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Application of brain computer interface in rehabilitation medicine

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Abstract. The definition of a brain-computer interface can be thought of as a brain version of a computer, making our brains more digital. Brain computer interface involved fields artificial intelligence, rehabilitation and bioengineering, and it is of great significance to promote the development of rehabilitation medicine. This essay introduces the working principle of brain computer interface. Some key techniques of BCI design are discussed from the aspects of system design, data acquisition method and processing. Finally, some major problems and future development trends are pointed out.

Keywords: brain-computer interface, invasive, non-invasive, semi-invasive, application of brain-computer interface.

1. Introduction

The so-called brain-computer interface is to connect and control our brains with digital information, plus an interface connecting two media. A pathway created between a human or animal brain and an external device for information exchange channels [1]. Ever since Hans Berger first recorded the electroencephalograph in 1929 [2], scientists want to use this technology to enable humans to control brain machines with their minds rather than physical contact. However, limited by the technology of the time and the lack of understanding of the brain's mental mechanisms, little progress has been made in this area. However, with the development of society, progress of science and human's endless fantasy of future technology, brain-computer interface technology has also been rapidly developed.

Brain computer interface is a connection between humans and machines, used to convert signals sent by the human brain into digital information and operating modes, enabling humans to control machines with their brains [3]. Based on the actual data in China, there are about 2 million new stroke cases every year, and 88% of the survivors have varying degrees of motor dysfunction [4]. Therefore, brain computer interfaces can allow patients to establish signal connections with the outside world, thereby re stimulating damaged parts to drive physical activity through autonomous consciousness.

2. The working principle of brain computer interface

Jacques Vidal, a professor of computer science at UCLA, first coined the term "brain-computer interface" in the early 1970s [5]. The three main components of the brain computer interface system are: signal securing, signal handling and control. Signal processing includes four basic steps: preprocessing, feature extraction and pattern classification algorithm. Research has shown that neural activity in the brain is a key factor in stimulating signal transmission that can stimulate motor intent in the cerebral

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cortex. When the patient has the intention to move, the electrical signal of the brain is turned into functional electrical stimulation, and the extracted features are converted into instructions, which are transmitted to the output device through the calculation of the computer and the chip, and the output device completes the instructions to stimulate the damaged muscle nerves.

2.1. Signal acquisition
Signal securing is a key stage in the execution of cerebrum PC interface innovation. When weighing the benefits and drawbacks of various methods of information acquisition, we must take into account three criteria based on the state of the research at this point [6]:

Scale — the number of neurons that can be recorded. Goal - the degree of detail with which this apparatus gets data. There are two types of resolution in this case: both temporal and spatial resolution.

2.2. Signal processing
There are four stages in signal processing: signal feature extraction, signal classification, signal preprocessing, and control output. The original signal then needs to be pre-processed to remove interference and noise. The pre-processing methods include filtering, removing ophthalmic electricity, etc. [7]. The filtering can be done by digital filter, and the removal of the ophthalmic signal can be done by independent component analysis. After pre-processing, useful signal features need to be extracted to classify or identify signals [8].Time domain features, frequency domain features, and time frequency domain features are all frequently utilized features. Amplitude, energy, slope, and other time domain characteristics are examples. also, recurrence space highlights incorporate power unearthly thickness, recurrence band energy, and so forth. After extracting features, the features are classified through data analysis to judge users' intentions or behaviors [9]. The commonly used algorithms are support vector machine, neural network, Bayesian classifier and so on. After classification, the user's intention or behavior needs to be converted into instructions or operations that the computer can understand to control external devices or perform information processing. For example, you can use robot control, graphical interface operations, text input, and so on to complete the output.

2.3. Signal feedback
The feedback link is actually a process of man-machine adjustment and running-in. The brain-computer interface obtains users' wishes through real-time processing of brain signals to control external devices. At the same time, the external device feeds back the results to the user through various means such as image, sound and virtual reality to guide the user to adjust the control mode [10]. In the brain-computer interface feedback link, the patient generates electrical signals in the brain by sensing the response of the external environment, and then adjusts the state of brain activity to achieve a good human-computer interaction. However, this link involves multiple parts and functions of the human body, such as touch, hearing, taste, smell and vision, etc. Since the movement imagination of different parts of the body is related to the ERD/ERS phenomenon of the sensory motor cortex, the movement intention of the subjects can be predicted by detecting the changes in the rhythmic activity of the EEG signals of the subjects [11].

3. Classification of brain-computer interfaces
According to the acquisition method, it is usually classified as non-invasive, invasive and semi-invasive based on "invasive" [13].

First of all, non-invasive means that there is no need to invade the brain. The patient wears an electrode cap to collect brain information and only records and interprets the brain information through a wearable device (electrode cap) attached to the scalp. This method is simple to operate and has low risks. Although this technique avoids expensive and dangerous operations, the cranium interferes with the transmission and reception of brain signals, the spatial resolution of signals is poor, and high frequency signals cannot be effectively utilized, as well as the scattering and obscuring impacts of electromagnetic waves transmitted by neurons. As a result, the recorded signals lack resolution and

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intensity, making it challenging to precisely record the activity of the brain region from which the signals originate and the neurons that are associated with it.

Secondly, invasive means that signal acquisition devices are surgically implanted into the cerebral cortex to obtain high intensity and high resolution nerve signals. This method has the advantages of high accuracy, high sampling rate and high degree of freedom, but there are high safety risks and costs. And it is an invasive operation. Due to foreign body invasion, it may cause immune response and callus (scar tissue), resulting in deterioration or even disappearance of electrode signal quality. In addition, the wound is also prone to difficult healing and inflammatory reactions [14]. In addition, a famous case is that in July 2019, Musk announced on Neuralink that he had "found a way to efficiently implement brain-computer interface". At the Neuralink launch conference, Musk introduced two devices. One is only the size of a coin, with 1024 channels, can be placed inside the skull, read the brain nerve activity information, real-time wireless transmission of brainwave data chip; The other is a surgical robot that can cut a small hole in the skull, avoiding blood vessels, and implant the chip quickly and precisely into a predetermined location. Musk said it would only take a day to implant the device and leave the hospital, and the surgery would bypass the blood vessels without significant damage. At the event, Musk showed off three piglets that served as a control group for the brain-computer interface surgery. The brain-computer interface system, which has more than 3,000 electrodes that can monitor more than 1,000 neurons, is surgically implanted in the brain. When the pigs walked in the field, their brainwave signals were transmitted through the brain-computer interface device to a large screen, which was visually displayed in the form of images + sounds [15].

Semi-invasive signal acquisition means that the signal acquisition device is implanted between the cerebral cortex and the scalp, not completely implanted in the cerebral cortex like invasive devices and not just a device worn on the user's head like non-invasive devices. In other words, the mind PC connection point is embedded in the cerebrum pit, yet outside the cerebral cortex. Data examination is basically founded on cortical electroencephalogram (ECOG). ECOG's signal strength and resolution are better than those of non-invasive methods, making surgery less risky and the risk of an immune response lower.

4. Brain-computer interface in rehabilitation medicine

According to the clinical application of brain computer interface in rehabilitation, BCIs can be divided into auxiliary type or rehabilitation type. Assistive BCIs are designed to replace lost functions (such as communication or motor functions) and control external devices to assist daily life (such as robotic arms and exoskeleton devices); Rehabilitative BCIs (including rehabilitative training and neurofeedback BCIs) are designed to promote (partial) recovery of brain function and motor function by controlling or self-regulating neurophysiological activities.

4.1. Rehabilitative BCIs

Lower limbs, as one of the most commonly used and developed limbs, are mainly used for weight support and walking function. Limb dysfunction after stroke, especially lower limb movement disorder, not only has an impact on patients' quality of life but also places a significant mental strain on them. Therefore, intelligent wheelchairs, prostheses and other external devices are controlled by BCI to realize the alternative movement of lower limbs, so as to improve the motor function and activity space, and improve the ability to live independently. Functional electrical stimulation of FES can be used to restore lower limb motor function [16]. Bypassing diseased neural pathways (such as the spinal cord), stimulating the nerve fibers of specific muscles to activate the target muscles, and rejuvenating paralyzed limbs are all directly controlled by the electrical activity of the motor cortex. Brain-computer interface can also be used for consciousness assessment of patients, which can verify the existence of consciousness in patients with consciousness disorders through brain-computer interface. The traditional assessment of consciousness disorder mainly relies on behavioral scale, but this method is easy to diagnose the microconscious state as vegetative state or unresponsive awakening syndrome, with a misdiagnosis rate as high as 40% [16]. However, brain-computer interface can screen out specific

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components related to compliance response in brain signals as evidence of the existence of consciousness, and on this basis distinguish vegetative state, unresponsive arousal syndrome and lock-in syndrome. Some studies have proposed that brain-computer interface as a supplementary method for consciousness assessment can make up for the deficiency of consciousness assessment using only coma recovery scale.

4.2. Auxiliary BCI

Assistive BCI systems can help patients regain the ability to move their limbs. For amputees, BCIs can be used to control the movement of the prosthesis. Through engine representation, the BCI framework can interpret the electrical signs sent by the mind into the engine ways of behaving of the prosthesis, hence assisting the patient with recapturing the capacity to perform day to day exercises. For instance, a team from the Battelle Research Institute and the Ohio State University Wexner Medical Center in the United States claims that they were able to use a brain-computer interface system to allow patients with severe spinal cord injuries to regain their ability to touch. The latest work was published in the journal Cell. The brain-computer interface technology uses tiny nerve signals that are imperceptible to the naked eye. By converting residual tactile signals, which are below the range of perceptual responses, into conscious perception and then feeding them back to the participants, it aims to enhance nerve signals. The technology has also greatly enriched motor function in patients with paralysis. "We are studying tactile signals under perception and elevating them to conscious perception," said Patrick Ganzer, lead author of the study and principal research scientist at Battelle Research Institute. "And when we did that, we saw some functional improvements. When we first restored participants' sense of touch, it was an exhilarating moment." [17].

5. The challenges of brain-computer interfaces

In spite of the fact that applications for brain computer interfaces in the field of rehabilitation medicine have shown great promise, the current brain computer interface rehabilitation system is still in the initial application stage, and there is still decades of development ahead of large-scale marketization and popularization. The research still face challenges in terms of technological complexity, safety, and ethical ethics. Overall, the current brain computer interface technology is only initial application and development period. Although the current brain computer interface system is still in the early stages of application, its application potential is very impressive and it will undoubtedly be a significant technology in the coming decades. And we still face challenges of technical complexity, safety, and ethics. In general, the current brain-computer interface technology is only suitable for simple applications, and cannot fully achieve accurate control and full development of functionality, as well as how to precisely connect the mental signals sent by the brain to actual behavior. In particular, there is currently no clear neuroscience research on the brain's fundamental working mechanism, which will limit the development and application of brain-computer interface technology. Second, there are threats to safety. Invasive BCI requires electrodes or chips to be inserted into the cerebral cortex. These can easily result in intracranial bleeding and infection, and rejection following surgery may occur. Moreover, implanting physical devices into the human brain through brain-computer interface will make users feel that there is a foreign body in the body, which is easy to bring psychological burden and pressure to users. Once the "enhanced ability" brought by brain-computer interfaces disappears, it may lead to cognitive impairment, psychological anxiety and other problems. In terms of ethics, the essence of brain-computer interface is to connect the path of machine and human brain thinking, and ultimately achieve man-machine integration, which will inevitably expose the brain thinking, that is, the privacy of patients, and carry certain ethical risks.

6. Conclusion

This study explores the application and challenges of brain-computer interface in rehabilitation medicine. There are two main applications of BCI in rehabilitation medicine: auxiliary BCI and rehabilitation BCI. Although brain-computer interface technology still has a long way to go from the

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real clinical practice of rehabilitation, it has important application prospects in the field of rehabilitation medicine, providing new ideas and means for rehabilitation treatment, and creating an opportunity for patients with movement disorders to restore physical defects. Life science, sensor technology, artificial intelligence, embedded computing, and other technologies will all be inseparable from the brain-computer interface as a result of neuroscience's development and application, which will propel human civilization's science and technology to a new level.

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