Neuroelectrostimulation from Natural Electricity to Multifactorial Systems: A Review

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Abstract: The article discusses the problem of the neuropsychiatric health deterioration in the face of new challenges to humanity: the complication of the scientific and technical environment and the technosphere, social relations in society against the background of an increase in the duration of a person's active life, as well as the relevance of the development of neurorehabilitation technologies for restoring human health in these conditions. The paper presents a review of the evolution of the technology of transcutaneous neuroelectrostimulation from ancient times to modern technologies, transcranial electrical stimulation, electrical stimulation of cranial nerves, spinal cord and neck nerve structures. The prospects of a mobile hardware and software system for polyfactorial neurostimulation and its potential for use in personalized medicine are considered. Possibilities of promising medical technologies for homeostatic regulation, capable of modulating autonomic processes, influencing motor control and cognitive functions are discussed.

1 INTRODUCTION

In the 21st century, a person lives in a dynamically developing scientific and technical environment, the complication of the technological sphere, social relations in society against the background of an increase in the duration of an active life. The consequence of these processes are new global problems and challenges that did not exist before - overpopulation, globalization, hyper information environment, man-made disasters, interethnic conflicts, local wars. In such conditions, the load, especially on the neurological and mental health of a person, increases significantly, leading to its exhaustion, chronic stress and, as a result, to depressive disorder and personality deformation with complete loss of ability to work and life guidelines.

According to the World Health Organization, today diseases of the central nervous system have come out on top among diseases leading to disability among young people in developed countries. At the same time, all areas of human health suffer, limiting his adaptive capabilities throughout his life. Increased funding is required to restore health. health care (WHO, 2016).

The global pandemic of the coronavirus infection COVID-19 has raised these problems. According to a WHO study, the COVID-19 pandemic has increased the demand for neurological and mental health services: bereavement, isolation, loss of income and fear for the future disrupt mental health, exacerbate existing problems. A high level of social stress pushes people to abuse substances and alcohol. Meanwhile, there is convincing evidence that the coronavirus has a neurotoxic effect, leading to impaired perception, delirium, asthenia, depression. People with pre-existing mental, drug addiction and neurological disorders are more vulnerable to coronavirus infection - they are at high risk of severe outcomes and even death (WHO Survey, 2020).

Under these conditions, there is a demand for non-invasive medical technologies for

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neurorehabilitation, capable of restoring psycho-neurological disorders formed as a result of depression, stroke, brain and spinal cord trauma or progressive degenerative and hereditary diseases (Parkinson's disease, motor neuron disease, etc.).

2 ORGANIZATION PRINCIPLES OF NEUROPROTECTIVE THERAPY

Modern approaches to the treatment of neurological dysfunctions are based on neuroprotective therapy, which enhances the activity of nervous tissue and its structural restoration in response to emerging pathogens. New neurostimulation techniques should enhance the brain's natural ability to repair damage, form new functional pathways, facilitate the recovery process, as well as increase and accelerate functional neurorehabilitation, improve and optimize the treatment of acquired brain damage, as well as the patient's ability to learn. Regardless of the nosological form of the disease, modern technologies of neurorehabilitation combine natural therapeutic factors, drug and non-drug therapy, as well as other methods aimed at restoring impaired functions (Doidge, 2007).

Of the specific neuroprotectors, the most studied and have a strong evidence base are pharmacological drugs. To date, a large group of drugs that were effective in the experiment, in clinical therapy were not so effective because of side effects, in their severity commensurate with clinical (Tamburin et al., 2019). The described situation is especially unfavorable in those cases when the treatment, along with the existing disease, "interferes" with the natural course of the regulatory, adaptive processes of the central nervous system, acting as stress factors.

With non-drug therapy, in which targeted stimulation is provided by non-thermal physical signals and fields, side effects problems can be virtually eliminated (Nudo et al., 2001).

The key link in non-drug technologies for the restoration of functional disorders of the brain is the use of the brain's ability to significant functional restructuring, which triggers the mechanisms of neuroplasticity when restoring and compensating for disturbed functions (Egiazaryan & Sudakov, 2007).

When creating modern medical devices and technologies, the achievements of cybernetics, medical physics, instrumentation, microelectronics and information technologies are applied.

3 PERCUTANEOUS NEUROELECTROSTIMULATI-ON

Since prehistoric times, people have tried to understand natural phenomena and use their capabilities. So, according to the evidence of numerous artifacts and written sources, even in ancient times, amber and some species of fish were used for treatment, capable of generating electrical discharges. Amber was used to prevent tonsillitis and other diseases of the throat, and amber, crushed and mixed with Attic honey, was used for low vision, in the treatment of delusional conditions. For diseases of the stomach, amber was recommended to be consumed either in the form of a finely ground powder, or with water and mastic. In many ancient cultures, doctors recommended that their patients wear stones in the form of amulets and talismans for health, protection and good luck (von der Emde G, 1999). Persian philosopher and physician Avicenna (Abu Ali Hussein ibn Abdallah ibn Sina, 980 - 1037). in his encyclopedia of medical knowledge "Canon of Medicine" mentions amber as a remedy for many diseases at any age.

The Roman physician Scribonius Largus, who lived from 1 to 50 AD, was the first to suggest using the "strikes" of stingrays for medical purposes: he advised standing on live rays to relieve headaches and treat gout. Other physicians of that time also advised to relieve pain with live rays in the treatment of several diseases - from epilepsy to rectal prolapse. There is also a description in the Russian chronicles of the XIV century, which tells about outlandish fish placed in a barrel, which, by their touch, caused a healing effect in humans.

Scientists in medieval Europe studied the phenomenon of electric fish ("animal electricity"). It should be noted here the works of G. Cavendish, D. Walsh, L. Galvani and A. Volta, the results of which formed the applied direction in medicine - medical physics, which became an integral part of medical science. Today we know that electric current is one of the key phenomena in medical physics, primarily because the functioning of the human nervous system is provided by neurons that can generate and transmit electrical impulses. Therefore, for a living organism, electric current is a "familiar" physical phenomenon, and it is widely used in the treatment process.

If we restrict ourselves only to non-invasive percutaneous solutions, then the following groups are known from an extensive variety of medical devices used for neuroelectrostimulation.:

1. Transcranial electrical stimulation - provides regulation of the cerebral blood supply system and stimulation of the cerebral cortex. The therapeutic effects in this case are associated with selective ionic conductivity and systemic-selective biochemical transformations in the brain tissues. Depending on the characteristics of the current used in this case, the following stimulation methods are distinguished (Mutz et al., 2019):

1.1. Anode transcranial electrical stimulation (known as "Transcranial direct current stimulation, tDCS") uses direct electrical current to stimulate. The function of the active electrode in this case is performed by the anode, which is located in the projection of the cortical region to be stimulated, while the reference electrode is usually located in the area not associated with the studied brain processes (forehead, crown, or not on the head). This is a purely neuromodulation method: the current generated during tDCS does not induce an action potential but is maintained at subthreshold levels in order to affect only cortical excitability. tDCS alters the spontaneous activity of neural networks without causing suprathreshold membrane depolarization and generation of neuronal electrical impulses (Nitsche et al., 2008). tDCS induces long-term effects that persist after the end of stimulation due to modulation of inhibitory intracortical and corticospinal neurons (Liebetanz et al., 2002). Since a constant electric field affects all polar molecules, and most neurotransmitters and receptors in the brain have electrical properties, tDCS can also affect neuronal function, causing long-term neurochemical changes. In this case, tDCS modulates not only the activity of single neurons, the induced activity of neurons, but also spontaneous oscillations of neurons, causes not only long-term changes in the evoked motor potentials, but also affects the somatosensory and visual evoked potentials and can affect the state of the cerebellum (Ardolino et al., 2005). In a study using functional magnetic resonance imaging, it was found that tDCS of the primary motor cortex in healthy volunteers leads to a significant increase in resting-state cerebral blood flow during and after stimulation. In this case, cerebral blood flow increases linearly with increasing current strength (Shigematsu et al., 2013). tDCS leads to significant changes in the regional connections of the brain in the default mode network, frontal-parietal neural networks in the stimulation and associative areas. Similar changes were observed in studies involving patients with Parkinson's disease: strengthening of connections in neural networks by default is associated with improved working and semantic memory, and activation of the frontal and parietal regions is associated with attention and working memory. Strengthening of connections in frontal-parietal neural networks was observed after cognitive training (Pereira et al., 2012; Wirth et al., 2011). It was found that tDCS can restore disturbed functional connections in regulatory systems, which is due to an improvement in interneuronal, interstructural and intersystem interactions. The restructuring of the central functional mechanisms continues after the end of stimulation, which indicates the activation of self-regulation mechanisms and, consequently, an improvement in homeostasis (Lewis et al., 2009). The effectiveness of using tDCS in medical practice primarily depends on the choice of current parameters and the correct positioning of the electrodes on the head, depending on the type of restored cognitive function.

1.2. Cathode transcranial electrical stimulation, Cathode CS, uses direct or alternating electric current for stimulation, and the cathode acts as an active electrode. It has been experimentally established that CathtCS activates the protective mechanisms of the brain. Only sagittally directed current (location of the electrodes forehead - occiput or forehead - mastoid processes) can reach the structures of the protective mechanisms of the brain. With this position of the electrodes, the current to the structures of the protective mechanisms of the brain (the ventral nuclei of the hypothalamus, the central gray matter of the midbrain, the nucleus of the suture) flows through the cisternal and intraventricular pathways. With the bilateral arrangement of the electrodes (mastoid process - mastoid process), no current flows to the structures of the protective mechanisms of the brain. CathtCS influences endorphinergic mechanisms, which leads to a significant increase in the concentration of beta-endorphin in the structures of the brain stem, dorsal horns of the spinal cord, in the cerebrospinal fluid and blood, as well as met-enkephalin in the cerebrospinal fluid. The maximum increase in the concentration of beta-endorphin is observed when using rectangular current pulses with a duration of 3.5 ms and a frequency in the range from 60 to 80 Hz. At the same time, the level of serotonin in the cerebrospinal fluid also increases (Gabis et al., 2003).

1.3. Transcranial alternating current stimulation, tACS, uses amplitude modulated alternating current, usually sinusoidal, to stimulate. It was found that in the case of tACS, frequency, intensity and phase are the main factors influencing the effectiveness of stimulation. In contrast to tDCS, tACS does not change the excitability of neurons, but their transmembrane potential and polarization change. This leads to an increase in the number of neurons participating in the formation of the exogenous frequency: it is assumed that this is due to the fact that the alternating current participating in the stimulation process excites endogenous neuronal oscillations, possibly by increasing the oscillation power or the index of phase synchronization between excitatory and endogenous oscillations (Neuling et al., 2012). This ability to engage neurons in a specific area of the brain to excite them at a predetermined frequency allows researchers to identify key frequencies associated with different types of behavior, and to identify causal relationships between them. The specific parameters of these changes depend on the task, area and state of the brain and are believed to reflect the structural and functional characteristics of the activity of neural networks that mediate local and distributed cortical functions and their cognitive manifestations. Currently, the most problematic issue of tACS is the choice of stimulating current parameters: amplitude and frequency.

1.4. Transcranial random noise stimulation, tRNS, uses an alternating electrical current with noise-like amplitude modulation to stimulate. The method was developed relatively recently. Compared to tDCS, CattCS and tACS, tRNS is the most effective method for increasing the excitability of the motor cortex (Battleday et al., 2014). Based on the results of physiological and pharmacological studies, several theories have been proposed to explain the mechanisms underlying tRNS. According to one of the proposed theories, broadband amplitude modulation, formed according to a pseudo-random law in the tRNS signal, provides a quasi-resonant effect in target neurons, which increases the sensitivity of neurons to external influences. However, it is suggested that the mechanism of action of tRNS is based on repeated subthreshold stimulations, which can prevent homeostasis of the system and potentiate task-related neural activity (van der Groen & Wenderoth, 2016). To date, relatively few studies have been published on the effect of tRNS on functional processes in brain tissues. But the available evidence shows that tRNS can modulate cognitive processes, including connectivity. And this testifies to the great prospects of this direction in solving problems using neuroelectrostimulation in neurology and psychiatry.

2. Electrical stimulation of the cranial nerves, which are input channels directly to the brain. The effect of neurostimulation in this case is determined by the effect on the structures of the brain stem, which leads to the activation of the reticular formation, the release of neurotransmitters and the suppression of epileptiform patterns of the cerebral cortex. The most elaborated solutions in this direction are realized with the help of translingual neurostimulation and electrical stimulation of the trigeminal nerve (Bach-y-Rita, 2004). Medical devices for translingual Neurostimulation, TLNS, and medical techniques for their use, known as Cranial Electrical Stimulation (Cranial Nerve NonInvasive NeuroModulation, CN-NINM), were developed by a group of scientists from the University of Wisconsin-Madison (USA). The ideologist of this trend was the outstanding American neurophysiologist Paul Bach-y-Rita, known for his pioneering work in the field of neuroplasticity. Using the tongue as a target for stimulation can be beneficial for many applications. The anterior dorsal surface of the tongue is an area of human skin with a unique pattern of innervation. Relatively thin, in comparison with other areas of the skin, the epithelium of the oral cavity is saturated with mechanical and taste receptors, as well as free nerve endings. It is uniquely suited for electrotactile stimulation because, in the protected environment of the mouth, on the dorsal surface of the tongue, there is no stratum corneum or protective layer of skin, such as on the hands and feet, and sensory receptors are located either on the surface or close to it. The tongue is constantly washed with an electrolyte solution (saliva), which has a constant acidity and temperature. Two main nerves from the tongue deliver information flows directly to the brainstem: the lingual nerve, which is a branch of the mandibular section of the trigeminal nerve (CN-V), and the chorda tympani, the terminal branch of the intermediate nerve extending from the facial nerve (facial nerve, CN-VII). Currently, several modifications of the PoNS ™ (Portable Neurostimulator) device have been developed, which implements the TLNS technology. TLNS technology was originally developed for modulating neural networks in neurorehabilitation tasks. Further studies have shown the possibility of its use for restoring balance and posture in patients after peripheral vestibular disorders, as well as for the treatment of infantile cerebral palsy, imbalance in patients with multiple sclerosis, restoration of gait in patients with Parkinson's disease, multiple sclerosis, after TBI and stroke, restoration of some parameters of cognitive functioning, such as the ability of a person to quickly switch attention from one task to another (multi-tasking), concentration of attention, memory (Paltin et al., 2017).

The target of trigeminal nerve stimulation technology, TNS, is the supraorbital nerve, which is the superior ophthalmic branch of the trigeminal nerve. TNS increases blood flow to areas of the brain that are associated with the regulation of attention, emotion, and behavior (Generoso et al., 2019). It has been found that this stimulation also has an anticonvulsant effect. These results and data from pilot clinical trials provide an optimistic view of this technology in the treatment of epilepsy, depression, post-traumatic stress disorder and attention deficit hyperactivity disorder (ADHD).

3. Electrostimulation of the spinal cord - ensures the restoration of the functioning of the descending and ascending neural networks of the spinal cord, which control postural and locomotor functions: this effect stimulates the primary sympathetic neurons and interneurons of the spinal cord involved in the regulation of autonomic functions (Gerasimenko et al., 2015a). A breakthrough in the development of spinal cord electrical stimulation technology was created by fundamental research carried out by scientists at the I.P. Pavlov Institute of Physiology of the Russian Academy of Sciences under the leadership of Yu. P. Gerasimenko. In these studies, direct experimental evidence was presented for the existence of a neural spinal network in humans, a generator of stepping movements, which forms a locomotor activity program and provides stereotyped rhythmic coordinated activity of the muscles of each limb, interlimb coordination, as well as coordination of the activity of the muscles of the limbs and trunk for movement in space. The possibility of replacing activating and controlling supraspinal influences on stepping generators by means of electrical stimulation of the spinal cord and pharmacological effects has been shown. The knowledge gained made it possible to develop an original electrical stimulator BioStim-5 (Gerasimenko et al., 2015b), as well as a technique for transcutaneous electrical stimulation of the spinal cord, which combines the ability to determine the place of installation of stimulating electrodes through which single pulses of a rectangular shape are supplied, and directly stimulate the spinal cord with modulated impulses of different frequencies and shapes simultaneously several segments and roots of the spinal cord. The most important difference of this device from others is that it implements the technology of multisegmental stimulation. The BioStim-5 electrostimulation device allows you to speed up the rehabilitation process, increase the amplitude and improve the coordination of the evoked movements, which is achieved through synchronous stimulation of various parts of the spinal cord, carried out simultaneously with natural physiological stimulation.

4. Electrostimulation of the neck nerve structures - provides correction of the activity of the suprasegmental and segmental parts of the autonomic nervous system by means of exposure to the projection of the cervical ganglia of the sympathetic part of this system (V. S. Kublanov, 2008). The principles of organizing technical means for stimulating the cervical ganglia of the sympathetic division of the autonomic nervous system were proposed in the early 90s of the last centuries and implemented in the device "Corrector of the activity of the sympathetic nervous system SYMPATHOCOR-01" (V. Kublanov et al., 2018). The SYMPATHOCOR-01 device is structurally made in the form of a monoblock, consisting of two multi-element electrodes (ME) and an electronic unit, and has a mass of 1500 g. 13 electrodes are placed on the cuff of each ME. The appearance of the device and the layout of its electrodes on the patient's neck during the treatment are shown in Fig. 1. Between two MEs, a spatially distributed field of monopolar positive current pulses is formed, the vector of which is projected into the target area for stimulation - the cervical region of the sympathetic trunk, represented mainly by the upper and middle nodes (ganglia) and the inter-nodal branches connecting them (Kublanov et al., 2017).

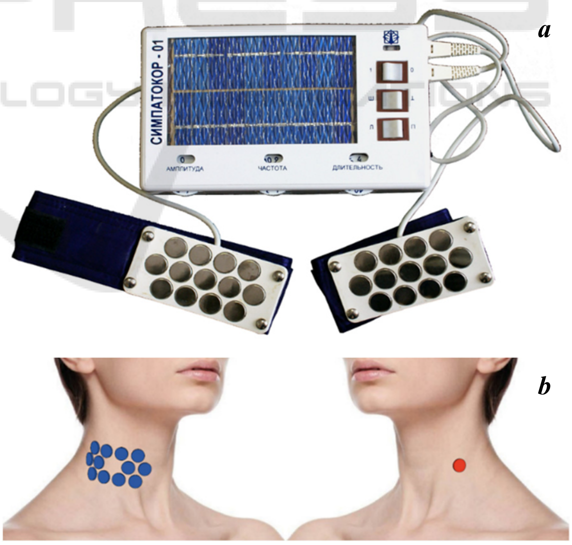

Figure 1: The appearance of the SYMPATHOCOR-01 device (a) and the layout of its electrodes on the patient's neck during the treatment procedure are shown (b).

For implementing the algorithm for correction of the activity of the sympathetic nervous system, alternation of modes of stimulation and its absence is used. A typical version of the cyclogram of such an algorithm looks like this: the patient's functional rest for 5 minutes. - stimulation in the projection of the left cervical ganglia of the sympathetic nervous system - no stimulation for 5 minutes. - stimulation in the projection of the right ganglia of the sympathetic nervous system - functional rest of the patient for 5 minutes.

An information indicator of the processes corrected with such a dynamic correction of the activity of the sympathetic nervous system is the index of vagosympathetic interaction (autonomic balance), defined as the ratio LF / HF, where LF is the activity of the low-frequency component of the heart rate variability spectrum in the frequency range from 0.15 to 0.04 Hz, HF - activity of the high-frequency component of this spectrum in the frequency range from 0.4 to 0.15 Hz.

The device is effectively used in the treatment of vegetative-vascular dystonia, migraine, headache, tension pain, autonomic dysregulation syndrome, headache, hyperhidrosis syndrome, orthostatic hypotension syndrome and postural tachycardia, neurosis-like syndromes and neuropathies of various origins, vestibulopathic syndrome, for effective replacement of invasive insults, treatment of depression, tic disorders, attention deficit hyperactivity disorder, hypertension, sensorineural hearing loss, vasomotor rhinitis, degenerative diseases of vision and atrophy of the optic nerve, glaucoma, computer vision syndrome and asthenopia, incurable epilepsy with attention deficit hyperactivity disorder in children disorders, Korsakov's (amnestic) psychosis, panic attacks, anxiety disorders (Petrenko et al., 2020).

4 POLYFACTOR ELECTRIC STIMULATION

The technology of polyfactorial electrical stimulation should provide an effect on three levels of human nervous regulation: peripheral, autonomic and central, and be able to combine it with other technologies. To do this, it is necessary to implement in a medical device:

1. Possibility of choosing for neuroelectrostimulation of several local zones of the neck (targets), the projections of which correspond not only to the cervical ganglia of the sympathetic nervous system, but also to targets anatomically associated with various parts of the brain.
2. Control of the structure of the field of current pulses and its biotropic parameters is adequate to pathophysiological changes in the central and autonomic nervous systems.
3. Compactness and mobility of its implementation due to the use of new circuit and technical solutions using microcontrollers and electrical radio products of a high level of system integration, as well as modern materials and technologies that made it possible to implement it in a compact and mobile device.
4. New hardware and software solutions for neuroelectrostimulation both for individual and group use in the treatment process using one control unit.
5. The functions of modern information technology that will allow it to be used in personalized medicine.

Modern capabilities of electronic instrumentation and information technology allow these requirements to be implemented using a mobile hardware and software system, consisting of three autonomous functionally complete modules, which must perform the following tasks:

• the first module provides the formation of a field of monopolar rectangular voltage pulses between two MEs, the installation of stimulation targets, field structure and biotropic parameters of spatially distributed pulses of this field;

• the second module is a specialized patient interface and provides data transmission for the first module, which are necessary for selecting a stimulation target, changing the structure of the voltage pulse field and setting the values of biotropic parameters of pulses, as well as collecting information about the patient, his clinical data and functional parameters of the central and vegetative nervous systems, as well as control data of the neurorehabilitation process and transfers them to the third module;

• the third module is a specialized interface of the doctor and provides analysis of data about the patient, his clinical state and functional parameters of the central and autonomic nervous systems, as well as data from the control of the neurorehabilitation process; transmitting data to the second module for selecting the stimulation target, the structure of the voltage pulse field and the values of the biotropic parameters of the pulses; provides the second module with information for managing the treatment process (turning on / off the first module, changing the parameters of the stimulation procedure cyclogram), as well as comments about the patient and the course of the treatment process.

To implement the functions of the second module, it is required to perform certain computational procedures when generating commands and the structure of a spatially distributed field of current pulses and parameters of pulses of this field. These tasks can be solved using a mobile wearable computer (smartphone, tablet or personal computer), which will perform the functions of a specialized interface of a polyfactorial electrostimulation device.

The third module can be implemented as a web application located on a server with access to the Internet.

Information between the first and second modules is transmitted via a telemetric communication channel Bluetooth Low Energy (BLE): for this purpose, transceivers built into the first and second modules are used. Information between the second and third modules is transmitted via the Internet. The block diagram of the polyfactorial electrostimulation device is shown in Fig. 2. General view of the first module of the polyfactorial electrostimulation device is shown in Fig. 3.

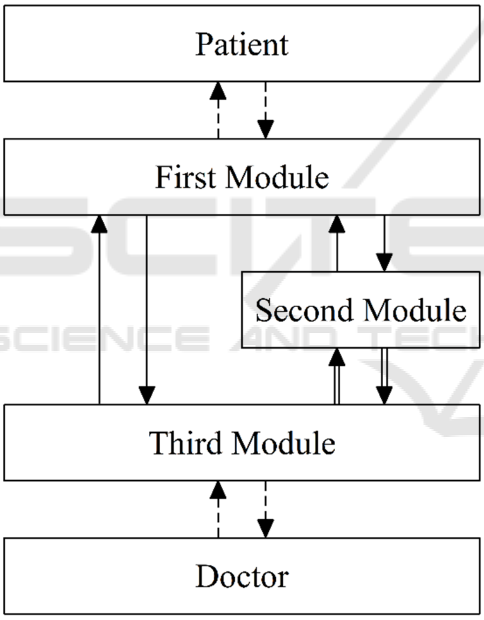

Figure 2: Block diagram of a polyfactorial electrostimulation device.

The proposed approach for the implementation of a polyfactorial electrostimulation device made it possible to make it compact and mobile with the mass of the first module less than 200 g.

Figure 3: General view of the first module of polyfactorial electrostimulation device.

The projections of the cervical ganglia of the sympathetic nervous system (target 1), the vagus nerve (target 2), the carotid plexus (target 3), the cervical spinal plexus (target 4), the accessory nerve (target 5) and branches of the glossopharyngeal nerve (target 6).

It is known that several interconnected systems are involved in ensuring the functional processes of the brain: neural networks, neuroglia, cerebral membranes, the cerebrospinal fluid system and the blood supply system. The latter is a complex multiparameter biophysical structure with cross-links, the control of which is provided by neurogenic, humoral, metabolic and myogenic regulatory circuits. These circuits are in dynamic interaction and their activity is aimed at providing physical homeostasis, determined by the balance of the process of filtration of water from the blood into the brain tissue under the action of hydrostatic pressure in the arterial segment of the capillary and its absorption in the venous segment of the capillary under the action of oncotic pressure of blood plasma, and chemical homeostasis internal environment of the brain.

To implement homeostatic regulation during polyfactorial neuroelectrostimulation in an electrostimulation device, it is possible to correct not only the vegetative balance, but also the very low-frequency component of the VLF of the heart rate in the frequency range from 0.04 to 0.003 Hz. VLF reflects the functional state of the brain in psychogenic and organic pathology and is also a sensitive indicator of metabolic processes control and reflects well the energy deficit states of the brain.

One of the possible algorithms for the implementation of this task is shown in Fig. 4.

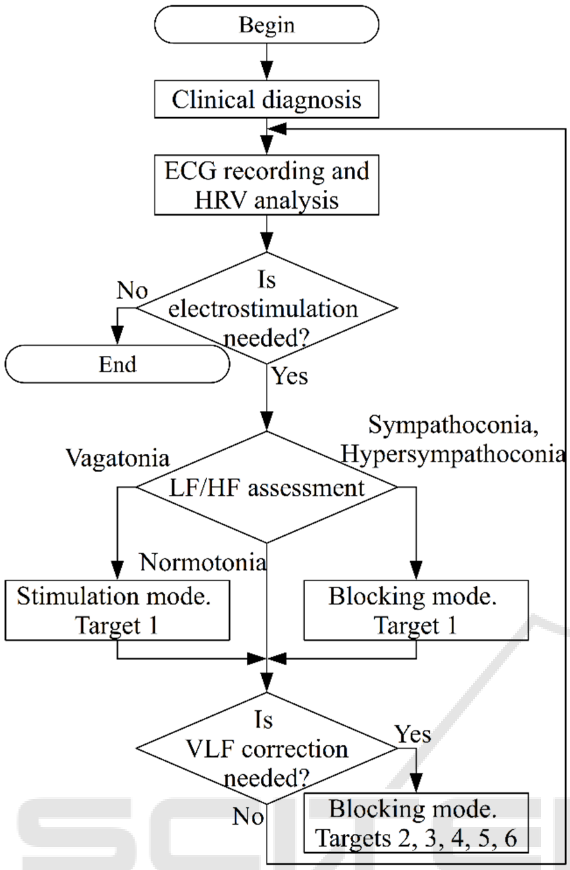

Figure 4: Algorithm for the implementation of polyfactorism.

The algorithm consists of two stages:

1. At the first stage, target 1 is selected for stimulation and the LF / HF vegetative balance indicator is adjusted using the dynamic correction of the activity of the sympathetic nervous system technology.

2. At the second stage, one of the targets (2, 3, 4, 5 or 6) or their combination is selected for stimulation, depending on the leading pathological process of the central nervous system. In this case, stimulation occurs through the reticular formation, thalamic structures and cerebral cortex, and affects both the vascular tone of the cerebral arteries and the autonomic nuclei of the spinal cord. The low-frequency component of the VLF spectrum is an indicator of changes in the activity of the suprasegmental cerebral pathways.

The proposed system of neuroelectrostimulation is capable of fully modulating autonomic processes, influencing motor control and cognitive functions.

5 CONCLUSIONS

An analysis of the electrostimulation technologies considered in this work shows that, since ancient times, the criteria for the formation of these technologies were based on knowledge about the processes occurring in the human body. Our understanding of physiological regulation has evolved over time from the Greek idea of the balance of fluids in the body to the concept of homeostasis and the theory of controlling regulatory processes at the cellular, tissue and organ levels. Homeostasis has become the central unifying concept of physiology and is defined as a self-regulating process through which a living organism can maintain internal stability while adapting to changing external conditions. The health and vitality of the body is the result of homeostatic regulation of the internal environment.

When creating new technologies for neurorehabilitation, other approaches are possible today, but their foundation should remain the homeostatic mechanisms of the whole organism, determined by the coordinated interaction of the autonomic, immune and endocrine systems, which support most of the stable states of the organism.

We must proceed from the fact that it is impossible to create one technology, a panacea for treatment: the human body is too complex, and its regulatory mechanisms are diverse. Further research and testing are needed. And, of course, the results of the implementation of polyfactorial neuroelectrostimulation considered in the work are another step in the movement from natural electricity to multifactorial systems.

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