Neurotechnology for ADHD and Depression: Mechanisms, Evidence, and Challenges

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Abstract: Common mental disorders that decrease the quality of life include Attention-Deficit/Hyperactivity Disorder (ADHD) and Major Depressive Disorder (MDD). A lot of patients are not receptive to medication or psychotherapy. This generates the necessity of alternative therapies. The question this paper poses is how neurotechnology can be utilized to aid in treating ADHD and MDD. It discusses the recent empirical studies and meta-analyses of neurofeedback and non-invasive brain stimulation. The results indicate that it is possible to directly manipulate the abnormal brain activity with the help of neurotechnology. Brain stimulation and neurofeedback have benefits in ADHD in terms of attention, inhibitory control, and working memory. The neurofeedback and advanced TMS protocols used in MDD decrease depressive symptoms and enhance cognitive performance. The research potential of the closed-loop and AI-assisted systems also demonstrates the potential of personalized intervention. Altogether, neurotechnology represents one of the promising, non-drug options.

Keywords: Neurotechnology, ADHD, Major Depressive Disorder, Neurofeedback

1Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) and Major Depressive Disorder (MDD) are common mental disorders. They affect children, adolescents, and adults worldwide. ADHD mainly affects attention, impulse control, and executive function [1]. MDD mainly affects mood, motivation, and emotional regulation [2]. Both disorders reduce quality of life and daily functioning. They also create long-term social and economic expenditure. Medication and psychotherapy are the main treatments today. However, many patients do not respond well to these treatments. Some patients also experience negative side effects. Because of these limits, new treatment approaches are needed. Neurotechnology has become an important field. This includes neurofeedback, brain stimulation, and brain-computer interfaces. These methods interact with the brain to change abnormal patterns. Thus, they become promising tools for ADHD and MDD treatment.

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Recent studies use different neurotechnology methods to support ADHD and MDD treatment. Research by Yang & Kim reviewed neurofeedback, transcranial direct current stimulation (tDCS), and transcranial magnetic stimulation (TMS) for ADHD [3]. They found that these tools can improve attention in some patients, but results vary across studies.

Research by Courrèges et al. compared neurofeedback, tDCS, and repetitive transcranial magnetic stimulation (rTMS) in adults with ADHD using a meta-analysis [4]. The study found that tDCS and rTMS showed stronger and more consistent protocols than neurofeedback, but these methods still need large samples and clearer standards to confirm their effectiveness.

Depression research has focused on brain-based feedback as well as imaging. Khaleghi et al. have reviewed studies conducted on patients who did not respond positively to standard treatments and used fMRI-based neurofeedback to treat depression [5]. According to the review, most of the studies reported changes in the activity of sections of the brain that process emotions and a reduction in symptoms of depression.

Woodham et al. conducted a home-based randomized controlled trial experiment on 10 weeks of tDCS in adults with MDD fully remotely over ten weeks [6]. The study discovered that, while retaining high safety and acceptability, active tDCS that targeted the left dorsolateral prefrontal cortex decreased depressive symptoms more than sham treatment.

This paper is aimed at examining the utilization of neurotechnology in assisting individuals with ADHD and MDD. It will examine some of the most significant neurotechnology approaches, which have been utilized in recent research. These are neurofeedback as well as non-invasive brain stimulation. It also contains developments and obstacles of the present improvement. Lastly, the paper reflects on the future as it could be investigated with respect to the individualized neurotechnology and the closed-loop neurotechnology. The current essay attempts to elucidate the application of neurotechnology in the treatment of mental illnesses.

2 Neurotechnology mechanisms and clinical significance

Neurotechnology consists of instruments and techniques that engage work directly with the nervous system. These instruments measure, infer, and adjust the brain functions. They might shape the behavior, feelings, and thinking of the people. The tracking of brain signals in real time is the topic of many neurotechnologies. Electroencephalography (EEG) is a well-known type of neurotechnology that could be used to record brain activity at the scalp. Little electrodes are placed on the head to record impulses of the brain. These impulses indicate the brain cell communication and functionality. EEG helps people to have a clear understanding of emotions and attention [7]. Nonetheless, EEGs are most readily affected by interpersonal variations and external interference, making it hard to interpret them. Owing to such constraints, machine learning has been used to ensure that the EEG signal processing is more precise and robust. EEG can be used to assist communication and therapy via brain- computer interfaces (BCI) [8].

Some categories of non-invasive neuromodulation include TMS and tDCS [9,10]. TMS produces minimal electrical currents within the selected parts of the brain by the use of magnetic fields. This modulates the neuron firing and neuron connections. tDCS is a weak current applied to the neurons in order to change the neuron's resting potentials. This activates or deactivates areas of the brain. The two strategies seek to encourage neuroplasticity. They enable them to fortify brain networks through the use of many sessions. These techniques are commonly involved when researchers are conducting a study on cognition and emotion. In this case, such neurotechnologies as EEG-based neurofeedback and tDCS are extensively studied in ADHD. Such studies were controlled in nature, and they concluded that these methods result in slight or modest improvements in attention and cognitive control [11].

Closed-loop neuromodulation systems have integrated brain monitoring and brain stimulation into a single brain stimulation system. The system modulates stimulation using the prevailing activity of the brain. This enables stimulation to react to the live neural stimulus. The users are able to control brain functions more accurately. These systems integrate neurofeedback and direct stimulation, which enhances the efficacy of treatment [12].

Both ADHD and MDD have abnormal brain networks. ADHD disrupts executive and attention through the fronto-striatal and the fronto-parietal loop. This causes disruption of everyday operation [11]. MDD impairs the prefrontal-limbic relationship and dysfunctional dynamic functional connections, mood, and cognition [13]. Neurotechnology can directly respond to these circuits to help in recovery by improving mood, attention, and daily functioning.

3 The use and impact of Neurotechnology in Neurological Disorders

3.1 Neurotechnology in ADHD

ADHD is associated with impairments in brain structure, brain networks, and brain chemistry. The studies indicate that the frontal cortex and networks participate in this case perform relatively poorly in people with ADHD. The imbalance of dopamine and norepinephrine influences attention, inhibitory control, and working memory [1].

During the last several years, scientists experimented with the use of various neurotechnologies in the treatment of ADHD. Yin et al. studied tDCS. In the experiment, patients underwent scalp electrodes, and a weak electrical current was forced through the brain [14]. This oscillated neural activity of the prefrontal cortex is vital in attention, inhibitory control, and, working memory. The subjects received a series of tDCS treatments over a number of weeks. Treatment resulted in improvement of inhibitory control, working memory, and attention. Maximal effects were noted in the process of stimulation of F3/F4 regions, whereas F8/Fp2 did not enhance cognitive functions. tDCS was more efficient with medication or repetition. Another treatment method that Yin et al. tested is repetitive transcranial magnetic stimulation (rTMS), in which magnetic pulses are used to induce electric fields in the prefrontal cortex that enhance neural plasticity. Others showed some improvement in attention and hyperactivity, although rTMS was used less, and one patient had a seizure. It was expensive in both equipment and maintenance. Yin et al. presented an initial finding of transcranial alternating current stimulation (tACS) and transcranial random noise stimulation (tRNS). tACS applies alternating current to alter neural activity. It was found to enhance attentiveness and inhibition. tRNS involves stimulation of random noise, and in combination with cognitive training, it enhances some working memory, processing speed, and executive functions. However, selected studies did not have control groups, and results are therefore to be taken cautiously.

Zhong et al. examined the neurofeedback training (NFT) in ADHD children. The participants were given the opportunity to use EEG caps to record the activity of the brain and provided feedback on a screen or a game [15]. This enabled them to know how to manage the brain activities in real time. Classes were several weeks long. The children developed inhibitory control and working memory after training. Stronger effects were caused by longer total training, which exceeded 1260 minutes. NFT was effective in strengthening desired brain activity and minimizing hyperactivity associated with ADHD. The case with Zhong et al. was no different. Constant and regular sessions were required to sustain improvements. The results will be influenced by different NFT protocols, and Theta-beta ratio (TBR) is the protocol that has the most effect on the inhibitory control.

These neuro-techs offer innovative non-pharmacological methods of treating ADHD. They are able to enhance attention, inhibitory control, and working memory. They are also not as invasive as other treatments in the medical field. Yet these ways, too, are limited. A lot of them have a need for costly equipment. The training and stimulation continue over weeks or months. There are studies that show inconsistency in some results. The problems impact their accessibility and the durability of their use.

3.2 Neurotechnology in MDD

MDD has an impact on the brain structure and functioning. These are the important sites, such as the prefrontal cortex and limbic system. Those alterations negatively affect the functionality of mood and thinking brain networks. There may also be disregards in neurotransmitter systems that influence emotional processing and cognition [2].

Cole et al. experimented with an advanced version of transcranial magnetic stimulation known as Stanford Accelerated Intelligent Neuromodulation Therapy (SAINT) [16]. The position dealt with the treatment-resistant depression in MDD patients. The functional connection magnetic resonance imaging (fcMRI) was first used to identify the part in the left dorsolateral prefrontal cortex (DLPFC) that had the highest functional connection with the subgenual anterior cingulate cortex. The circuit is hyperirritable during depression. There was a target for each patient. Afterward, patients were theorized to receive intermittent theta burst stimulation (iTBS). The treatment was intense since patients had ten sessions each day for five consecutive days. In every treatment, short magnetic pulses were applied to the targeted part of the brain. This stimulation was done to restore normal network activity. Most participants reported a rapid and massive process of symptom abatement after treatment with an application of 19 of the subjects (90.5%) in clinical remission with no pernicious side effects on cognition. It is more effective and rapid than the regular TMS procedures. The study, however, was done in an open-label design and a sample of 21. This constrains conclusions made regarding the effectiveness in the long run.

A meta-analysis recently published by Xia et al. reported the review of 22 studies and a total of 580 participants in the study to determine the effectiveness of neurofeedback in MDD. The EEG- or functional magnetic resonance imaging (fMRI)- based neurofeedback scans were administered to the participants [17]. In these sessions, they were trained to have self-control over activity in certain areas of the brain. Target areas were the amygdala, dorsolateral prefrontal cortex, or frontal alpha asymmetry (FAA). In such interventions, the patients were trained to control certain signals in the brain with the help of real-time feedback. In this training, participants learn to regulate activity in specific parts of the brain associated with mood and cognition. There was a significant improvement in various outcomes in the meta-analysis. The symptoms of depression were greatly reduced (Hedges' $g = -.762$, $P < 0.001$). This implies that there is a high treatment effect and a statistically significant increase in mood. Improvement in neurophysiological outcomes was also observed (Hedges $g = -0.505$, P value < 0.001). These actions indicate the alterations in the patterns of activities in the brain. There was a moderate improvement in neuropsychological functioning too (Hedges $g= -0.676$, $P < 0.001$). This involves the mental faculties of attention and emotional processing. Larger negative Hedges' g values represent greater symptom reduction. The value of p with a 0.001 or less indicates that the findings are highly statistically relevant. The longer the duration of intervention and the number of sessions, the more depressive symptoms and cognitive functions were improved.

Neurofeedback was published as a more effective therapy in comparison with rTMS and tDCS. Nevertheless, its use in various phases of depression, its combined impact with drug therapy, and its long-term impacts require more studies to be elucidated.

4 Developments and Problems in Neurotechnology

Neurotechnology studies are moving forward into the field of AI and BCIs that are potentially useful in the treatment of ADHD, depression, and other mental disorders. BCIs and AI systems are designed to interpret and read signals from the brain so that they assist in diagnosis, therapy, and intervention in real time. Currently, AI can be implemented in processing complex neural data from EEG or imaging. It has the capability to enhance the signal decoding and feedback systems. Such tools can adjust to the specific patterns of the brain, which results in more personalized treatment strategies [18].

Although AI is improving, neurotechnology has a number of challenges in the treatment of ADHD and MDD. Neurofeedback in ADHD is rather inconclusive. Some studies show that there is an improvement in attention or self-reported symptoms. In other studies, core ADHD symptoms are not affected when blinded measurements are applied. This means that the existing neurofeedback plans are not always effective[19,20]. It is hard to optimize treatments due to the absence of clear connections between changes in the neural abnormalities and the behavioral consequences.

MRI biomarkers used to direct personal therapy can play a key role in MDD. Nevertheless, the majority of the research continues to do group-level research. Such an approach fails to measure variations in the brain among patients [21]. Various imaging techniques, preprocessing procedures, and analysis plans are used in studies, which makes them inconsistent. And it complicates relating diagnostic data with treatment response and planning of the interventions.

Hence, the future employment must render neurotechnology more specific and individual. Behavioral measures and wearable EEG will be useful in the case of ADHD. Chen et al. showed that multimodal types of EEG and attention evaluation AI models can accurately classify young children with ADHD [22]. The study might be extended further in the future by continuing to monitor brain activities and behavior during therapy. Real- time feedback provides the capability of making changes based on the neural signal immediately.

In MDD, research indicates that diagnosis, prediction of treatment, and intervention could be incorporated within closed-loop systems. Those systems may adapt therapy as the brain of a patient changes over time. Furthermore, the cooperation of multiple centers aid into developing mutual scanning guidelines and uniform data processing. This would enhance reproducibility, enabling the results to be compared across the sites [21]. All these innovations would help neurotechnology become more accurate and functional in the delivery of tailored mental health care.

5 Conclusion

The paper has discussed the neurotechnological application in the treatment of ADHD and MDD based on the recent empirical research and meta-analyses on the use of neurofeedback and non-invasive brain-stimulation techniques in treatment.

As seen in the review, in both disorders, neurotechnology has the direct ability to target abnormal brain activity. Some methods that demonstrated effectiveness in enhancing attention, inhibitory control, and working memory in ADHD included tDCS, rTMS, tACS, tRNS, and EEG-based neurofeedback. The neural activity within the prefrontal cortex with brain stimulation was also beneficial in executing the executive functions. Neurofeedback also enabled patients to learn how to control signals in their own brains through repetition in training. Nevertheless, they differed in terms of treatment effectiveness depending on the protocols, location of stimulation, and duration of the session.

Neurotechnology in MDD emphasized the networks of mood regulation. New TMS algorithms like SAINT have delivered fast responses in reducing symptoms in patients who are resistant to the therapy. Studies also showed significant improvement in depressive symptoms, patterns of brain activity, and cognitive functions. These results explained why prefrontal-limbic circuit-based strategies may be effective in harmonizing emotions. The more prolonged and more intensive interventions tended to have a stronger result.

In both disorders, neurotechnology offers non-pharmacological therapy. The majority of them are not invasive methods and demonstrate reasonable safety. Certain strategies may be used alongside medication or psychotherapy to produce better results. Closed -loop systems also have potentials to provide real time and adaptive treatment.

Yet there are certain limitations. A lot of research had a small sample size or was an open-label design. There was a variance in protocols between labs. Equipment costs were high. Training took a long and repetitious process. Not all the results followed-up. Such considerations reduce accessibility, standardization, and clinical translation.

Research in the future should establish more customized and accurate systems. Improved diagnosis and target treatment could be given with the help of AI analysis, wearable EEG, and multimodal biomarkers. Closed-loop neuromodulation can enable interventions to change in response to variations of the brain state. To check the long-term effectiveness, big multi-centers will prove to be useful.

On the whole, neurotechnology can be viewed as a potentially promising trend in the mental health treatment. These tools might be increasingly reliable, accessible, and effective to the patients with mental disorders such as ADHD and MDD as areas of technology and clinical progress continue to rise.

References

[1] ADDA Editorial Team: Inside the ADHD brain: Structure, function, and chemistry. Available at: https://add.org/adhd-brain/ (2022)

[2] Dai, L., Zhou, H., Xu, X., Zuo, Z.: Brain structural and functional changes in patients with major depressive disorder: A literature review. PeerJ. 7, e8170 (2019)

[3] Yang, C., Kim, J.W.: Neuromodulation as a potential intervention for children with attention-deficit/hyperactivity disorder. Journal of the Korean Academy of Child and Adolescent Psychiatry. 36(1), 2–10 (2025)

[4] Courrèges, M., Hoareau, M., Levenes, C., Rahioui, H.: Comparative efficacy of neurofeedback, tDCS, and TMS for adults with ADHD: A systematic review and meta-analysis. Journal of Affective Disorders. 388, 119585 (2025)

[5] Khaleghi, A., Samiei, H., Zarafshan, H., Baloochi, S.A., Mohammadi, M.R.: Effectiveness of fMRI-based neurofeedback therapy on depression: A systematic review. Clinical Psychopharmacology and Neuroscience. 23(3), 337–355 (2025)

[6] Woodham, R.D., Selvaraj, S., Lajmi, N., et al.: Home-based transcranial direct current stimulation treatment for major depressive disorder: A fully remote phase 2 randomized sham-controlled trial. Nature Medicine. 31(1), 87–95 (2024)

[7] Mayo Clinic: EEG (electroencephalogram). Available at: https://www.mayoclinic.org/tests-procedures/eeg/about/pac-20393875 (2024)

[8] McFarland, D., Wolpaw, J.: EEG-based brain–computer interfaces. Current Opinion in Biomedical Engineering. 4, 194–200 (2017)

[9] Alfihed, S., Majrashi, M., Ansary, M., et al.: Non-invasive brain sensing technologies for modulation of neurological disorders. Biosensors. 14(7), Article 335 (2024)

[10] Jog, M., Anderson, C., Kim, E., et al.: Structural changes induced by transcranial direct current stimulation in depression. Biological Psychiatry. 89(9), S290–S291 (2023)

[11] Rubia, K., Westwood, S., Aggensteiner, P., Brandeis, D.: Neurotherapeutics for attention deficit/hyperactivity disorder: A review. Cells. 10(8), 2156 (2021)

[12] Kachhadia, M.P., Sibhai, I., Vaghela, R., et al.: Open-loop and closed-loop neuromodulation across neurological disorders toward personalized brain stimulation: A narrative review. Cureus (2025)

[13] Sun, S., Yan, C., Qu, S., et al.: Resting-state dynamic functional connectivity in major depressive disorder: A systematic review. Progress in Neuro-Psychopharmacology and Biological Psychiatry. 135, 111076 (2024)

[14] Yin, Y., Wang, X., Feng, T.: Noninvasive brain stimulation for improving cognitive deficits in ADHD: A systematic review and meta-analysis. Brain Sciences. 14(12), 1237 (2024)

[15] Zhong, X., Yuan, X., Dai, Y., Zhang, X., Jiang, C.: Neurofeedback training for executive function in ADHD children: A systematic review and meta-analysis. Scientific Reports. 15(1) (2025)

[16] Cole, E.J., Stimpson, K.H., Bentzley, B.S., et al.: Stanford accelerated intelligent neuromodulation therapy for treatment-resistant depression. American Journal of Psychiatry. 177(8), 716–726 (2020)

[17] Xia, Z., Yang, P., Chen, S., Zhou, H., Yan, C.: Meta-analysis of neurofeedback effectiveness in treating major depressive disorders. Cerebral Cortex. 34(6) (2024)

[18] Baydili, İ., Tasci, B., Tasci, G.: Artificial intelligence in psychiatry: A review of biological and behavioral data analyses. Diagnostics. 15(4), 434 (2025)

[19] Westwood, S.J., Aggensteiner, P., Kaiser, A., et al.: Neurofeedback for attention-deficit/hyperactivity disorder. JAMA Psychiatry. 82(2), 118 (2025)

[20] Fan, H., Sun, C., Cheng, Y., et al.: Self-reported efficacy of neurofeedback for adolescents and adults with ADHD: A pilot meta-analysis. Scientific Reports. 12(1) (2022)
[21] Gao, Q., Chen, X., Castellanos, F.X., Lu, B., Yan, C.: Towards closed-loop precision psychiatry using MRI biomarkers for major depressive disorder. Psychoradiology. 5 (2025)
[22] Chen, I., Chang, C., Chang, M., Ko, L.: Wearable EEG combined with behavioral measures for ADHD diagnosis in young children. Journal of Neurodevelopmental Disorders. 16(1) (2024)