

# The Influence of Non-Invasive Brain-Computer Interfaces on Drug Abuse and Sobriety

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**Abstract.** Substance abuse disorders are one of the most prominent and propagating disorders to tackle in the modern world, especially as accessibility, potency, and stigma have recently peaked. Such disorders frequently are some of the most complicated and intricate to diagnose and treat. It is also the case that substance abuse disorders are widely misunderstood in pop culture, which extends into the medical world. Non-invasive brain-computer interfaces (BCIs) such as an electroencephalography (EEG) based treatment could yield noteworthy results due to their flexibility in all aspects. This paper reflects upon EEG based treatments and detection methods and reviews articles that provide critical data and results that show the promise of these technologies. The question is whether BCI-based techniques are worth pursuing – whether extensive research in these fields is necessary to halt the societal progression of disorders such as substance abuse disorders. The disposition of results indisputably represents the start of a major intersection between neurotechnology and clinical medicine, as tests in detection as well as in treatment show an increase in efficiency and effectiveness with BCI-based additions.

**Keywords:** Substance abuse disorder, addiction treatment, drug abuse, electroencephalography, remediation therapy

## 1. Introduction

The recent development of brain-computer interfaces (BCIs) in the last couple of decades is a necessary catalyst for the development of drug abuse prevention. As electroencephalography (EEG) technology has been more widespread in the general market, new research using EEG based BCIs have really shown significant impacts in the treatment of Parkinson's Disease, prosthetics, and various other injuries and disorders [1]. EEG technology is also non-invasive, which greatly improves accessibility problems and allows for a more realistic approach to treating certain disorders. Now, due to the technology's potential and prolific nature, research is being done with it to detect substance abuse disorders at an extremely early time and improve sobriety rates.

Substance use disorders have wide arrays of implications that could be detrimental to an individual and their physical and mental wellbeing. These disorders prove to be one of the most challenging disorders to diagnose and treat, where upwards of 80% of individuals who seek treatment fail to complete it [2]. Heightened drug consumption has been found to physically alter the shape of cortices and neural pathways, causing the user to become more addicted, causing a circular loop. These addictions can cause cognitive deficits and eventually lead to irreversible brain damage [3]. Usually when the abuse disorder is caught, it is unfortunately extremely late, and treatments would be playing a game of catch up to repair the damages done. Additionally, many substance abuse disorders have irresolute treatment plans, as well as dangerous medications that could contribute multiple side effects to the user. Such medications are also inaccessible, with rigid treatment schedules [4]. However, with new methods of early detection using BCI, such rigid treatment plans could be avoided in suspected patients early on. Furthermore, after diagnosis, other BCI techniques can impact sobriety rates, as BCIs can help restore a baseline for cognition in patients, which directly influences their agency [5].

This paper aims to review how neurological models of addiction can be synthesized with brain computer interfaces, how the detection of substance abuse disorders can be improved by brain computer interfaces, and how treatment from brain computer interfaces can greatly improve the quality of life of a patient.

## 2. Methods

This paper aims to scrape many existing studies and accumulated data on the usage of non-invasive BCIs on several aspects of drug addiction. The methods section will be separated into studies on substance abuse prevention by BCIs, and studies on therapies and relief by BCIs. The accumulated data on this subject matter as a whole is rather scarce due to its developing nature, but extremely promising.

Non-invasive BCIs can greatly decrease the fatality of substance abuse disorders as they can detect the disorder early, which may potentially save countless lives. Generally, substance abuse disorders rapidly progress and worsen over time, so the early catching of such is very important. The main goal of one study was to understand whether significant brain abnormalities could be detected with the EEG based system that could allow the efficient diagnosis of substance abuse disorders. If this system were to be proved successful, with the rapid development of the field, it is probable that EEG based BCIs will eventually become mainstream to public use and public health, especially as the efficiency and technology progresses - such technology is extremely helpful for detecting the severity of substance abuse disorders and other disorders alike. In the study, participants in Indonesia that were in rehabilitation facilities (n=10) and healthy participants (n=5) for control were asked to take the opioid methadone. Participants were subsequently tested by EEG for 3 sessions (Before taking the drug, 10 minutes after, and 60 minutes after) [6]. In each session, a random assortment of drug related images were displayed on a computer screen, which thus provided the necessary EEG recorded data from 10 scalp positions and channels Fp1, Fp2, F7, F3, Fz, F4, F8, P3, Pz, and P4 [7].

Non-invasive BCIs can also provide extensive relief for patients with substance abuse disorders. In one study, cognitive remediation therapy (CRT) was used with EEG based BCI monitoring to adjust the treatment to the needs of each patient. CRT is a method used to target specific memory and executive functions of the brain. This treatment method allows patients to perform exercises or tasks that could enhance their memory, impulse control, or self-control abilities, which has large overlaps with the treatment of substance abuse disorders and how strong the patient is at dealing with stress or various obstacles. The main goal of this treatment was to improve the resilience to stress in each individual patient, such that they can participate in daily life in a way that is not hindered by cognitive roadblocks. In this study, an EEG based BCI could analyze the specific brain waves of each patient during their CRT training - optimizing the effectiveness of the treatment by providing personalized guidance [8]. Participants (Treatment: n=200, Non-treatment: n=121) were voluntarily recruited from alcohol or drugs (AOD) treatment centers that were poly-substance abusers performing tasks derived from the Woodcock-Johnson III cognitive tests (WJ-III cognitive battery) on a computer. Within each session, participants performed various exercises that provided data to a BrainMaster 24E system from a 19-channel EEG monitor. The EEG electrodes were placed on the scalp positions and channels FP1, FP2, F3, Fz, F4, F7, F8, C3, C4, Cz, T3, T4, P3, Pz, P4, T6, T8, O1, and O2. Each patient in the treatment group completed 48 sessions before reassessment. With this method, over each session, the BCI evaluation can track each patient's cognitive performance - and subsequently help change the exercises for the next sessions, tailored to individual needs [9].

## 3. Results

In the study from Indonesia, significant results were shown in subsequent brain activity maps and raw graphical EEG data. In the P300 brain activity maps, it is evident that a significant difference is described between patients, with a correlation of the number of brain abnormalities to the degree of drug abuse that the patient described [10]. This is especially important in the context of substance abuse prevention, as it is now clear that EEG based BCI systems can directly fish out the differences between the brain activity of a person with varying degrees of substance abuse, as well as a healthy person. Through brain activity maps, a short scan using an EEG based BCI can efficiently detect the prevalence of drug related problems and abnormalities within the cortices. However, due to the small nature of this study, as well as its limited trial space, one question that arises from this data is whether

it can be generalized to the prevention of short-term substance use, as a couple usages of a substance would likely not commit any major brain abnormalities to the P300 brain mapping EEG scan, especially if substances were not used in a recent manner. One major drawback of this study is its lack of explanation of the topic, and what its usage of the term “brain abnormalities” represents. More data on this subject would impact the field drastically and allow for further analysis.

In the BCI-integrated CRT treatment study, a huge difference between the treatment and non-treatment populations was discovered, with  $p < 0.001$  across all domains of the WJ-III cognitive battery [11]. EEG testing showed that while the non-treatment group had similar results before and after the designated time period, the treatment group showed significant increases in scoring in all WJ-III tests, for example, thinking efficiency, verbal comprehension, and spatial relations. It is probable that the mastery of these fields significantly improved cognitive control and stress management over the course of the 48 sessions each patient participated in. One can make the conclusion that this increase in scoring has no effect on sobriety and is only indicative of practice with the CRT based treatment plan and exercises. However, after an 18 month follow up, it was shown that around 89% of the treatment group had abstained from any substance usage, but only 31% of the non-treatment group had maintained sobriety, consistent with the national average [12].

#### 4. Discussion

Substance abuse disorders are very common in our society today, and it is important to address the issue. However, it is important to address the ethical and social implications of the treatment of these disorders. Historically, substance abuse disorders usually attract various stigmas associated with the disorders that are harmful towards the treatment process. In the treatment of substance abuse disorders, it is important to consider the individual's right to autonomy and their volition, and to consider the fear of self-disclosure. When approaching and discussing the prevention of substance related disorders and abuse, it is critical to understand these topics. This fact - however means that there are likely far more cases of substance abuse disorders than we have any account of. As this BCI technology increases in efficacy and accessibility, and gradually makes its way into the medical world, necessary precautions must be taken to ensure the sustainability of the generated programs - including considering the voice of the patients, as well as their circumstances. While it is impossible to control all aspects of substance abuse disorders, it is imperative to improve the treatment options available for patients, as current treatment options such as opioid agonist treatment (OAT) lack convenience and accessibility, and additionally are systemically challenged and stigmatized in society [13]. These large improvements in the treatment of substance abuse disorders would be extremely beneficial towards the quality of life of the patient. In substance abuse disorders, impaired social, functional, and occupational practices may be shown. Furthermore, multiple personal variables are evident, such as mental and psychological statuses affected by such disorders. There are a wide variety of symptoms associated with substance abuse disorders and an even wider catalog of the affected areas of life. Substance abuse disorders may take away from the quality of life substantially [14]. This is one of the major reasons why treating substance abuse disorders with compassion and responsibility is one of the most important medical practices in our society today.

The early detection of substance abuse disorders is necessarily to prevent worsening of the symptoms. The progression of substance abuse disorders is rapid and difficult to halt at a late stage. One study took a population of adolescents from an American middle school and determined that a substantial basis of substance use can lead to serious developmental complications and dependence down the line [15]. From national survey results, 15.7% of 8th graders have tried marijuana. These early use individuals are significantly predisposed to later dependency on such substances [16]. It is clear that early prevention programs to identify early users are essential to disrupt a major population of persons that have substance abuse disorders [17].

Patients undergoing traditional rehabilitation methods are frequently met with obstacles that are not addressed to the capacity that they are required to be. Obstacles include neurophysiological

problems that could affect their cognitive abilities such as control and dealing with stress [18]. Patients with long addictions may exhibit certain losses of function or metabolism in various cortices of the brain, and increased activity in others. One prime example of this is in patients dealing with stimulant withdrawals - drugs such as methamphetamine and cocaine. These patients show a decrease in functioning of the left anterior cingulate gyrus and the right dorsolateral prefrontal cortex, which is generally thought to modulate behavior control [19]. This executive processing is crucial in the context of addiction patients, and decreased functioning in the area may cause a more strenuous and mentally taxing recovery period. In fact, these EEG based monitoring systems using a task-based approach in the context of honing and improving various cognitive functions have already been extensively researched, but not in the context of substance abuse disorders. One study shows that the working memory load could be manipulated by various tasks that target specific regions of the brain. In this study, the anterior cingulate gyrus is suggested to be crucial to the working memory load, as well as complex cognitive functioning [20]. This region of the brain is in direct correlation with substance abuse disorders as mentioned previously. This study shows further evidence of specific cortical activation based on computer-based task related programs. Specific cortical activation such as anterior cingulate gyrus activation can strengthen pathways and promote synaptic plasticity in those areas.

## 5. Conclusions

The accumulated data and research of this paper is one of the first to connect the potential of the BCI to various aspects of one disorder such as detection methods and treatment methods and connect them in a way that generalizes the usage of BCI to a wide field of possibility. The implications of this research are extensive when discussing multi-faceted disorders such as substance abuse disorders. BCIs are widely regarded to be one of the most promising research areas because of the capability to detect disorders in a patient as well as the ability to modulate the recovery and treatment process. Non-invasive BCIs such as EEG related BCIs allow for effective treatment without the consideration of harmful and dangerous side effects via invasive means. The integration of EEG based BCIs allows patients to obtain an individual based assessment and treatment, which can be far more effective than traditional means, as results exemplify. It is evident that this data and results are a hallmark of substance abuse treatment and support, and it can even be further studied in other disorders to show a generalized significance and clinical advantage. The research would not only provide long-lasting relief for countless patients suffering from substance abuse disorders but could extend to any neuropsychiatric disorders with specific impairments in the brain.

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