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Advances in Brain-Computer Interface Technology for Depression Diagnosis: A Focus on EEG, MEG, and fNIRS

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Abstract. With the acceleration of the pace of modern social life, the psychological pressure on individuals has also increased. Consequently, a series of problems brought about by depression are increasingly recognized, such as its impact on mental health, social functioning, and overall quality of life, and the demand for accurate depression diagnosis has gradually increased. This has led to the exploration of innovative Brain-Computer Interface (BCI)-based diagnostic methods that leverage brain-machine interface technology. The application of related technologies for depression diagnosis is introduced from the aspects of Electroencephalography (EEG), Magnetoencephalography (MEG), and Near-infrared (NIR) imaging technology. These three technologies represent emerging approaches in depression diagnosis, adopting concepts that differ from traditional diagnostic methods. During the diagnostic process, they rely on electrocardiac and brain magnetic field patterns to provide important information related to brain activity. These methods enable non-invasive monitoring of cerebral blood oxygen levels, which is crucial for understanding the physiological underpinnings of depressive symptoms.

Keywords: Brain-computer interface, Depression diagnosis, Electroencephalography, Magnetoencephalography, Near-infrared.

1. Introduction

Depression is a multi-dimensional and complex phenomenon of modern society. It is mainly characterized by a significant and long-lasting mood. It is often accompanied by symptoms such as decreased interest, lack of energy, slow response, slow thinking, decreased memory, and even self - harm. Or suicide tendency to seriously affect the quality of life of patients.

In the contemporary development of globalization and informatization, the pace of people's life is generally accelerated, and it has also produced increasingly fierce competition. The psychological pressure and accumulation of anxiety brought about increasingly increased the risk of depression. At present, depression has become one of the most important diseases in the world's serious burden on humans. According to the website of the "Mountains of the Parliament" in the United States, a latest poll published by the US Gallop Consulting Company in May 2024 shows that 29%of Americans call at least once in their lives to be diagnosed with depression. The year increased by 2.1 percentage points [1]. At the same time, in other places in the world, the number of depression patients is generally increased. Therefore, the diagnosis of depression in time can help patients get accurate assessment of the disease, so as to ensure that patients can receive appropriate treatment, and then restore normal daily

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activities and work and interpersonal relationships, improve the mental state, and improve the life of patients' lives significantly. The ultimate goal of quality. The brain interface is a new way to diagnose depression in recent years. The brain interface is a system that directly connects the brain and the computer or other electronic devices. By analyzing the neuros signal of the brain to realize the interaction and control between the human brain and the computer. The diagnosis of depression through the brain machine interface has many advantages compared to the traditional diagnostic method (self -reporting, questionnaire survey, etc.). The brain interface technology can objectively evaluate the depression symptoms through multimodal physiological indicators, reducing the subjective factors in traditional methods in the traditional methods The influence; and the brain -machine interface technology can complete the evaluation of depression symptoms in a short period of time, which improves the diagnostic efficiency. In the application branch of brain -machine interface technology has gradually matured in recent years, playing an important role in the diagnosis of depression.

This article will introduce the research on depression diagnosis methods based on Brain-Computer Interface (BCI), including electroencephalogram (EEG), magnetoencephalogram (MEG), and functional near-infrared spectroscopy (fNIRS).

2. BCI-based depression diagnosis

2.1. Electroencephalogram (EEG)-based depression diagnosis

In 1929, Hans B recorded the electrical activity of the cerebral cortex on the surface of the scalp. He called it a special brain wave, which is now the 8-12 Hz α wave. It is mainly located in the occipital region when the eyes are closed and the brain is quiet. Depending on the frequency, brain waves also include δ waves, θ waves, β waves and γ waves [2]. This article mainly discusses α waves, β waves and γ waves.

Electrocatics record the electrical motion of the brain through the electrode. The electrode is usually embedded in the electrode cap. The electrode in the electrode cap will collect the electrical signal passed by the human brain in real time. The EEG system is relatively cheap and portable. It is the most commonly used method of electrical and electrical record in the research of electrical signal [3]. Considering that the electrode is only placed on the scalp, the technology realizes the completely non -invasive Electrical signal collection. However, the electrical signal obtained by this method may be affected by the resistance of the scalp itself and the interference of external noise. As a result, the short -term high -frequency brain electrical signals are often omitted, and the signal strength captured may also be attenuated.

2.1.1. α bands. Normal adults can see α waves about 10 Hz in a quiet and closed state, and the pillow is obvious in the future, and the left and right are symmetrical. At present, the appearance of α waves reflects the state of static and relaxation of the brain [4]. There are studies pointed out that the α -frequency band energy level of the forehead and left frontal leaves of the health control group is significantly higher than the depression group, while the α-band energy level of the ceiling and pillow leaves is lower than the depression group [5, 6]. Compared with the changes in the α -frequency band energy level, the asymmetry of alpha waves is especially the value of the asymmetry of the alpha wave at the forehead. By comparing the asymmetry of alpha waves of the alpha waves of the test queen of depression and the health control group, it is found that there is indeed a significant difference in the two. Ear-leaf α activity is stronger than the left frontal leaf [7, 8]. The enhancement of the left α α activity of the left side of depression patients foreshadows the reduction of the activity of the left leaf cortex on the left side, which weakens the ability of pleasure and perception. And some specific clinical symptoms, such as irritability and fatigue [9]. Therefore, the asymmetry of the alpha wave in the middle of the mileage is considered to be a potential indicator of depression.

2.1.2. β and γ bands. β wave is the wave of 14 ~ 30 Hz, and the γ wave is the wave of> 30 Hz. These two are fast waves [10]. β waves are related to expectations, anxiety and concentration, and γ waves are

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related to attention and attention and attention and attention. Feeling system-related and may be associated with emotional instability [4]. Some research shows that compared with the test of the normal control group, depression patients have an absolutely high-level β-band absolute energy level in the frontal lobe [11]. Although the object of the study is male, it also obtained in other studies also received in other studies [12]. It is confirmed and the research does not distinguish gender. Another study conducts the analysis of conventional EEG and shows that there are no asymmetric in the health control group's test and depression patients with depression [13]. Leaf bias, and depression patients do not have the asymmetry of the frontal lobe. In the past, the role of γ waves in clinical work has often been ignored, and now it is getting more and more attention. There are studies [14,15] found that patients with depression and health control groups are different from the γ-frequency bands, but the conclusions are deviated because of their respective attention points. In addition, patients with a tendency to commit suicide tendencies are significantly higher in some brain areas [16]. Therefore, the change of γ-frequency bands can be used for the diagnosis and identification of depression under certain circumstances [17].

2.2. Magnetoencephalography (MEG)-based depression diagnosis

The brain magnetic diagram can support the analysis of the internal activity position on the anatomical images such as Magnetic Resonance Imaging (MRI) to provide the structure and function of the brain. As an important basis for clinical diagnosis and treatment, brain magnetic diagrams have been highly valued by many countries and scientists. By detecting the physiological information of the human brain areas, the patient can effectively analyze the patient's behavior and emotions. At present, many emotional diseases have been effectively prevented, treated, and restored through the detection of brain magnetic diagrams.

Slow wave activity of patients with depression is significantly reduced compared to patients with schizophrenia and normal people, and the slow wave activity of the temporal lobe and top lobe of patients with depression is also reduced compared to patients with schizophrenia. The slow waves corresponding to the brain area of density depression patients are reduced, especially compared to patients with schizophrenia. The percentage of the puppets in the entire brain area of depression is significantly reduced. A significant difference is in the frontal leaf area. Through further research on the abnormal slow wave activity of these brain areas, it is found that they are related to the symptoms of clinical targets. For example, the cracking illusion patients are related to the increase in the slowdown of the left temporal lobe in the brain and depression. Related symptoms are related to the reduction of the left forehead wave of the brain [18].

The Autoregressive (AR) and Autoregressive Fractionally Integrated (ARFI) models are used to analyze the differences in information storage in the magnetoencephalograms of healthy individuals and patients with depression, and the multi-scale conditional entropy method is used to analyze the differences in brain complexity between healthy individuals and patients with depression, which can be used to diagnose depression [19]. This study shows that when the brain magnetic diagram of healthy subjects is stimulated by different emotional pictures, the information storage value of most channels is less than patients with depression, that is, the condition entropy value of the health sample brain magnetic diagram signal is higher than the emotional Patients with depression under the screen. Through the study of the information storage value of the brain magnetic signal in the two models, it can be seen that the information storage value of depression patients and healthy people under the same experimental conditions can be analyzed, and similar conclusions can be obtained among the two models.

Therefore, depression can be diagnosed by comparing the conditional entropy value of the magnetoencephalogram signal when the subjects are faced with different emotional picture stimuli with the standard value under such conditions.

2.3. Functional near-infrared spectroscopy (fNIRS)-based depression diagnosis

fNIRS is a non-invasive brain imaging technology with outstanding advantages such as easy operation, safe performance, and strong noise resistance. It has been widely used in cognitive neuroscience research to identify patients with depression [20].

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The occurrence of depression is associated with the excitement of oxidation. Hydrogen sulfide (H2S) is involved in regulating oxidation and reduction balance in the body, which may become a potential biomarker for depression testing. Therefore, it is necessary to develop a method for monitoring the level of H2S levels in the brain in real time. Due to the advantages of rapid response, simple operation, and real -time imaging, the fluorescent probe can be used for the detection of biomarkers and realize the diagnosis of diseases. Ren Ru of Hebei University believes that two fluorescence probes can be synthesized based on biocyanobyl dexoltone design, which is used to monitor the horizontal changes in H2S in the brain of depression in real time, and achieve the diagnosis of depression [21].

Establish a near-infrared fluorescent probe, and the DCI-PY-H2S is selected as the best fluorescence probe through the analysis of its physical and chemical properties and optical performance testing. The experimental results showed that the probe's Stocks displacement (184 nm), the minimum detection of H2S was 72.9 nmol/L, and could respond quickly with H2S (<150 S). In addition, through the test of the toxicity of the probe, the probe was found to have good biocompatibility, and the probe was used to monitor the H2S level in the depression model in the cell and animal levels.

After injecting the probe into the mouse, with the continuous extension of the time, the fluorescent strength of the mice's brain is increasing, indicating that the probe enters the brain faster, and it is proved that the probe can reach the small brain barrier to the small barrier to the small barrier to the small barrier to the small barrier to the small barrier. Fluorescent imaging on the brain. Then, the probe was applied to the experiment of the depression model rat, and the fluorescence signal appeared in the brain of normal mice; the fluorescence strength of the mice of the mice decreased significantly, and the two groups had significant differences [21].

The experimental results show that by applying near-infrared fluorescent probes to mice and detecting the fluorescence intensity in the mouse's brain after a period of time, it can be determined whether the mouse suffers from depression, which provides theoretical support and reference for the diagnosis and pathogenesis of human depression.

3. Discussion

The diagnosis of depression based on electroencephalogram, magnetoencephalogram and near-infrared methods is a new treatment method that has emerged in recent years. These three methods each have their own advantages and disadvantages.

The advantage of the application of EEG in the diagnosis of depression is its non -invasive and electronic physiological activities that can reflect the brain. The shortcoming is that the EEG cannot be used to diagnose depression alone. It can only be used as auxiliary judgment tool, because the anomalies of the EEG may be caused by various reasons such as the resistance of the scalp and the interference of external noise. Not limited to depression.

The advantage of magnetoencephalography in the diagnosis of depression is that it can provide detailed information about the brain's neural activity, especially the detection of deep brain regions. However, its disadvantages are that it is expensive, it is currently difficult to achieve large-scale popularization, and it is not conclusive for the diagnosis of depression.

The advantage of near-infrared imaging technology in diagnosing depression is that it can provide objective data on brain blood oxygen levels, which helps to understand the functional state of the brain. The disadvantage is that the application of this technology in the diagnosis of depression is still in the research stage, and more experiments and data are still needed to verify its effectiveness and reliability.

4. Conclusion

This article analyzes the three diagnostic methods of depression based on EEG, brain magnetic diagrams, and near infrared. The three technologies have their own strengths in the diagnosis of depression, but they need to be combined with other technologies to achieve depression. Accurate diagnosis. EEG and brain magnetic diagram can provide important information associated with brain function, while near -infrared imaging technology provides a non -invasive method of monitoring the level of cerebral blood oxygen. The three diagnostic methods of depression discussed in this article will help people better

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understand the cutting -edge diagnostic technologies of depression. In the future, they can be further refined on the basis of the above methods. Different types of different types have more accurate correspondence to achieve more accurate diagnosis of different types under depression, so as to facilitate in -depth research on the issue.

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