Dean&Francis

ISSN 2959-6157

The applications of BCI in the Treatment of Mental Disorders and the Development of Antipsychotic Drugs

Sai Hong

Department of Chemistry and Chemical Engineering, Northwest Normal University, Lanzhou, China

Corresponding author: 202331805608@nwnu.edu.cn

Abstract:

Globally, a wide range of mental disorders continues to significantly impact people's lives, with traditional treatment methods often falling short of providing effective and systematic solutions. Brain-computer interface (BCI) technology, one of the most rapidly advancing fields, offers promising applications across various sectors of human society, including production, healthcare, and media. By combining different BCI technologies, such as EEG monitoring and Deep Brain Stimulation, medical institutions can now offer patients a broader spectrum of effective or potential treatment options. This paper provides a comprehensive review of the current application status of various representative BCI technologies in mental health treatment. It also explores the prospect of constructing an integrated treatment system for mental disorders based on BCI technology, aiming to enhance this paper understanding of BCI applications in mental health care. The study examines how different BCI technologies can be utilized at various stages of disease progression, from early diagnosis to long-term management. Additionally, it discusses the potential of BCI in improving patient outcomes, quality of life, and social integration, while addressing ethical considerations and future research directions in this rapidly evolving field.

Keywords: BCI; mental disorders; drug development.

1. Introduction

At present, a large number of people around the world suffer from mental disorders, which have not been effectively treated since they were clinically diagnosed. This is because that the evaluations of the patient's symptoms which made by researchers are not based on pathological results, and traditional clinical diagnosis and treatment cannot be carried out [1]. This has led to a series of problems, such as the inconsistency of diagnostic results of mental disorders, and the accuracy of the evaluation of the response to the treatment effect of psychotropic drugs and the monitoring of disease development at the stage of clinical medication. Thus, the relative inefficiency of feedback on the efficacy of drug treatment has slowed down the development of psychotropic drugs, and the prevalence of most mental disorders has further increased, making the situation facing people with different degrees of such disorders around the world more and more serious.

With the development of brain-computer interfaces, this technology can monitor and collect information on patients' brains, which is of great significance for the discovery, subsequent development and evaluation of psychotropic drugs, and the evaluation of treatment effects [2]. Among them, the non-invasive brain-computer interface, such as electroencephalogram (EEG), can evaluate the therapeutic effect of antidepressants by analyzing information collected from the patient's brain activity, such as alpha and Theta wave changes, and complex EEG data can be analyzed by machine learning (ML) [2][3]. At present, due to the lack of specificity of some drugs, drugs cannot accurately act on the corresponding target sites, while invasive brain-computer interfaces can achieve the effect of delivering drugs to the local area by constructing brain probes, and can treat or improve the development of the disease by directly stimulating the nerve tissue of the brain [4]. It can be seen that the diversified development of brain-computer interface provides feasible ideas and methods for the treatment of mental disorders.

In conclusion, brain-computer interfaces have great clinical practical value and development potential in the treatment of mental disorders and the development and evaluation of correlative drugs. Therefore, this study will explore and analyze the role of brain-computer interface in the diagnosis and treatment of mental disorders, and its significance from EEG brain information collection for the discovery and evaluation of psychotropic drugs, and explore and analyze the role of brain-computer interface in the treatment of mental disorders to build a systematic treatment and drug development process. In order to improve the understanding of the significance of brain-computer interface for the treatment of mental diseases, the current challenges and future development potential of brain-computer interface are summarized and prospected.

2. Brief description of BCI technology

The origins of BCI technology can be traced back to 1973. In that year, Professor Jacques Vidal of the University of California, Los Angeles formally proposed and defined the basic concept of Brain-Computer-Interface (BCI) in his article "Toward direct brain-computer communication" [5]. The main purpose of brain-computer interface is to record and analyze the activity changes of the human brain by constructing a channel between the human brain and external devices, or directly stimulate the brain tissue, so as to achieve the corresponding production, medical and other effects. Because researchers and clinicians are unable to diagnose mental disorders with pathological results, traditional medicine cannot be effectively implemented in the diagnosis and treatment stages. However, BCI technologies, such as Deep Brain Stimulation (DBS) can be used to treat diseases such as depression and treatment-resistant obsessive-compulsive disorder by stimulating the target location with intracranial electrodes [6]. And EEG analysis can be used for the diagnosis of disorders such as attention deficit hyperactivity disorder (ADHD) and schizophrenia [7]. In addition, based on the one-dimensional convolutional neural network (1D-CNN), a diagnostic model of deep depression with an accuracy of 98.32% can be constructed [8]. It can be seen that the diversified treatment methods of brain-computer interface are a major advantage in the field of psychiatric disease treatment. Efficacy monitoring of psychotropic medications. Traditional therapeutic drug monitoring (TDM) uses the monitoring of blood drug concentrations in patients to determine the therapeutic effect of drugs, but this method still has the problems of weak interpretive power of drug monitoring and certain risks in the preservation and transportation of clinical samples [9]. EEG can be used to systematically evaluate the effect of drugs on brain activity by analyzing and evaluating the effects of drugs on brain activity by analyzing and evaluating the patient's Alpha, Beta, and Theta waves [10].

3. BCI for the diagnosis and treatment of mental disorders

3.1 EEG for the diagnosis and prediction of mental disorders

EEG collects information from the brain activities through electrodes attached to the scalp. This technology provides a systematic means of brain monitoring by showing the different time and frequency characteristics of EEG signals to reflect the activity of different brain regions as Fig. 1 shows [2]. Because the pathogenesis of most psychiatric disorders is still unclear, traditional pathology-based diagnosis is not possible. For example, the Hamilton Depression Rating Scale is used as a criterion for the assessment of depression, but it has been criticized for its limited accuracy and subjectivity to give misdiagnosis [11]. The deep learning system based on EEG has brought a new means to the diagnosis of mental disorders. By analyzing EEG signals in different frequency bands of the brain, and

ISSN 2959-6157

trying to construct a depression recognition model based on stimulus linear features and random forest algorithm, the accuracy of depression recognition rate can reach 91% [12]. In addition, EEG monitoring of brain activity in patients with epilepsy can more accurately detect the specific intensity and frequency of seizures, so as to predict seizures and explore their pathogenesis [13]. Therefore, at the early stage of clinical diagnosis for mental disorders and the prediction of disease onset, EEG technology can be extended to more types of mental disorder treatment. In addition, a deep learning model for the diagnosis of related diseases is constructed to improve the efficiency and accuracy of diagnosis

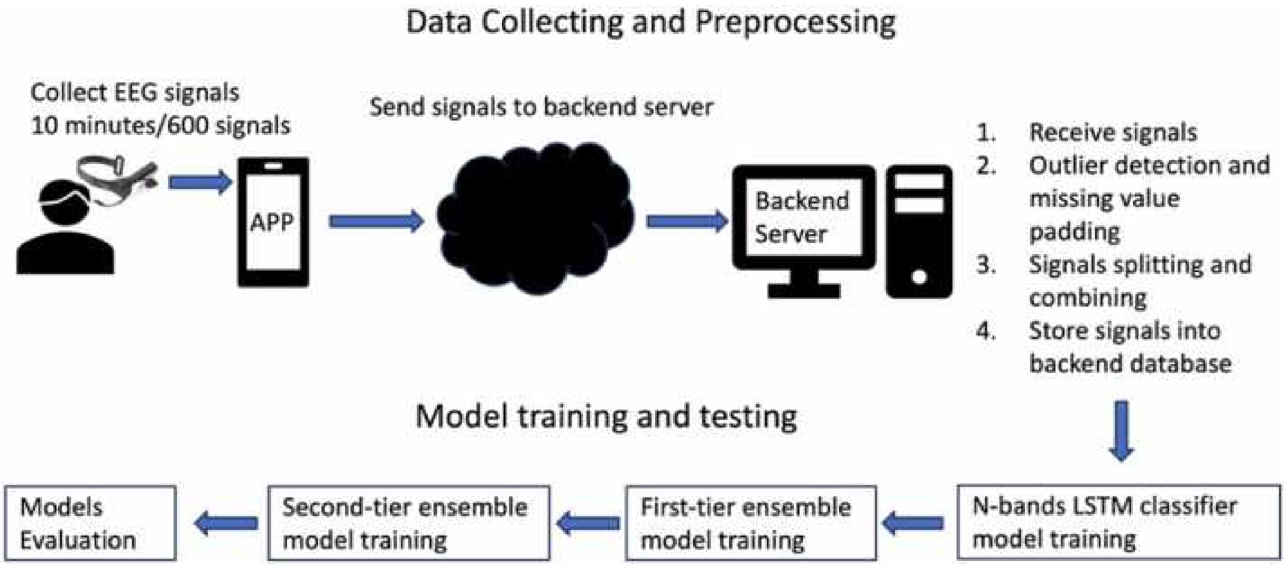

Fig. 1 Flow of EEG signal collecting and processing [2].

3.2 BCI for the interventional treatment of mental disorders

For the treatment of mental disorders, the current use of brain-computer interface technology in clinical treatment can also play a certain therapeutic effect. For example, neuromodulation is carried out by stimulating brain tissue with electrodes. Another example is the construction of effective drug pathways to act on brain targets.

3.2.1 Deep Brain Stimulation(DBS)

Deep brain stimulation is a neuromodulation technique with great clinical application value. As Fig. 2 brings out, DBS stimulates the target encephalic zone to regulate the nerve action for patients. Because of its minimally invasive properties, low potential for severe disabling adverse effects, and its ability to precisely act on brain targets [6] [13]. These advantages can contribute to its wide range of potential applications. DBS has been used for the treatment for Treatment Resistance Depression(TRD). According to studies, patients with TRD have been significantly relieved by targeted stimulation of different brain regions of the inferior cingulate gyrus (SCG), ventral capsule/ventral striatum (VC/VS), medial anterior tract (MFB), and nucleus accumbens (NAcc) [14][15]. In addition, research on the mechanism of neural circuits in the treatment of refractory obsessive-compulsive disorder (OCD) with DBS is also being advanced [16]. The prospective development of different stimulus paradigms and stimulus algorithms used in the DBS configuration system also brings possibilities for treating other mental disorders.

This shows the great potential clinical therapeutic value of DBS technology, and has some prospects for applying it to the treatment of more mental disorders in the future.

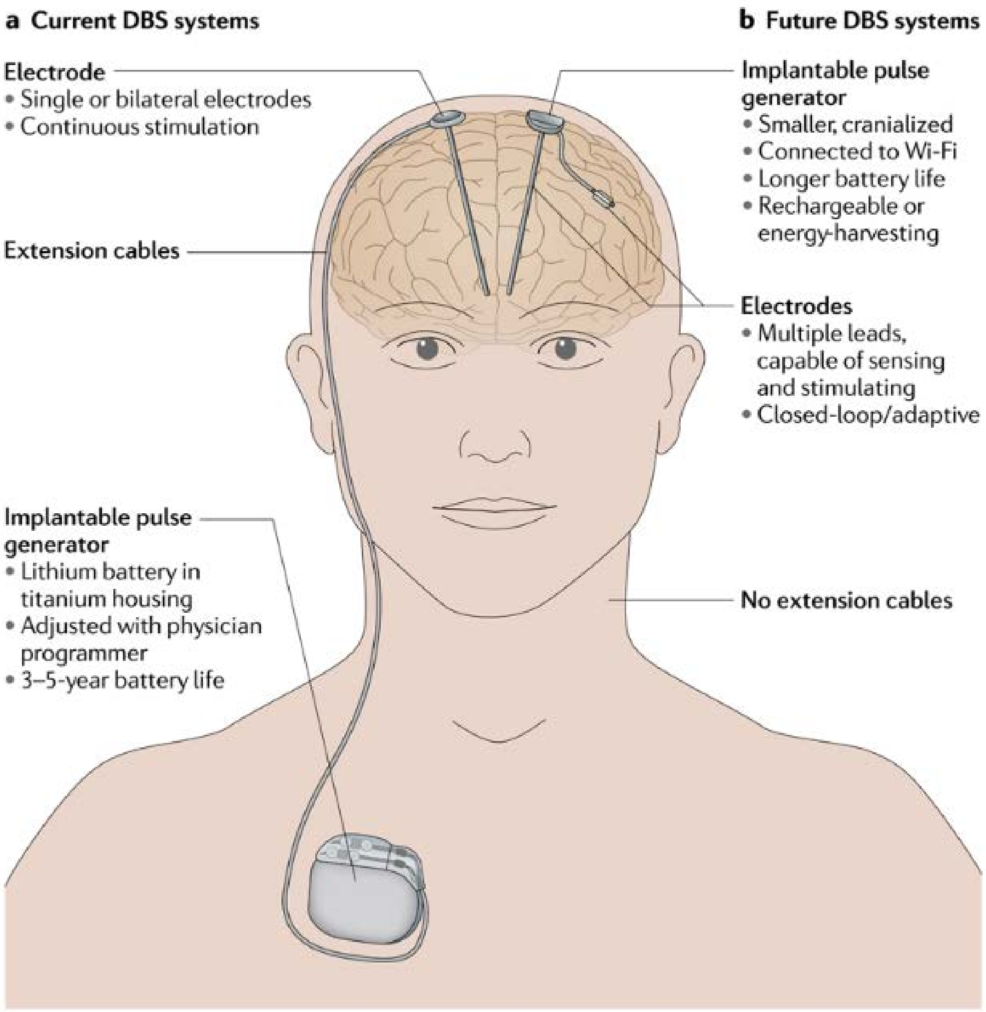

Fig. 2 Current and prospective configuration of DBS [6].

3.2.2 Optofluidic Brian Probes

To understand the complexity of the brain's neural circuits is one of the main issues in the development of interventions in the treatment of psychiatric disorders [4]. This can help researchers to discover and design more versatile approaches for disease treatment. To some extent, the construction of brain probes may help us better decode neural circuits to reveal the pathogenesis of psychiatric disorders and explore treatment options for such disorders [4][17].

At present, researchers have developed smartphone-controlled wireless optofluidic brain probes for mice. The implant's features include, but are not limited to, plug-and-play replaceable drug cartridges that can be controlled remotely via Bluetooth by smartphone, can independently deliver drugs and different wavelengths of light to deep areas of the brain [17]. This probe is used to study chronic in vivo pharmacology and optogenetics and may help explain the basis of neurological diseases.

4. BCI for the development and evaluation of psychotropic drugs

4.1 Drug discovery based on EEG data analysis

In recent years, the development of traditional psychotropic drugs has almost come to a standstill, because the pathogenesis of mental illness is still unclear and there is a need to avoid or reduce the side effects of drugs on patients. EEG technology brings new opportunities for this. Pharmaco-EEG plays a valuable role in the early screening and development of psychotropic drugs. This technology combines biomarkers and neuropharmacology to evaluate the clinical therapeutic effect and safety of drugs [2]. It effectively solves a series of difficulties in the early development of psychotropic drugs, such as identifying the exact marks for drug assessments and predicting the clinical efficacy. Drug EEG has great prospects as a tool to assist the development of psychotropic drugs, but how

ISSN 2959-6157

to improve its prediction accuracy and analysis speed is a difficult problem at present. Perhaps the introduction of machine learning (ML) and the development of new algorithms can gradually mature this process.

4.2 EEG-based psychotropic drug prediction model

Given the variability in individual responses to psychotropic drugs after taking them, identifying corresponding biomarkers is crucial for predicting drug efficacy and moving towards personalized treatment approaches. Constructing a predictive model of psychotropic drugs is an effective means.

Based on clinical EEG data, researchers have concluded that pre- and early-treatment EEG data and machine learning models can be used as tools to predict the response to antidepressant [3]. In addition, the Transformer model was used to predict drug response with an accuracy of 97.14% [18].

4.3 Privacy and ethical considerations regarding the use of predictive models

One of the inevitable problems in the use of brain-computer interfaces is that users generate large amounts of neural data, and there is no doubt that this data can bring considerable business value to relevant companies and research institutions. Defining the relationship between users and their generated data, particularly in terms of ownership and access rights, is an unavoidable challenge that needs to be addressed. A current survey shows that 58% of BCI researchers believe that users can access the raw data they generate after the study ends, but that the power to use that data should be limited [19]. This ambiguity highlights the need for clear guidelines on the ownership and authority of neural data generated by individuals using BCI technology. Therefore, it is necessary to promptly improve the corresponding laws and regulations to better develop the field of brain-computer interfaces and protect user rights in order to develop the field of brain-computer interface in a safer and better way.

5. BCI in the construction of an integrated treatment system for mental disorders

With different sorts of BCI technologies acting on disease treatment respectively, the blueprint of a complete integrated treatment system for mental disorders has taken shape. From the begin of diagnosis to the subsequent specific treatment options, BCI technologies, such as EEG monitoring and versatile invasive neuralcontroltechnology, can serve as a kind of useful tool for the treatment. The combination of brain-computer interface technology in all stages of the treatment of mental disorders will effectively improve the treating efficiency and systematization for more mental diseases, so that the group with this kind of disease would make a better living of their own lives. However, some of the problems that have emerged from this, such as the high cost of treatment and the neurological data generated by the treatment process of patients and medical institutions, still need to be addressed. Brain-computer interface technology has great potential in the field of mental disorder treatment, and how to use this technology correctly and effectively is the goal this paper will continue to explore.

6. Conclusion

As brain-computer interface meets a rapid development in this technological age, a bright future it may have. In mental disorders treatment, it is believed that BCI can be a very practical tool with advancing it gradually. And moreover, it can help us mankind to make progress on many problems of the development of manufacturing, medicine, technology etc. But simultaneously, it would also bring us trouble if this paper cannot get a balance while using this kind of technology. In summary, this paper need to keep advancing and be careful in the development of BCI and try to find good way to get rid of unknown dangers.

References

[1] PhRMA. 2014 Global advances in drug development for psychiatric disorders. Journal of China Pharmaceutical University, 2014, (3): 324.

[2] He Z., Chen L., Xu J., et al. Unified convolutional sparse transformer for disease diagnosis, monitoring, drug development, and therapeutic effect prediction from EEG raw data. Biology (Basel), 2024, 13(4): 203.

[3] Jaworska N., de la Salle S., Ibrahim M. H., Blier P., Knott V. Leveraging machine learning approaches for predicting antidepressant treatment response using electroencephalography (EEG) and clinical data. Frontiers in Psychiatry, 2019, 9: 768.

[4] McCall J. G., Qazi R., Shin G., et al. Preparation and implementation of optofluidic neural probes for in vivo wireless pharmacology and optogenetics. Nature Protocols, 2017, 12(2): 219-237.

[5] Vidal, J. J. Toward direct brain-computer communication. Annual Review of Biophysics and Bioengineering, 1973, 2(1): 157.

[6] Krauss J. K., Lipsman N., Aziz T., et al. Technology of deep brain stimulation: current status and future directions. Nature Reviews Neurology, 2021, 17(2): 75-87.

[7] Sridhar C., Bhat S., Acharya U. R., Adeli H., Bairy G. M. Diagnosis of attention deficit hyperactivity disorder using imaging and signal processing techniques. Computers in Biology and Medicine, 2017, 88: 93-99.
[8] Mumtaz W., Qayyum A. A deep learning framework for automatic diagnosis of unipolar depression. International Journal of Medical Informatics, 2019, 132: 103983.
[9] Chen T., Mao S. Advances in the application of in vivo drug analysis technology in clinical pharmacy. Journal of Pharmaceutical Practice and Service, 2024, 42(2): 60-65.
[10] De Pieri M., Rochas V., Sabe M., Michel C., Kaiser S. Pharmaco-EEG of antipsychotic treatment response: a systematic review. Schizophrenia (Heidelberg), 2023, 9(1): 85.
[11] Bagby R. M., Ryder A. G., Schuller D. R., Marshall M. B. The Hamilton Depression Rating Scale: has the gold standard become a lead weight? American Journal of Psychiatry, 2004, 161(12): 2163-2177.
[12] Luo Ruipeng, Zou Renling, Meng Lingpeng, et al. Research on EEG recognition of depression based on machine learning. Intelligent Computers and Applications, 2023, 13(11): 82-87.
[13] Rasheed K., Qayyum A., Qadir J., et al. Machine learning for predicting epileptic seizures using EEG signals: a review. IEEE Reviews in Biomedical Engineering, 2021, 14: 139-155.
[14] Xu J., Zhang C., Tang Y. Research progress on the targets of deep brain stimulation in the treatment of treatment-resistant depression. Chinese Journal of Neuropsychiatric Diseases, 2022, 48(5): 310-314.
[15] Zhou C., Zhang H., Qin Y., et al. A systematic review and meta-analysis of deep brain stimulation in treatment-resistant depression. Progress in Neuropsychopharmacology & Biological Psychiatry, 2018, 82: 224-232.
[16] Slepneva N., Basich-Pease G., Reid L., et al. Therapeutic DBS for OCD suppresses the default mode network. Preprint. bioRxiv, 2024.
[17] Qazi R., Gomez A. M., Castro D. C., et al. Wireless optofluidic brain probes for chronic neuropharmacology and photostimulation. Nature Biomedical Engineering, 2019, 3(8): 655-669.
[18] Saeedi, A., Maghsoudi, A., Rahatabad, F. N. Depression diagnosis and drug response prediction via recurrent neural networks and transformers utilizing EEG signals. Preprint. arXiv, 2023.
[19] Naufel S., Klein E. Brain-computer interface (BCI) researcher perspectives on neural data ownership and privacy. Journal of Neural Engineering, 2020, 17(1): 016039.