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Multi-neural interface of borderline mental disorders express-evaluation

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Abstract

In the article analysis of known neural interfaces of brain activity monitoring is conducted, which showed the limited possibilities for their application for the express-evaluation of borderline mental disorders using medical electrical (cardiographic (ECS), encephalographic (EES) and speech signals (RS),. In the work the development of a new multi-neural interface for person's borderline mental disorders express-evaluation is justified, which differs from the known analogs of the detection capability of a wider spectrum of important for parameters diagnostic purposes, obtained by ECS, EES, and RS signals recording. In the article the main technical parameters of multi- neural interface the borderline mental disorders express-evaluation is described, the structural and functional device diagram, including a digital electrocardiograph with three dry electrodes for limb leads recording, a digital electroencephalograph with seven dry electrodes for four frontal leads recording, a digital speech recorder and specialized software.

Keywords: Multi- neural interface; express-evaluation; borderline mental disorders.

INTRODUCTION

Modern science considers the preservation of population health process as the perfection and development of physiological, biological, mental and social functions.

According to Ushakov G.K. [1] the diagnostics of borderline mental disorders is an interdisciplinary direction of research focusing at the intersection of medical, biological, psychological, social and technical sciences. The development of psychiatry cannot be successful without a systematic full analysis of approaches to clinical diagnosis, as well as obtaining of additional information and knowledge about the formation of pathological abnormalities.

When deciding the issue on the possibility of the emergence of borderline mental disorders, the significance of the established interaction of various biological signaling systems should be taken into account: cardiovascular, central nervous and the system of organs of the speech apparatus, which are direct indicators of person's borderline mental disorders[2-4].

The result of work of these biological signaling systems is the obtainment of various signals: electroencephalographic (EES), electrocardiographic (ECS), speech (RS) signals reflecting the patient's mental health. In the literature [2-5], the urgency of express diagnostics of neuroses and neurosis-like conditions is widely noted on the definition basis of the significant medical parameters of EES, ECS and RS.

However, the possibilities of instrumental methods for studying of the diagnosis of borderline mental disorders based on the determination of significant informative parameters of medical electrical and acoustic signals have not been studied. This creates a basis for conducting research in the direction of developing and improving of new methods and tools for instrumental diagnosis of borderline mental disorders on the basis of determining of the informative parameters of biological signaling systems [6-9].

ANALYTICAL REVIEW

According to monitoring «Markets and markets» companies [10], the potential of the world market for various mobile medical devices for monitoring and predicting of the health human condition by 2021 will be more than 9 Billion USD.

Recently, on the market of medical devices a new category of health condition evaluation systems has appeared by person himself - the neural interfaces. Most of these systems are based on the brain activity monitoring with the help of EES.

The first available neural interface was presented on the world market by NeuroSky company in 2009, under the name "Neuro Sky Mindset" [11]. This neural interface was a portable, wearable device based on recording of single-channel EES and electromyogram (EMG).

In 2014, the world community a new neural interface "BrainLink" by Macrotellect company [12] was presented. The purpose of this device is comparable to "Neuro Sky Mindset". The advantage of the well-known neural interface is the ability to operate with a large number of NeuroSky software applications. However, most efficiently operating applications are entertaining and usually paid (figure 1).

Figure 1: Neural interface BrainLink.

The next neural interface presented on the market in 2014 is "Epoc", by Emotiv company [13]. The "Epoc" neural interface is designed as an affordable wearable wireless device for EES multi-channel recording in high-intensity noise conditions of various kinds and free motor activity of the user. The advantage of the device is the use of 14 electrodes. However, this advantage is also a drawback: all electrodes must be treated with a special gel (figure 2).

Figure 2: Neural interface Epoc.

Another "Muse" neural interface by Interaxon company is presented in 2015 on the mass market only in Canada and the US [14]. From a technical point of view, Interaxon company took into account all the advantages and disadvantages of its predecessors (figure 3).

Figure 3: Neural interface Muse.

The "Muse" neural interface is equipped with seven dry electrodes for EES four leads recording. The main purpose of "Muse" is health status adjustment in the presence of stressful situations. In the process of neural interface using, the user is offered to view on the PC or smartphone the natural landscapes corresponding to the mood, allowing carrying out the relaxation procedure.

Based on the conducted analytical reviews of known neural interfaces results [11-14] and our own studies [15-17], many wearable devices ECS and EES recording have been revealed, but most of them are used for brain activity measuring or for calculation and evaluation of general non-standardized health indicators. Consequently, known devices cannot be used for actual application and evaluation of a person's mental health.

The results of the patent research also revealed new trends in the development of wearable portative devices for a person's mental health evaluation.

Medtronic, Neuropace and St.JudeMedical companies are actively conducts of joint developments of neural interfaces for brain activity monitoring and control of its response to external stimulation factors [18].

CNS Response and Advanced Brain Monitoring companies are develop the neural interfaces [19], which allows to analyze the large data arrays (big date) of the EES products of the initial for specified functions.

Toyota and Freer Logic Companies are develop the integrated in-car driver evaluation systems in real time based on the recording and EES analysis [20].

Microsoft company is actively patenting the development of neural interfaces for increase of labour productivity [21].

Posit Science and Lumos Labs Companies are develop the neural interfaces for the intellect development and human memory through a thought experiment [22].

Known the "Method for the Classification and Treatment of Physiological Deviations in the cerebration Using the Quantitative EES Evaluation " [19] which makes it possible to use the correlation method for EES analyzing recorded before, during and after the user performs certain tasks using the neural interface.

The work of the known method are consists in implementation of the following actions:

• preliminary task selection for research conducting;

• EES recording before, during and after tasks completed;

• EES Segmentation to the areas of the recorded data before, during and after tasks completed;

• model construction of EES quantitative parameters;

• Conducting of correlation research of the selected parameters.

The main drawback of the known method [19] from the point of view of practical application for use in express-evaluation systems of borderline mental disorders is conduction of research only for determination of the three psychological conditions of patients: surprise, satisfaction and disappointment.

Another method is known for "The EES application for tasks of classification and recognition of brain activity" [21] allowing to determine and compare EES in patients with psychiatric disorders before and after taking medications such as beta-blockers, antipsychotics, tranquilizers, anticoagulants and others that effect on cerebration.

The results of the work of the known method [21] allows to formulating the recommendations for the treatment of patients with psychiatric profile, to develop classifications and categorization (gradations) of various mental states: physiological imbalance of the brain, paroxysmal events of the brain, and others.

The work of the known method [21] are consists in in implementation of the following actions:

• EES patients recording of psychiatric profile and healthy patients;

• EES patients recording of psychiatric profile before and after taking medications;

• construction of EES quantitative parameters model;

• Conducting of correlation research of the selected parameters.

The main drawback of the known method [21] from the point of view of practical application for use in express-evaluation systems of borderline mental disorders is the conduction of research only for patients of psychiatric profile with obvious pathologies in cerebration during treatment and rehabilitation.

None of the well-known neural interfaces [11-14] and objects of intellectual activity [18-22] does not to allow fully to use them for express-evaluation of mental health, especially with the use of various types of medical signals that have proved of their importance in detection efficiency improving wider range of meaningful for purposes parameters diagnostic.

EQUIPMENT

For development of the multi-neural interface the modern equipment of the scientific and technological laboratory of biomedical and cognitive technologies of the Research Institute for Fundamental and Applied Research of the Penza State University is used. The head of which is the author of the work is Tychkov A.Yu. [23]:

1) Muse Nneural interface (2016 year of release).

It is intended for EES recording with 5 leads using "dry" electrodes and transmitting signals via Bluetooth 4.0. The device is used as an analog for the development of a multi-neural interface for express-evaluation of a person's mental health.

2) Poly-Spectrum-Radio-1 (2015 release year).

It is designed for recording and transmission on the radio channel at a 900 MHz frequency of physiological signals (ECS and respiratory rhythm) from a person. The recorded signals are displayed in real time on the computer screen. The device is used for signals recording from several patients simultaneously.

3) Cardio-analyzer computer EC9TS-01-CARDI (2014 year of release) .

It is designed for ECS automatic analysis with possibility of electronic archive research conducting, providing 12-channel recording and signal filtering (LF, HF, 50 / 60Hz). The device is used as a stationary cardiac analyzer for patients ECS recording in a clinic

4) ZET Spectrum Analyzer 017 (2014 release).

It is intended for measuring of signal parameters, analyzing and recording of spectral and correlation signals structure. The analyzer is realizes the functions of measuring instruments: a generator, voltmeter of direct and alternating current, an octave, a 1/3-octave and a narrow-band spectrum analyzer. The device is used for conducting of spectral analysis of research medical signals in different frequency bands for the calculation of autospectrums, mutual spectra, auto- and cross-correlation and coherence functions signal functions, the algorithmic application of which is described in Chapters 3 and 4 and used for signal biomarkers determination of person's borderline mental disorders.

This equipment is used for development of multi-neural interface for person's borderline mental disorders evaluation.

DEVICE DEVELOPMENT

For the purposes of borderline mental disorders diagnosing, of the developed multi- neural interface assessing of borderline mental disorders should be characterized by high mobility, multifunctional and reliability in measuring of vital signs of a person's mental health.

Body centered networks and sensors will be represent a system of heterogeneous nodes located in the immediate vicinity of the human body and interacting with each other and with the central coordinating node via wireless communication for obtaining of beneficial effect for the consumer in conditions of free human motor activity.

The principle of operation of the proposed in work multi-neural interface of person's borderline mental disorders express-evaluation is to performing of the following tasks:

- Recording of medical electrical (ECS in one lead, 5-lead EES) and acoustic (PC) signals.
- Transfer of recorded data in real time via Bluetooth to PC or smartphone.
- Visualization and algorithmic processing of medical electrical (ECS, EES) and acoustic (PC) signals on a PC or smartphone.
- Detection and visualization of critical significant parameters - signal biomarkers of borderline mental disorders.
- Signaling (sound and light) of critical mental states of the patient.

The proposed multi-neural interface for express-evaluation of human borderline mental disorders includes a digital electrocardiograph with three dry electrodes for recording of limb leads; Digital electroencephalograph with seven dry electrodes for recording of four frontal leads, digital voice recorder; Chemical current source; specialized software.

Thus, the multi-neural interface will be aimed at the implementation of a full operational and effective mental health survey conducted by the person himself. This will allow to timely access to specialists and take preventive measures for the prevention and treatment of borderline mental disorders.

The structural scheme of the proposed multi- neural interface of express-evaluation of human borderline mental disorders is show, the functional scheme is shown in figure 4.

The multi-neural interface includes a recording block (1) for medical electrical (ECS EES) and acoustic (PC) signals, comprising a module (6) from at least 7 dry electrodes for EES recording, a module (7) from at least 3 dry electrodes for ECS registration and module (8) from at least one microphone for PC registration; A real-time data transfer block (2) including a Bluetooth 4.0 module (9) for wirelessly transmitting of recorded signals and a module (10) from at least two Micro USB ports for wired transmission of recorded signals and the device's charging battery; A visualization data recording unit (3) comprising a PC module (11) or a smartphone supporting a Windows 2000/7/10 / XP / Vista / Linux / Androin / IOS operating system; (4) processing and displaying of the study results block, including a module (12) of pre-noise-proof ECS, EES and RS processing, and a module (13) for biomarkers detecting of borderline mental disorders; (5) signaling block of critical patient status including a (14) audible and light signaling of a battery malfunction or discharge, module and (15) signaling module (acoustic and light) of critical patient conditions in real time and conditions for free motor activity.

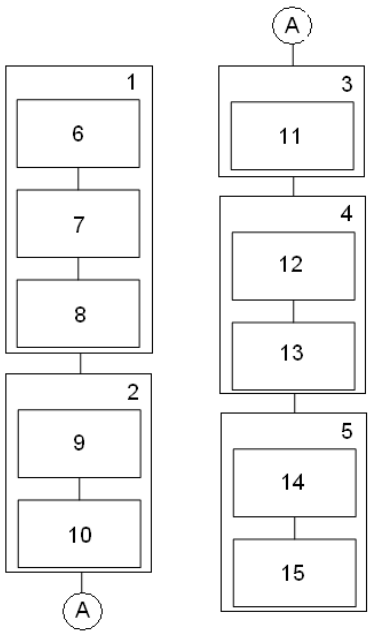

Figure 4: Structural diagram of a multi-neural interface.

Based on the results of the conducted studies, the main technical characteristics (quantitative and qualitative characteristics) of the multi-neural interface of the express-evaluation of borderline mental disorders are formed:

- number of dry electrodes for EES recording: at least 7;
- the number of dry electrodes for ECS recording: at least 3;
- microphone sensitivity: - 60 dBmV;
- microphone pattern: unidirectional cardioid (insensitive to posterior axis and off-axis sounds originating from sources that are located on the side or behind the microphone);
- Frequency range of the PC: from 20 to 20,000 Hz;
- recording signals: 5 leads of EES, 1 lead of ECS, RS;
- The hardware filter used for ECS and EES: 3 Hz to 100 Hz;
- Dynamic range of EES and ECS: 1 mV;
- dynamic range of PC: 0.2 mV;
- Hardware power filter network (50 Hz) ECS and EES filter;
- hardware side-noise filter in the PC;
- ADC for ECS and EES: 12 bits;

- ADC for PC: 16 bits;
- sample rate of ADC for ECS and EES: 512 Hz;
- sample rate of ADC for PC: 44100 kHz;
- the value of the signal-to-noise ratio in conditions of free motor activity in the presence of external noises: more than 90 dB;
- sound pressure level in the PC: 105 dB;
- uneven of the PC frequency response: less than 10 dB;
- Bluetooth 4.0 module for wireless transmission of recorded signals of a multi- neural interface;
- range of the Bluetooth module of the multi-neural interface: at least 10 m;
- the number of USB ports for the multi- neural interface recharging and wired transmission of registered signals: at least 2;
- Lithium-ion rechargeable battery (not removable) of a multi- neural interface connected to a USB port for device recharging;
- Battery uptime of the multi-neural interface: not less than 10 hours;
- charging time of the multi-neural interface battery: no more than 4 hours;
- readiness time of the multi- neural interface for operation after switching on: no more than 1 minute;
- The battery capacity of the multi-neural interface: at least 550 mAh;
- Mean time between failures of a multi-neural interface in compliance with operation and maintenance requirements: not less than 8000 hours;
- average lifetime of the multi-neural interface: not less than 8 years;
- software-hardware module for signaling (sound and light) of a malfunction or discharge of a multi- neural interface;
- software module of pre-noise-proof processing of ECS, EES and RS;
- software module for transferring the registered signals of a multi- neural interface to a PC or smartphone;
- software module for signaling (sound and light) of patient critical states of the multi- neural interface;
- Support for multi-neuron interface operating systems:

  Windows 2000/7/10 / XP / Vista / Linux / Androin / IOS.

The appearance of the proposed neurointerface is shown in Figure 5. The technology for replicating the prototype of the neurointerface is carried out with the support of the Penza State University.

Figure 5: Multi-neural interface.

CONCLUSION

In the article the development of a new multi- neural interface for the express-evaluation of human borderline mental disorders is proposed, which differs from the known analogs in the ability to recording of several medical signals - ECS, EES, RS, use of 10 dry electrodes and the ability to users notification to the onset of critical mental health conditions.

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REFERENCES

[1] G.K. Ushakov, " borderline mental disorders," 2 Id. Pererab and additional. M .: Medicine, 1987, 304 p.

[2] A. N. Kalinichenko, "Recognition of human psychophysiologic conditions by indices of heart rate variability," The Russian academy of sciences, St. Petersburg: Politechnica, vol. 2, 2010, pp.273-276.;

[3] S. Olbrish, "EEG biomarkers in major depressive disorder: Discriminative power and prediction of treatment response," International Review of Psychiatry, vol. 25(5), 2013. pp. 604–618.;

[4] R. Williamson "Vocal biomarkers of depression based on motor incoordination," AVEC '13 Proceedings of the 3rd ACM international workshop on Audio/visual emotion challenge, 2013, pp. 41-48.;

[5] T. Horrell "Neurofeedback effects on evoked and induced EEG gamma band reactivity to drug-related cues in cocaine addiction," Journal of Neurotherapy, vol. 14(3), 2010, pp. 195-216.

[6] A.Y. Tychkov, A.V. Ageykin, A.K. Alimuradov, VB Kalistratov, S. Yu. Mitroshina, "Modern ideas about the

specifics and problems of diagnosis of borderline mental disorders," Mental Health 2017, (5), p. 69-75.Wilhelm von Rosenberg, "Smart Helmet: Wearable Multichannel ECG and EEG," Wearable Sensors and Health Monitoring Systems, volume 4, 2016

[7] Wilhelm von Rosenberg, "Smart Helmet: Wearable Multichannel ECG and EEG," Wearable Sensors and Health Monitoring Systems, volume 4, 2016

[8] A.Y. Tychkov, A.K.Alimuradov, P.P. Churakov, "Adaptive signal processing method for speech organ diagnostics," Measurement Techniques, 2016

[9] Tim R. Mullen "Real-time Neuroimaging and Cognitive Monitoring Using Wearable Dry EEG," IEEE Trans Biomed Eng. 2015 Nov;62(11):2553-67

[10] Telehealth Market worth 9.35 Billion USD by 2021, USD: http://www.marketsandmarkets.com/PressReleases/telehealth.asp

[11] NeuroSky, USD: http://store.neurosky.com

[12] BrainLink by Macrotelllect, USD: http://o.macrotellect.com

[13] Emovit, USD: http://www.emotiv.com

[14] Muse, USD: http://www.choosemuse.com

[15] A. Y. Tychkov, P. P. Churakov, A. K. Alimuradov, A. V. Kuzmin, "Design Of The Portable Electrocardiograph On The Basis Of MDL-IDM-L35," International Journal of Applied Engineering Research, vol. 10, Number 23 (2015), pp. 43776 – 43778

[16] A. Y. Tychkov, O. V. Abrosimova, A. V. Kuz'min, "Development in the LabView Environment of a Virtual Instrument for Noninvasive Measurement of Arterial Pressure Measurement Techniques", vol. 58, Issue 9, 1 December 2015, pp 1062-1065

[17] A. Y. Tychkov, "Development and study of a virtual encephalograph," Biomedical Engineering, vol. 49, Issue 1, 22 May 2015, Номер статьи A009, pp 26-29

[18] Patent US № 8706241 B2 System for patent interactive neural stimulation with robotic facilitation of limb movement 2014 г.

[19] Patent US № 8562951 B2 Methods for classifying and treating physiologic brain imbalances using quantitative EEG 2013 г.

[20] Patent US № 8289172 B2 Method and system of aircraft pilot assessment and for remedial action upon pilot impairment 2007 г.

[21] Patent US № 7580742 B2 Using electroencephalograph signals for task classification and activity recognition 2009 г.

[22] Patent US № 8821242 B2 Systems and methods for enhancing cognition 2014 г.

[23] Penza State University, USD: http://science.pnzgu.ru/nii_fipi/ckp