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Research on the BCI Treatment and Inventions in ADHD

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Abstract:

Attention-deficit/hyperactivity disorder (ADHD) is a behavioral disorder that typically begins in childhood and is characterized by a short attention span, which refers to inattentiveness, an inability to be calm and stay still, which refers to hyperactivity, and poor impulse control, which refers to impulsivity. People with ADHD usually experience the following types of symptoms: (1) Attention means a person may have difficulty staying on task, sustaining focus, and staying organized, and appear not to listen, even when spoken to directly. (2) Hyperactivity means a person may seem to move about constantly, including in situations when it is not appropriate or excessively fidgets, taps, or talks. They may often be on the go, in constant motion, and have trouble playing or doing an activity quietly. (3) Impulsivity means a person may act without thinking or have difficulty with self-control. Impulsive behavior also occurs when their desire for reward is not satisfied or temporarily put on hold. An impulsive person may interrupt others or make important decisions without considering long-term consequences. Those people's behaviors are more severe, occur more often, and interfere with or reduce the quality of how they function socially at school or in professional life.

Keywords: Brain computer interface (BCI); ADHD; multi-channel; neurofeedback; EEG

1. Introduction

More people are realizing that ADHD is a severe mental illness with long-term effects [1]. ADHD is frequently identified in childhood, but it can also linger into adolescence and adulthood and negatively impact functional results [1]. Three types of symptoms can be used to categorize attention deficit hyperactivity disorder (ADHD): loss of attention, hyperactivity, and impulsiveness.ADHD is a multifaceted disorder. The former encompasses focusing too much on details, conversing too much, and engaging in excessive physical activity. Children with ADHD exhibit these traits at an early age, which negatively affects the social, emotional, and cognitive facets of their typical development. One definition of attention is the capacity to maintain a steady concentration on a certain action or idea. Regional cerebral blood flow, which rises during attentional tasks like reading, naming, blinking rate, which rises or falls, respectively, as attention increases, and, lastly, markers derived from electroencephalographic activity can all be used to indicate levels of attention [2]. BCI is widely believed to be a hardware and software system designed to act as a brain-computer interface [2]. A brain-computer interface (BCI) converts EEG signals from the brain into computer commands that provide meaningful interaction between the user and the outside environment [3]. The potential for EEG signals to be converted into unrestricted computer commands has created countless opportunities [3]. With EEG-based BCI, the only limitation is their creativity [3]. The practical aspects of several classifiers for EEG-based BCI will be discussed in this work, along with theoretical developments in signal processing and the applicability of these developments to real-time EEG-based BCI [3]. In the management of Attention Deficit Hyperactivity Disorder, BCI predominantly utilizes Neurofeedback Training, a method that trains individuals to be cognizant of and regulate their brainwave patterns. In ADHD, there‘s a common neurophysiological characteristic observed is an imbalance in brainwave patterns. There‘s typically an excess of theta waves that are linked with inattentiveness and a scarcity of beta waves, which are associated with focus. Through real-time EEG feedback, patients engaging in attention-requiring tasks receive instantaneous insights into their brain activity, often represented through interactive and engaging formats like games, which respond to the patient‘s brainwave states. This method effectively strengthens the patient‘s ability to maintain focus, akin to muscle training, by promoting higher beta wave activity.

2. Related Works

2.1 Neurofeedback

The brain-computer interface (BCI) serves as the foundation for neurofeedback carrying out via a software system and a five-stage processing pipeline, which is shown in Figure 1 [4].

Steps 1 and 2 show how Neurofeedback measures the pre-processed brain activity of the subject, as depicted in the figure on the screen [4]. Step 3 demonstrates Online calculations are made using pre-selected brain parameters, such as a certain frequency range or brain potential [4]. Step 4 displays converted signals that are instantly returned to the user [4]. Neuroplasticity via Hebbian plasticity or anti-Hebbian/homeostatic plasticity is predicted to occur during neurofeedback training as a result of these learning mechanisms [4].

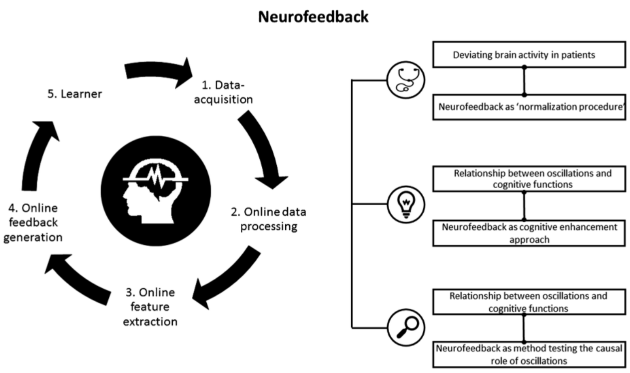

Fig. 1 Neurofeedback as a treatment intervention in ADHD: Current evidence and practice [3]

2.2 Building Neurofeedback through EEG Signals

Neurofeedback systems that rely on electroencephalography (EEG) have been created as a substitute modality for training attention and have demonstrated the efficacy of function recovery [5]. An EEG is a test that looks for irregularities in your brain‘s electrical activity or brain waves [5]. Electrodes, which are tiny metal discs with thin wires attached to them, are applied to your scalp throughout the process [5]. Your brain cells produce minute electrical charges, which are detected by the electrodes [5]. The charges are magnified and show up as a recording that can be printed either on paper or as a graph on a computer screen [5]. After that, your healthcare professional interprets the reading [5].

2.3 EGG Feedback Training

The most extensively documented EEG features linked to ADHD are either a decrease in the power of beta waves or an increase in the power of theta and delta waves, which are slow [6].

A brain-computer interface-based attention-training gaming system has been developed especially for the treatment of children with ADHD who exhibit severe symptoms of inattention [6]. Through the use of attention training games, which are shown in Figure 2, where feedback is used to reflect measured attention levels, children are asked to manage their brain activity [6]. Maintaining player interest and maximizing the transferability of real situations through the use of virtual situations are values incorporated into the system [6]. After receiving BCI training, children with ADHD demonstrated a noteworthy improvement in parent-rated symptoms of excessive impulsivity and inattention on the ADHD Rating Scale (ADHD-RS), suggesting that this procedure may be used as a novel treatment strategy [6]. It is believed that the brain‘s capacity for change and adaptation, or brain plasticity, and the effective regulation of brain activity are the therapeutic benefits of this neurofeedback-based training for children with ADHD [6].

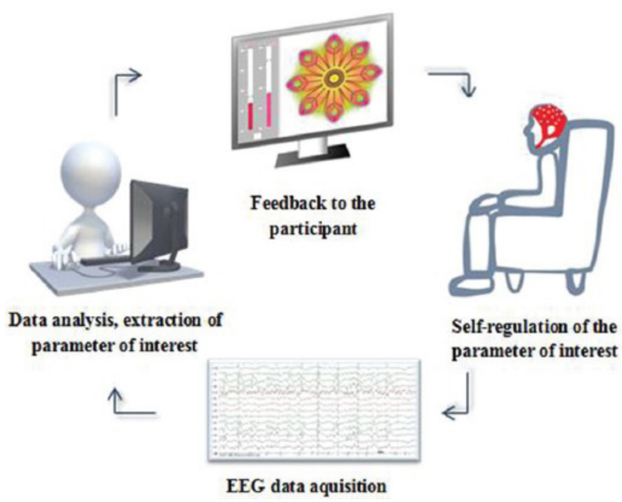

Fig. 2 A diagram presenting the neurofeedback training loop [6]

2.4 A Feasibility Trial

2.4.1 Research background

For kids with ASD and ADHD, a brain-computer interface-based attention and social cognition training program was described in this study‘s research methodology [7]. The program monitors users‘ brain activity and attention levels using EEG signals and eye-tracking technologies users are required to complete training exercises and demonstrate their social cognition skills to evaluate the viability and effectiveness of the entire process [7].

2.4.2 Method

The method illustrated that kids were randomized to either the waitlist-control group or the intervention group [7]. The intervention took the form of eight weeks of BCI-based training conducted three times a week [7]. Four weeks later, both groups were re-examined. A series of attention- and gaze-modulated activities made up the BCI-based program, which was designed to train social cognitive abilities [7].

2.4.3 Results and effects

The results have shown that every participant finished at least 20 training sessions, and none of them left the research early [7]. It also indicated that the BCI-based program was tolerable for most participants, with no severe adverse effects reported [7]. Mild headaches, exhaustion, irritation, and self-harming behaviors were among the side effects [7]. Every one of them was covered in one session [7]. Therapists' feedback revealed that participants' motivation and interest may be maintained with suitable backs [7].

2.4.4 The difference between the BCI training program and neurofeedback therapy

Neurofeedback treatment and brain-computer interface (BCI) based training programs differ primarily in how the participant receives feedback [7]. EEG data are recorded, processed, and then sent back to the patient in real-time as perceptible stimuli in neurofeedback therapy [7]. The individual gains the ability to control their brain activity thanks to this input[7]. However, BCI-based training programs, like the one described in the article, measure the user's attention level using EEG patterns and let them use that focus to control several training games [7]. Both BCI-based training programs and neurofeedback therapy have demonstrated promise in terms of their ability to enhance attention and social cognition [7]. Numerous studies on neurofeedback therapy have demonstrated its effectiveness in treating symptoms of ADHD and enhancing attention contro l[7]. Research has also shown that children with ASD who get neurofeedback therapy exhibit gains in their socio-communication and executive function [7]. Conversely, prior research has demonstrated that BCI-based training regimens can restructure brain functional networks and lessen symptoms of ADHD [7]. It is crucial to remember that the efficacy of both strategies has varied in various studies, and additional study is required to completely comprehend their advantages and disadvantages [7].

2.5 Multi-channel EEG-based BCI

2.5.1 Difference between single-channel and multi-channel

While multi-channel EEG records electrical activity from several electrodes positioned at various points on the scalp, single-channel EEG simply records electrical activity from a single scalp electrode [8]. Single-channel EEG is frequently used for basic measurements and offers a restricted view of brain activity [8]. On the other hand, by concurrently recording signals from several brain regions, multi-channel EEG enables a more in-depth study of brain activity [8]. In addition to facilitating the identification of certain brain patterns and activities, it offers spatial information [8].

2.5.2 Whole method

The creation of an EEG-based BCI with many channels for continuous attention training [8]. Specific EEG areas involved in the cognitive activities transform into commands for commanding a serious game based on brain activity related to the user's attention level [8]. Unsupervised feature extraction is carried out using Riemannian geometry, and a novel method for choosing feature vectors that are more closely associated with the state of attention is put forth to improve class discrimination [8]. Furthermore, a control scheme based on cubic regression and classification is suggested to convert attention levels into game commands [8].

2.5.3 Brain tracking during game instruction modifies attention levels

By utilizing particular EEG regions that are relevant to cognitive tasks [8]. To pick feature vectors that are strongly associated with the attention state, probability analysis is done after the Riemannian geometry approach of unsupervised feature extraction is applied [8]. This enables the user's attention level to be translated by the BCI into orders for managing a serious game [8]. Furthermore, a control mechanism is put out to further convert attention levels into game commands using classification and regression techniques [8]. This approach enables adaptable BCI programming to accommodate individuals with varying degrees of attention deficiency [8]. It also takes into account modulation, a biomarker associated with attention activity [8]. All in all, this multi-channel EEG-based BCI improves attention training by efficiently tracking the user's state of attention and translating it into commands for the gaming controller [8].

2.5.4 Core innovations

Firstly, a model that translates brain signals into game commands via regression is proposed; this model would enable users to manipulate EEG areas of interest [8]. Those who performed well in controlling the game showed reduced activity in the frontal, temporal, parietal, and occipital lobes as a result of this technique [8]. This research highlights how crucial it is to create BCIs that offer visual feedback that is highly associated with attention level and brain activity [8]. Secondly, the suggestion of a programmable control scheme for a multi-channel BCI that offers visual feedback modulated over particular brain regions and connected with the attention state [8]. This approach views the modulation as a biomarker associated with attention activity and blends regression and classification techniques [8]. It makes it possible to program the BCI flexibly to accommodate people with varying degrees of attention deficit disorder [8]. Thirdly, the proof that theta and beta modulation across the attention neural network cannot be produced efficiently by simply using Riemann-type visual feedback on classifier outputs [8]. This was noted in people who, albeit obtaining excellent accuracy during BCI calibration, adopted the control method coded with lesser complexity [8]. Moreover, the suggestion is to choose feature vectors that more accurately represent each class in the BCI by employing probability analysis and Riemannian geometry for feature extraction [8]. This method classified both stages of attention and non-attention with an accuracy that was either higher than or on par with the state-of-the-art [8]. To improve the regulation/modulation of rhythms in certain brain regions and increase the efficacy of attention training programs, these developments aid in the creation of multi-channel EEG-based BCIs for sustained attention training [8].

2.6 fNIRS and EEG Combinations Treatment in ADHD

2.6.1 . Methods and indicators used to diagnose ADHD

Theta to beta power ratio decreased alpha and beta activity, and increased frontal theta and delta activity are only a few of the traits that the EEG evaluates in ADHD youngsters when compared to controls [9]. The complexity of EEG in ADHD has also been measured using complexity analysis, which includes entropy, fractal dimension, Lempel-Ziv complexity (LZC), Lyapunov exponent, and Hurst component [9]. The latency and amplitude of the P3 component of event-related potentials (ERPs), more especially auditory evoked potentials (AEPs), have been used to assess cognitive function abnormalities in children with ADHD [8]. The fNIRS assesses hemodynamic alterations in the prefrontal brain of ADHD patients, specifically in oxy-Hb. It has been demonstrated that the use of fNIRS in conjunction with EEG is complementary and may improve ADHD diagnosis [9]. Based on the data gathered from EEG and EEG-fNIRS systems, machine learning approaches including Support Vector Machines, Naive Bayes, and Multilayer Perception Neural Networks have been utilized to identify ADHD and control groups [9].

For the EEG and EEG-fNIRS systems, respectively, Naive Bayes offered the highest classification accuracy, with accuracy rates of 79.54% and 93.18% [9].

2.6.2 . Highlights and purpose

Both accuracy and objectivity are compromised by the use of traditional diagnostic techniques for ADHD, such as behavioral tests and self-report questionnaires [9]. That is why the purpose of this study is to investigate if integrating electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS) measurements could improve the accuracy of diagnosing ADHD using a multimodal approach [9]. Since the prefrontal cortex (PFC) is linked to attention and cognitive tasks, using fNIRS and EEG to measure both hemodynamic and electrical brain activity can lead to a more thorough understanding of the neural correlates of ADHD [9]. Previous research has shown that PFC dysfunction occurs in individuals with ADHD, underscoring the significance of assigning tasks that are appropriate for children with ADHD who may struggle to focus for extended periods on cognitive tasks [9]

2.7 Social Robots and BCI Video Games for ADHD Treatment

2.7.1 . Evaluation techniques and standards

A variety of techniques and measures have been used to assess social robots and BCI video games [10]. Usability testing, user satisfaction surveys, behavioral and cognitive tests, and clinical trials are some of the approaches used for evaluation [10]. Metrics including attention span, memory, learning capacity, communication abilities, and social interaction are utilized to assess these devices [10]. The research also discussed the degree of acceptability of technology and its possible advantages for those with ADHD [10]. In the assessment of social robots, participants with varying degrees of ADHD were tested, and in the assessment of BCI video games, participants with and without ADHD were tested [10].

2.7.2 . Influences, benefits, and challenges

It has been determined that social robots and BCI video games could be useful resources for youngsters with ADHD [10]. To optimize the benefits of cognitive training and increase children‘s intrinsic drive, these technologies are built with entertaining elements [10]. Automating components of supervision, coaching, incentive, and companionship in encounters with children diagnosed with ADHD has been done through the use of social robots [10]. Contrarily, BCI video games use a brain-computer interface and neurofeedback method to help kids stay motivated and focused on the work at hand while directing them toward predetermined objectives [10]. Nonetheless, there are still unresolved issues with the application of

BCI video games and social robots for ADHD kids [10]. Increasing the usefulness and impact of these technologies, resolving research constraints, and creating efficient computing systems are some of these issues [10]. Another method for treating ADHD is to use non-pharmacological therapies like social robots and BCI video games [10]. For kids with ADHD, these technologies offer a more appealing and interesting treatment environment that may lessen the need for prescription drugs [10].

3. Discussion

Overall, the using of social robots and brain-computer video grames revealed that the capacity to identify ADHD in individuals and the potential to promote non-pharmacological treatments for those with the disorder [11]. Secondly is the quick acceptance of technology refering to better engagemnt during therapy sessions [10]. According to studies, patients with ADHD are more likely to adopt brain-computer interface video games and social robot interactions than they are standard treatments [10]. Thirdly is the improvement of cognitive functions [10, 11]. Training with social robots and brain-computer interface video games has been shown in some studies to significantly improve children with ADHD‘s cognitive function [10, 11].

The standout aspect of feasibility trial treatment is personalization [10]. To give each patient the best possible treatment experience, social robots and brain-computer interface video games can be adjusted and customized based on their unique characteristics [10]. Patients may be better able to adjust to the course of treatment with this personalization option [10].

BCI systems may be appropriate for some ADHD patients, as there are restrictions and difficulties related to the disorder as well. Individual differences and the fact that not all ADHD sufferers are a good fit for these techniques are some of the drawbacks and difficulties associated with treating ADHD with social robots and BCI video games [10]. According to some studies, a tiny proportion of kids who use these new technologies report having bad experiences or feeling a little frustrated [10]. Because of this, creating adaptable systems that can be tailored to each person's unique characteristics in order to deliver the best possible treatment experience presents a number of significant challenges for developers [10].The following categories typically comprise the remaining difficulties and restrictions: First, its limited use in clinical treatment is due to issues like low BCi signal strength, low data transmission rate, and high error rate [11]. Second, the cognitive load, training duration, attention span, and emotional state at the time of the EEG recording are all strongly correlated with the BCI system‘s performance [11]. Last but not lest which demonstrates that high speed and greater accuracy in signal processing and conversion algorithms are necessary for the design and operation of BCI systems [11].

Personally, authors think the following ideas should be proposed: Readers can gain a better understanding of the features and applicability of various treatment techniques by delving deeper into the benefits and drawbacks of various treatment procedures as well as the research effects of their intervention therapy [11]; Additionally, to help candidates better understand the potential of robots in the treatment process, emphasis can be placed on elucidating the applicability of various robot types and their interaction effects in the study report [11].

4. Conclusion

This study discovered that by utilizing brain-computer interface technology to enhance children‘s attention and social cognitive skills, several BCI strategies have noticeable advantages in the treatment of ADHD. The brain-computer interface has played a significant role in the creation and advancement of these technologies, either alone or in conjunction with other high-tech outputs. Simultaneously, it demonstrates the potential and room for improvement of BCI in various intervention therapy procedures. Lastly, there are still issues and negative effects of using BCI when treating ADHD. After receiving BCI treatment for ADHD, minor headaches, exhaustion, irritation, and self-harming behaviors are likely to happen, as this study indicates. Research substantiates the efficacy of Neurofeedback Training in ADHD management, highlighting notable enhancements in concentration, impulse control, and a decrease in hyperactivity. The non-pharmacological nature of this intervention also positions it as a favorable alternative for individuals seeking personalized and adaptive treatment options, leveraging the brain‘s natural plasticity and self-regulatory capacities. The above-mentioned associated variables‘ operation and research can be improved in the future to provide a thorough examination of the entire.

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