels?	No, they cannot	<p>When a sharp sound and an aggressive image caused by stress appeared, it was difficult for the participants to lower their excitement and calm down. Also, being in a state of calm, it was difficult for the participants to maintain this state during the experiment.</p> <p>The annoying factors were: the whispering of classmates, footsteps in the corridor, sounds from the street, the internal state of each subject associated with an unusual state of the experiment for them.</p>
3) How long is the participant's brain under stress and at rest during team interaction when engaged in project activities?	65% of the time the brain is under stress	<p>After collecting statistics from the graphs based on the results of the exercises performed, it turned out that the participants managed to keep their relaxed state only during 35% of the time. The rest of the time - 65% - the brain was in a state of stress and the participants tried to get out of this state.</p>
Task 2		
4) Can participants manage their concentration and relax, if necessary, while being in a team?	No, they cannot	<p>Being in a team and performing exercises using the NeuroPlay-6C, the participants could not successfully perform the exercises. The average result of completing relaxation and concentration tasks in the allotted time per team: 67,5% (where 100% is the maximum result).</p>
5) Do the techniques used by the participants to control the state of concentration and relaxation work the same for different participants or not?	<p>The same techniques used by the participants to control the state of concentration and relaxation work in the different way.</p> <p>To get the same results participants used different techniques.</p>	<p>When performing a relaxation and concentration task, one team member tried several ways, testing hypotheses about what exactly would make his neurons relax or tense up. Having found suitable methods, the second team member tried to apply them on himself, but they did not give the desired result, while he managed to find other ways. The same thing happened with the third member of the team.</p> <p>As a result, it turned out that in order to achieve maximum concentration or relaxation, each team member needed individual ways (for example, for concentration, someone needed to remember the alphabet of a foreign language, someone - a score from 60 to 1, another participant - to remember tongue twisters. Conversely, for relaxation, it was enough for someone to just close his eyes, for someone - silence and immersion in memories, for someone - it was enough to turn on calm music in headphones).</p>
6) Which subjects do better: concentration or relaxation?	97% of participants did concentration tasks better than relaxation tasks.	<p>A number of exercises offered to the participants were aimed at training the state of relaxation and concentration. After collecting statistics and analyzing the results, it turned out that the team members coped better with performing concentration exercises than relaxation: 80% vs. 55%.</p>
Task 3		
7) Does team support help to increase the effectiveness of	Yes, it does.	<p>Tasks performed by participants individually (without team support) showed lower results than tasks performed in a team.</p>

exercises on Neuro-Play-6C?

8) What techniques are used by team members to create the conditions necessary to increase the effectiveness of exercises on Neuro-Play-6C for the subject?	Physical contact, advice, encouragement, silence	Creating the conditions necessary for the participant to get the necessary reaction.
9) How does the performance of team tasks affect the psycho-emotional state of team members?	It causes emotions such as joy, interest and involvement, satisfaction with the result.	According to the results of the survey, the psycho-emotional state in the team is radically different from completing tasks individually. When performing tasks individually, the participant experienced fear, a sense of despair, weakness.
10) What conclusions do the participants draw based on the results of the tasks?	<ol style="list-style-type: none"> 1. It is necessary to try and train the performance of those techniques that help each person to concentrate or relax. 2. Team members feel protected, feel a comfort zone, support, additional strength to complete tasks. 3. The presence of other participants does not interfere with concentration and relaxation. 	

Analyzing the results presented in Table 2, it can be concluded that:

- modern young people are in a state of stress and emotional strain more than in a state of calm and relaxation. It is extremely difficult for them to regulate psycho-emotional states, purposefully switching from a state of relaxation to a state of concentration and vice versa.
- in order to manage the psycho-emotional state it is necessary to find those techniques that are effective for each person and regularly engage in neurofeedback to train the brain activity. Neurofeedback can be regarded as “physiological mirror” which helps to detect the effectiveness of the strategies applied.
- the teamwork contributes to increased involvement, self-confidence, concentration and relaxation (!) of the participant, if necessary.

5. CONCLUSIONS

In this study, two experiments on the use of neurotechnologies among project team members were described.

The purpose of the first experiment was to apply BCI for neurofeedback and analyze the rhythms of the participants' brains. It was

found that the data received was reliable and suitable for further analysis.

The second experiment was based on heuristic modeling and was carried out using equipment and technology of functional biofeedback. It was aimed at diagnosing the level of stress and calmness among the participants, assessing the possibility of reducing stress levels, increasing concentration and relaxation. The results of the experiment were described in detail above.

At the end of the research, some recommendations could be given for project managers. In order to increase the efficiency of team work on a separate project and to increase the efficiency of team and community management, it is necessary:

- to reduce the feeling of stress, loneliness and oppression among team members, to identify those factors and root causes that cause such a feeling;
- provide space and conditions for teamwork, increase team spirit and encourage the involvement of each participant in teamwork;
- conduct neurofeedback trainings, that allow project team members to regulate

their psycho-emotional states of concentration and relaxation while performing their duties, and not experience a feeling of emotional, psychological burnout and exhaustion.

6. DISCUSSION OF THE OBTAINED RESULTS AND FUTURE WORK

The results of the theoretical study can be useful for further scaling up the practice of applying neurotechnologies in the field of Management, Project Management, Human Resource Management.

The results of the practical research can be useful for further study of brain activity, receptivity to information, various psycho-emotional states of employees of organizations, as well as for the practical application of neurofeedback technologies in the activities of managers of companies and project teams.

During the experiments, two phenomena were discovered that require further in-depth research:

- 1) There was also found a possible correlation between high activity of neurons when performing a cognitive task and when opening the eyes of the participants', which can be used and studied more deeply in subsequent studies. It has been hypothesized that the amount of information received by a person when opening his eyes (shapes of objects, distance, condition of objects, colors, shapes) exerts a cognitive load on the brain that is comparable or exceeds the load of the brain when performing a complex mental task.
- 2) The participant with speech problems and the participant who did not speak the language of teaching at the university performed the best in concentration and relaxation exercises. A hypothesis that needs to be tested has been put forward that people who do not possess high social and communication skills develop the ability of rapid concentration and relaxation during their lifetime. They don't need the support and assistance of a team. At the same time, people with highly developed social and communi-

cation skills do not do well with concentration and relaxation exercises. The help of other team members helps them to cope with tasks and train their brains.

The results of the research conducted in this article do not solve the questions posed, but bring researchers closer to solving them, raise new questions, draw attention to the study of the issue of Neuro Project Management from the point of view of neural activity of the brain, rather than machine learning and neural networks, and contribute to the development of Neuro Project Management as a science direction.

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APPENDIX

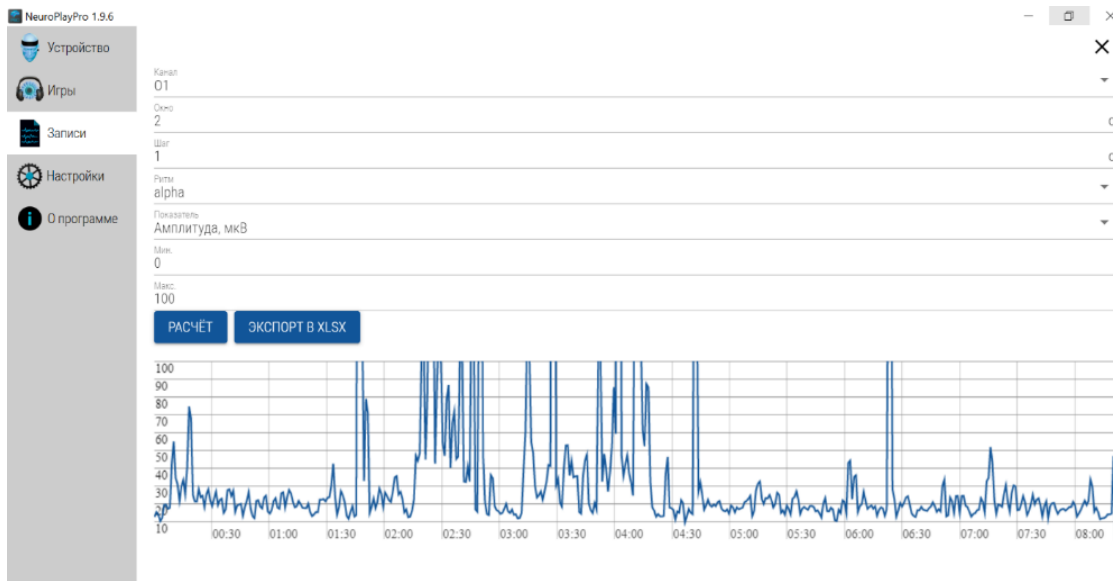


Figure 2: Alpha-rhythm of one of the participants

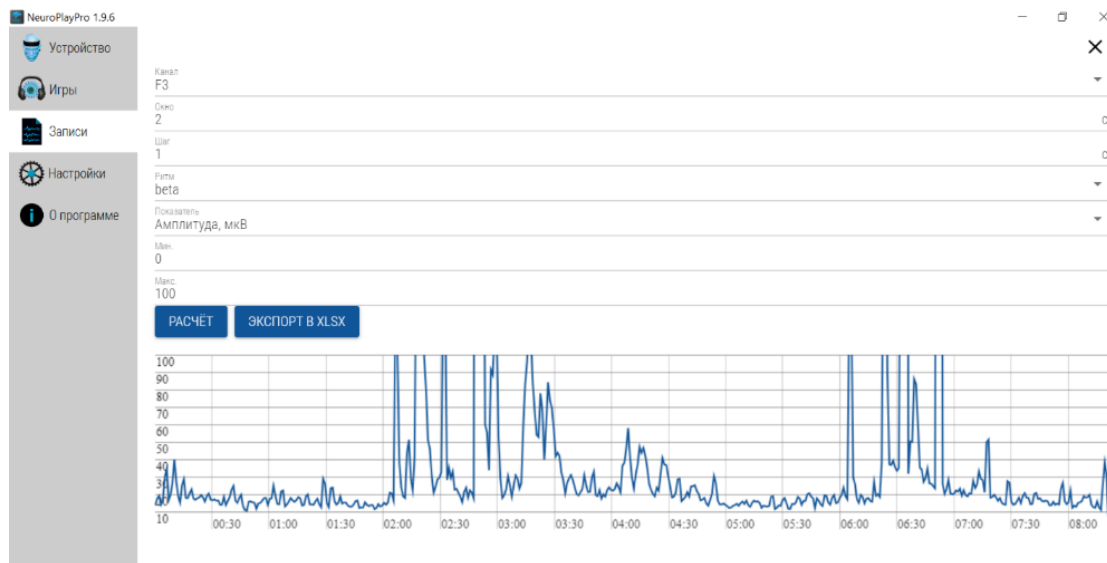


Figure 3: Beta-rhythm of one of the participants