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Application of Neurocomputer Interfaces for Rehabilitation of Patients With Disorders of Motor Functions of the Nervous System

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Abstract: *Brain-computer interface (BCI) technology allows a person to learn to control external actuators by means of arbitrary modification of their own EEG directly from the brain without involving nerves and muscles in this process, allowing to control external technical systems directly by brain signals. In the last two decades, BCI technology has been rapidly developing: its areas of application are expanding, new types of sensors for recording brain signals are being proposed, the quality of their recognition is improving, and methods for training subjects to control BCI are being perfected. At the beginning, the main goal of BCI development was to replace or restore motor functions of a person suffering from neuromuscular disorders. Currently, the tasks of BCI development have significantly expanded, increasingly capturing various spheres of life of a healthy person.*

Key words. *Brain-computer interface, EEG, Neurointerface, neurorehabilitation, exoskeleton.*

1. INTRODUCTION

Brain–computer interface (BCI) is one of the most promising technologies in the treatment of neurological diseases and injuries. BCI allows establishing communication between intact areas of the brain and prostheses of missing limbs, wearable neuroprostheses, wheelchairs, artificial sensory organs and other devices that compensate for lost functions. Currently, BCIs are rapidly developing due to the rapid growth of computing power, robotics, methods of recording brain signals and mathematical algorithms for decoding them. BCIs are usually classified as motor (reproducing movements), sensory (sensitive) and bidirectional (sensorimotor). There are also interfaces that interpret or affect higher nervous functions [1]. According to the degree of penetration into biological tissues of the body, a distinction is made between invasive (deeply penetrating) and non-invasive (interacting only with the surface of the body, but not penetrating) BCIs. Non-invasive BCIs are safer and easier to use, but have limitations in signal throughput. Invasive ones, due to direct contact of multielectrode matrices with neural ensembles without noise and additional filter barriers, allow reading signals in high resolution and locally stimulating nervous tissue to transmit feedback signals to the brain [2,3]. Paralyzed people, deprived of the ability to communicate with the outside world,

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thanks to the advent of screen control interfaces, have gained the ability to literally type text by the power of thought, due to the increase in general excitation read by EEG. BMC technologies are being developed not only for individual use, but also for performing collective tasks using brain networks. In Russia, "Neuro-chat" has been developed to solve this problem [4,5]. To control a person's mental state.

The Neurocourse APCS has been developed, which displays EEG and electrocardiography data in real time, NPV and electromyography. Device indicators concentration level attention and psycho-emotional relaxation, allowing the patient to learn to control these states [6].

More complex decoding, based on identifying the relationship between the occurrence of action potentials in a specific area of the motor precentral gyrus, allows the patient to control the monitor cursor [7]. The ability to control the monitor and type text helps to people With motor restrictions Not only communicate, But And work By many specialties. Before the advent of neural interfaces, this was considered impossible.

The EEG method allows predicting epileptic seizures. But the complexity of constantly wearing a non-invasive interface limits its use in clinical practice. Invasive interfaces are more accurate in reading biopotentials when recording from individual neurons not only of the cerebral cortex, but also of underlying structures. The main problem with their use is the ethical laws that allow the implantation of such complex implants in humans only for medical reasons, as well as problems of biocompatibility. Studies on predicting epileptic seizures seizures at rats at help multichannel EEG [8] allowed create an invasive device that not only recognizes an approaching seizure, but also stops it. The program recognizes areas that are synchronously excited in different areas of the brain during epilepsy. The spectral energy concentrated in the 5 and 10 Hz ranges increases - a gradual increase from 5 Hz empirically suggests increase interactions between neurons of these zones [9].

Biocompatibility of the invasive implant remains one of the main problems. Despite the ability to read individual neurons with an electrode, some time after the operation, the clarity of the indicators decreases. The body's defense mechanisms define the implant as a foreign object, forming a connective tissue capsule around it. Electrodes with greater biocompatibility are being developed, research is underway on the implantation of electrodes containing nerve growth factors and the development of materials that give a smaller immune response [10].

Neurorehabilitation is possible due to neuroplasticity – the ability of the nervous system to adapt through structural and functional changes. It is necessary to take into account that many innate reflexes are associated with certain neurons, while the function of conditioned reflexes (acquired during life) after the death of neurons can be taken over by nearby cells [11,12].

Functional knowledge of neuroplasticity helps patients with partial loss of motor skills functions, at condition insignificant damage neurons, responsible for transmitting signals to the immobilized area, recover faster. Multilevel electrical stimulation methods, massage And application medicinal substances For recovery motor and sensory functions do not always yield results. The neurocomputer interface reads the intention of movement from the motor cortex and transmits it to the limb exoskeleton, which in real time carries out the intended action of the poorly innervated limb. Thanks to this V central nervous system is formed relationship between intention produce movement and the action performed, which speeds up rehabilitation [13]. Even in the case of a long-standing injury, when the patient does not remember the sensations that lead to the movement, a specially programmed interface helps him send the right signals that are more likely to involve nearby neurons in the formation of a connection between muscle tissue and the motor cortex [14].

The algorithm, based on recordings of the motor cortex, can reproduce the kinematics of various movements Not only simple, But And complex [15]. Rehabilitation patients With movement disorders after a stroke promotes retraining of neuromotor skills based on individual plasticity. Imagination of movement by the motor cortex activates the work of the exoskeleton worn on the limb. Mirror neurons, during the implementation of passive movement of the limb using the neurointerface, additionally stimulate the motor nuclei of the central nervous system. Together with systematic repetitions of the exercise, the mechanism of neuroplasticity is activated. Using the method of multichannel encephalography with the direction of leads according to the localization of the stroke known from studies, the patient was taught the correct (kinetic) imagination of movement with alternating repetitions of the imagination of relaxation and movements immobilized limb. Summary control groups subjects: positive mood and involvement in processes in patients, increasing the indicators of motor function of the limb and strength muscles V average exceeding on 2-3% indicators patients, For neurorehabilitation which did not use a neural interface [16,17].

In the absence of one's own limb or the impossibility of restoring motor function after the death of neurons, it is possible to use neurointerfaces that transfer activity motor bark precentral convolutions on robotic device. Methods for reading signals from the cerebral cortex and transferring commands to a prosthesis have been studied and improved for many years [18,19]. One such device was demonstrated during the opening of the 2014 FIFA World Cup in Brazil, when a paralyzed man in a special exoskeleton was able to walk and kick the ball for the first time. Developments are underway to design simpler and cheaper analog exoskeletons, which are planned to be introduced into mass production [20].

The next step in advancing technologies that improve the lives of patients with movement disorders functions, is introduction of artificial tactile sensations And unification their into bidirectional interfaces that connect the transmission of sensory sensations to the brain and motor programs from the brain to an external device. At the moment, experimental devices are not available to the general public [21,22].

In the future, it is possible to create brain-to-brain neural interfaces that provide communication between several users. The possibility of connecting the brain of one organism with another gives hope on implementation more fast transmissions information between by users interfaces. Experiments on laboratory animals showed viability given theories. At premises in different rooms two rats (one carried out function transmitter, A other receiver), at the first rat, at the moment when it saw and ran towards the stimulus, certain areas of the brain were activated, which were transmitted to the second rat. Without seeing the first, it unerringly ran towards the required stimulus in its cage [23].

2. CONCLUSION

Brain-computer interfaces, or “mind control technology,” are rapidly changing and altering the way we see human-machine interaction. They link electrical signals from the brain to devices, opening up new ways to enhance human abilities and connect with our world. These interfaces are used in many areas, from helping people with disabilities to enhancing the enjoyment of games.

As technology improves, thanks to the hard work of researchers and the study of brain signals, we look to a future where humans and machines work together more smoothly. But we also need to think about how to use this technology well. We need to make sure it is used in a way that benefits everyone.

In the future, we expect great advances in brain-computer interfaces, which will change many areas, such as medicine and entertainment. But we still face challenges such as improving the accuracy of the technology and ensuring the security of user data. Despite these obstacles, the potential for improving lives is huge. As we explore new possibilities, we must be mindful of ethics. We want to make sure that this “mind control technology” helps everyone, not just a few.

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