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New Methodology of Brain Computer Interface for Rehabilitation of Obsessive-Compulsive Disorder

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Abstract: This article reviews past papers about obsessive-compulsive disorder (OCD), brain-computer interface (BCI) and experimental design guidelines, then proposes a new methodology for implementing BCI as a treatment for BCI patients and predicts possible results for this method. OCD is a neuropsychiatric disorder that leads patients to perform certain compulsions that relieve their feeling of impending doom. Other symptoms include intrusive thoughts and doubts. A new methodology was proposed in this paper because the most common treatment is currently limited to medication and cognitive behavioral therapy. It is predicted that, with the methodology proposed in this paper, OCD patients will be able to have reduced symptoms and develop an increase in awareness of performing specific actions to alleviate symptoms. There are some limitations to this new methodology, as the experiment was not performed, and thus there were no actual results to back up the proposal. This method proposal is only a theoretical approach, and more research must be done before implementing BCI as a treatment for OCD.

Keywords: neuroscience, Brain-computer interface, OCD, method proposal

1. Introduction

Obsessive-Compulsive Disorder (OCD) is a prevalent neuropsychiatric disorder that affects 2-3% of people around the globe [1]. Patients feel a sense of doom if they do not perform specific actions, and extreme anxiety may occur if the actions are not performed. Moreover, patients also experience intrusive thoughts, high thoroughness, and uncertainties that lead to confirmation-seeking actions. There is not enough access to diagnosis and treatment of this mental illness [2]. Currently, treatments for OCD include SSRIs and clomipramine which help reduce obsessions and compulsions. However, SSRIs can bring forth adverse effects, and clinical challenges to treatment-resistant patients remain [3]. This paper explores the possibility of using brain-computer interface (BCI) to treat OCD patients by training their thinking patterns and performing certain activities to rehabilitate symptoms. Brain-computer interface is a technology that allows interaction with the brain through collecting brain signals from EEG, analyzing the patterns of the brain waves, and relaying commands to an output device that performs a specific task. In the past, BCIs have been used to restore lost motor functions in patients with motor disorders. More recently, BCIs have been used for rehabilitating emotional mechanisms in patients with neuropsychiatric disorders [4].

Moreover, BCI-based implementations have successfully reduced ADHD symptoms [5]. Since there is little research focusing on BCI's application to OCD patients, and OCD treatment is limited

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to medications, this paper proposes a new possibility of BCI-based treatment for OCD. This paper examines previous literature on practical guidelines of BCI and then proposes a new methodology focused on rehabilitating OCD patients.

2. Literature Review

2.1. Definition of Obsessive-Compulsive Disorder (OCD)

Obsessive-Compulsive Disorder can be diagnosed if obsessions cause primary fear or anxiety about an object or situation, such as the fear of blood as a result of recurring thoughts of pathogen contamination like HIV or a fear of driving as a result of excessive images of hurting others), and if additional criteria for this disorder are confirmed [6]. OCD can be further defined as having two components. Obsession can be defined with four criteria. The first criterion is repetitive ideas, emotions, or images that lead to anxiety, the second is that the repetitive thoughts are not just heightened concern with real-life issues. The third is a person's efforts to suppress or counteract such ideas through other ideas or actions. The fourth is the individual's awareness that obsessive ideas result from their mind. Compulsions can be defined with two criteria. The first are repeated activities like hand-washing, ordering, and checking or cognitive behaviors such as repeating words and praying that a person feels compelled to execute in response to an obsession or following tight rules. The second category includes activities intended to prevent or lower suffering or avoid a feared occurrence or scenario. But these actions or mental activities are either not realistically related to what they intend to counteract or avoid or are obviously excessive [7].

OCD usually starts during adolescence or childhood before the age of 25. The average age of onset appears to be earlier in men and women, according to several studies. From a general literature review paper of 63 studies, males showed a higher possibility of early onset of OCD [8]. Gender is a crucial component when considering the prevalence of OCD.

2.2. Definition of Brain-Computer Interface (BCI)

Brain-Computer Interface collects neural signals, interprets them, and formulates them into commands sent to devices like computers to carry out specific tasks. There are both invasive and non-invasive BCIs. Invasive BCI involves the implantation of electrodes within the skull. Such forms of BCI produce high-quality recordings of neural signals and have a potential for improvement. However, the invasive procedure also carries health risks. In comparison, non-invasive BCI draws neural signals from the surface of an individual's head. The signals have limited bandwidth but help disabled people to interact with the outside world [9].

The purpose of BCI is to support patients with disabilities by restoring certain bodily functions. Initially, with the use of electroencephalography (EEG), researchers have used several instruments to record brain signals, such as intracortical and electrocorticographic ones. Some examples of output devices include cursors, prostheses, and robotic arms [10]. This paper explores the possibility of applying BCI to rehabilitate OCD patients.

2.3. Relationship

2.3.1. Previous Research Method Guidelines

A study explores experimental methods of Mental-Tasks based Brain-Computer Interface (MT-BCI), in which a user interacts with an output device based on neural signals produced during mental tasks. The study highlighted four essential components of an MT-BCI training procedure: environment, instructions, feedback, and training tasks. Environmental factors such as the comfort

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of different senses play a significant role in the variation of specific individual performances. Researchers noted that the aesthetics in technology improves training. It is also essential to prevent stimuli irrelevant to the task, such as background music, which could negatively affect training and the results. The user experience and interaction of BCIs are also crucial in training [11].

The same study discussed the recommendations of instruction designs in a BCI experiment. Instructions on normal mental activities can improve training since asking the user to perform an unfamiliar task is difficult. A goal-directed approach is also recommended. Providing examples and general instructions on technological stereotypes to reduce misconceptions. Moreover, researchers discussed the importance of screening before giving instructions since it is crucial to design the experimental approach according to the patient's specific characteristics. There are some challenges regarding general instructions, as it is unclear for the design of the models for good instructions [11].

Feedback is another essential element of BCI experimental design, it offers information regarding users' performance and understanding of the tasks. Supportive feedback, which increases user interaction, positively affects the user experience. Moreover, multimodal feedback (feedback with two or more sensory types of feedback) is more effective for more complex motor tasks. Timing also needs to be considered, as the amount of feedback needs to be determined following the participant's rate of brain activity recording. Overall, it is recommended that feedback should be informative, interactive (supports the user), provided with several sensory modalities, and timed [11].

Lastly, guidelines for designing training tasks in a BCI experiment are also provided. Tasks have three main stages: screening, training, and application. The screening part helps in determining if the participant can control a BCI and the best type of BCI for the participant. Moreover, to familiarize the participants with using a given BCI. The training part is often the central part of training tasks. The participant is further trained to control the BCI and perform the tasks. After the participant obtains control over the BCI, an application for it can be further trained, such as manipulating a prosthetic arm.

All in all, the paper offers several guidelines for training tasks. It recommends conducting screening before training to optimize the tasks used. Moreover, it strongly recommends exercises without BCI that have the potential for enhanced attention, such as mindfulness. A game-based BCI training can help participants' motivation and interaction. A training method with gradually increasing difficulty can also benefit training [11].

2.3.2. Summary

Several factors must be closely monitored in a mental task-based BCI experiment design from the study examined. The paper discusses the importance of the environment, in which the researcher should ensure the comfort of the experiment environment. Stimuli, such as music or images irrelevant to the experiment, should be excluded to prevent the unreliability of results. The visual appeal and level of user interaction with the technology should also be considered because they can positively influence user experience. This paper's experiment will ensure the environment is well-maintained and without excess stimuli [11].

The study also mentions instructions in an experiment, mainly discussing the benefits of goal-directed instructions and using examples to aid understanding. From the recommendations given in the study, the experiment will provide patients with instructions that are goal-oriented, easy to understand, and interactive. Before giving the instructions, the researcher will screen the OCD patient to gather the information that may modify the instructions [11].

The experimental method will also consider the feedback component the second study mentioned. Positive and supportive feedback will be provided to the patients to enhance their BCI experience. Feedback will also be tailored to utilise multiple sensory modes, such as the

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combination of auditory and visual feedback. Lastly, the feedback given will be timed according to the rate of brain activity collected from the patient [11].

The set-up of training tasks in a BCI experiment is crucial. From the paper's recommendations analyzed, there are several takeaways for BCI training design [11]. Conducting an initial screening before training would be very helpful for determining the type of training and tasks given. Exercises without BCI, such as meditation, can also enhance training. A game-based BCI training program and a training method with progressive difficulty levels are recommended.

2.3.3. Method Proposal

This paper proposes a non-invasive methodology for the BCI-assisted treatment of OCD patients.

2.3.3.1. Participants

The participants in this study would be patients diagnosed with obsessive-compulsive disorder by a doctor or medical professional. As it was proposed that a spectrum exists for OCD patients, in which the symptoms can be grouped into impulse control, body preoccupation, and neurological disorders, and it can be further divided into specific disorders, participants will be screened so that their BCI treatment can be modified to their needs [12].

2.3.3.2. Materials

EEG Brain-Computer Interface, Output device (phone or computer), Screening Test for Participants and a List of strategies and tips to help relieve OCD symptoms.

Several materials would be needed. An EEG-based Brain-Computer Interfaced will be used to detect the brain activity changes in OCD by collecting brain signals [13]. A non-invasive EEG collects brain waves from the scalp surface [14]. An output device such as a phone, an iPad, or a computer would also be needed. After the information from a BCI is relayed to the output device, stimuli will be provided as a reminder, including tips and strategies to help patients with OCD symptoms. A screening test for participants will be conducted to assess the patient's state before and after the treatment. A list of strategies and tips for relieving OCD symptoms must also be prepared. After analysis of results from screening, it needs to be tailored towards helping rehabilitate the specific disorder and symptoms the patient is experiencing.

The environment, instructions, feedback, and training tasks of this experiment need to be carefully manipulated. The environment surrounding the patient needs to be kept free of distractions, such as irrelevant visual and audio stimuli. The instructions given to the patient should be easily understandable and interactive. The instructions should also be positive and encouraging, with a clear goal. The feedback given to the patient should be timed in different intervals so that after performing certain activities, the patients can receive information on how their activities may have benefitted or worsened their mental state. The interface of the output device should also be visually appealing. Training tasks given to patients will consist mainly of non-BCI exercises, while feedback will be BCI based. The training tasks may change due to the effectiveness of the previous task.

2.3.3.3. Procedure

The procedure is a theoretical, experimental model and should be modified if needed (see Figure 1 to Figure 3). (1) Initial Patient Screening. An initial patient screening should be conducted by a medical professional. The patient's specific disorder within the spectrum of OCD should be determined, and their symptoms should be indicated so that further treatment can be tailored towards rehabilitating the specific patient. (2) Provide Instructions to the Patient. Instructions

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specific to the type of BCI and the patient's disorder will be provided to the patient. The instructions should be easy to understand, detailed, and goal-directed. The patients should know the treatment and how the entire method will be carried out. To avoid misconceptions, examples familiar to the patient can be provided in the instructions. Technological stereotypes should also be clarified to reduce confusion. Specific instructions unique to each method towards each participant should also be provided.

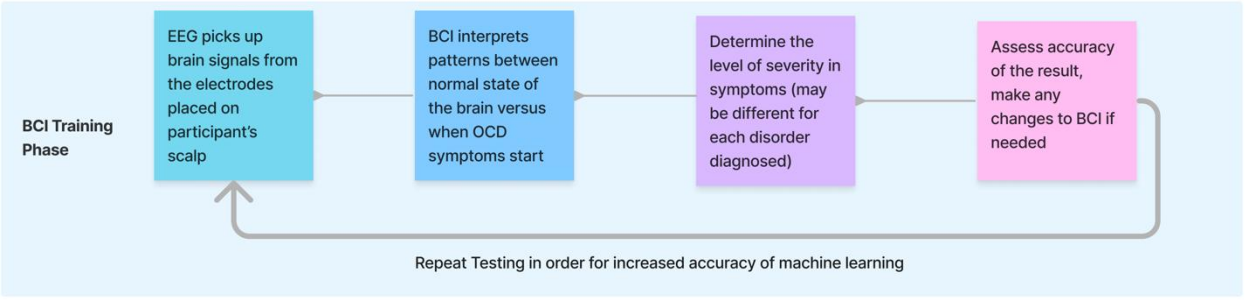

Figure 1: Procedure flowchart of BCI training.

(3). Training BCI Accuracy with Machine Learning. The accuracy of the BCI's identification of OCD needs to be improved after training it with machine learning. EEG first collects the neural signals, and then BCI will compare the brain wave patterns between the patient's normal state versus when OCD symptoms begin. The BCI will then determine the severity of the symptoms (for example level of compulsive wants). At the end of determining the severity, the accuracy of the result will be assessed, and this process will be repeated so that the BCI is trained to be very accurate. This training process will help reduce mistakes in symptom identification and dramatically improve the user experience.

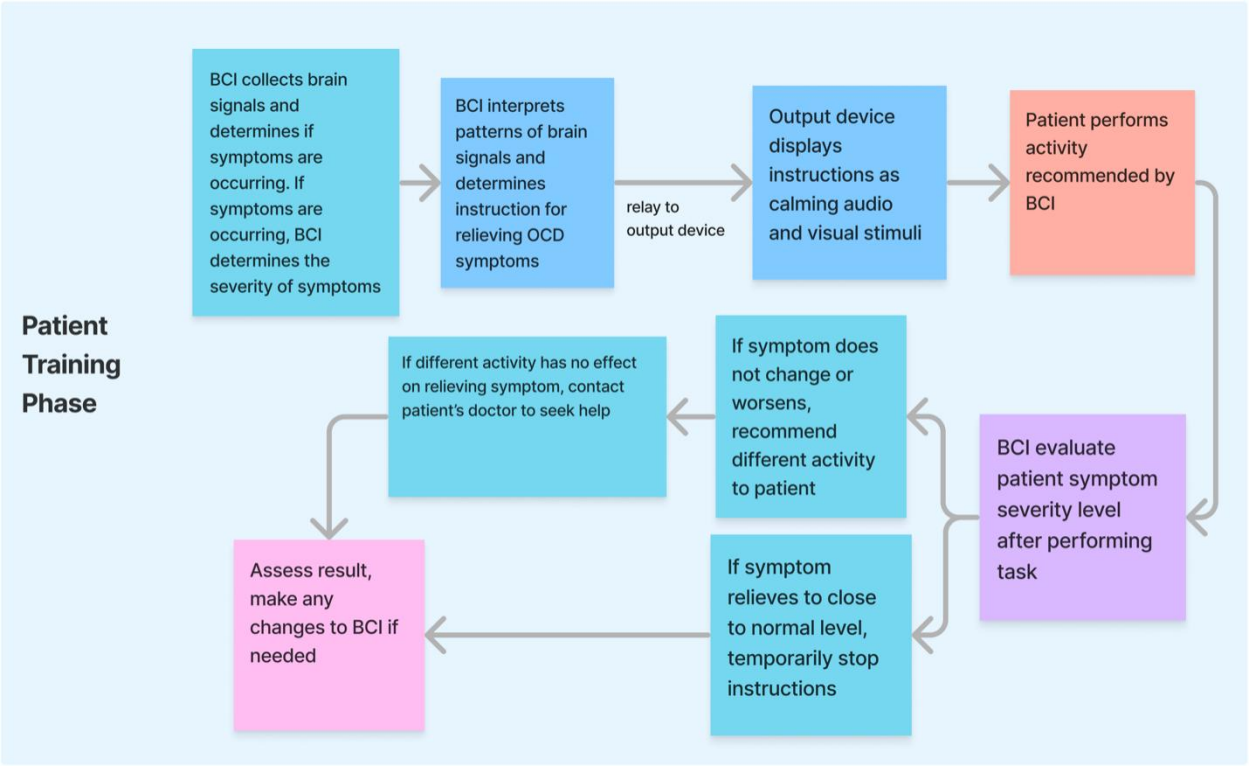

Figure 2: Flowchart of the patient training phase.

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(4) Patient Training. The patient will be trained to use the BCI to obtain further control over the BCI and carry out actions according to the ones recommended by the BCI. As shown in the flowchart above, after the participant performs the task(s) provided by the BCI, the symptoms will be evaluated by the BCI. Suppose the symptoms get worse after the activity. In that case, a different activity will be recommended. If the activity still has no effect in alleviating the symptom, the BCI will stop making recommendations, and the doctor will be notified. On the other hand, if symptoms relieve to a point where the patient is in a normal state, instructions will stop because there is no longer a need for the tips. The final part of the training will be an assessment of the results, and any changes will be made to the BCI if needed to prepare for the final application.

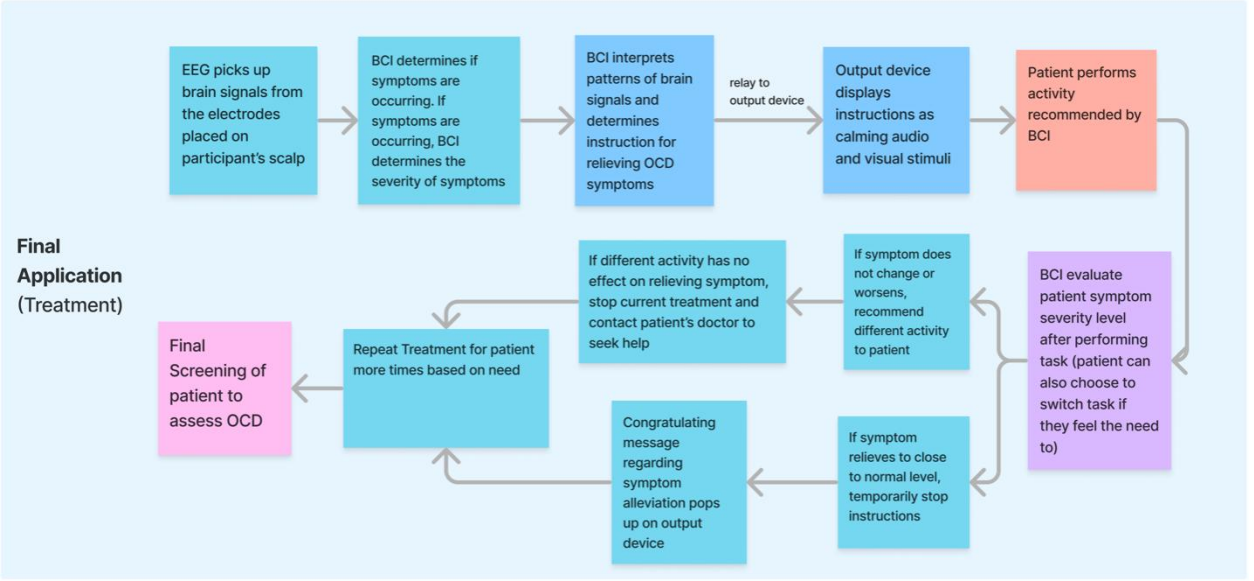

Figure 3: Flowchart of the final application of treatment.

(5) Treatment (application). The final phase of the training is the final application, in which patients use the BCI to alleviate their symptoms. Most of this part of the method is similar to the patient training part, but the final part is added with new elements. A reward, as a congratulatory note for encouragement, will be provided after the symptom is relieved to an average level. Moreover, to show the effectiveness of the treatment, it will be repeated more times based on the patient's state. After that, a final screening will be conducted to assess how their OCD symptoms were affected after the intervention of BCI, which is further explained in the section below.

(6) Patient Screening after BCI treatment. A final patient screening needs to be conducted by a medical professional after the treatment is given. The screening will assess the severity of the patient's OCD. The results of the final screening will be compared to the initial screening. After analysing the results, a conclusion will be reached whether the BCI intervention helped rehabilitate the patient's OCD.

3. Results and Discussion

3.1. Expected Results

For screening patients before BCI treatment, it is expected that the patients will be diagnosed with a particular branch of OCD, and their symptoms may vary in range.

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This paper expects the BCI Treatment, the patient's OCD symptoms will be somewhat relieved after BCI intervention. The BCI's recommendation of activities to perform may help the patients form a habit of performing specific tasks to combat the symptoms of their disorder, such as compulsive thought patterns. Examples of benefits may include a reduction in specific symptoms, a decreased interference of OCD with daily life, or a more positive thought pattern. According to a study which implemented gamified BCI to treat ADHD symptoms, an 8-week treatment program substantially improved patients' inattentive symptoms and hyperactive-impulsive symptoms. The patients with more severe acute symptoms also showed more positive development [5]. Though not much-supporting literature surrounds this approach, this paper predicts a similar improvement in symptoms after treatment. However, this methodology may lead to a reliance on BCI, as it provides tips whenever symptoms occur. It is essential for patients to independently identify their possible thought patterns and perform mental tasks when necessary.

3.2. Discussion

The method that this paper proposes has several possible contributions and limitations to the field of BCI-assisted support for mental disorders. This paper explores the use of BCI in disorders not commonly treated by BCI. Providing a possible approach to BCI-assisted rehabilitation is essential for future experimental applications on this new topic. Researchers can build on this method and improve it for future treatment. OCD patients may also benefit from ongoing research, as this treatment is a novel approach that can potentially alleviate symptoms. There are also various limitations to this paper. First, the author does not have a medical background, and the experimental approach may not be entirely according to a formal medical procedure.

Moreover, the methodology proposed is from a general framework for BCI training but is not backed up by too much previous research. Moreover, BCI might cause dependence in patients and lead to a lack of a sense of independent control. Another issue is that the tips provided may not be able to influence patients' thought patterns when their compulsive thought patterns become too overbearing.

4. Conclusion

This paper has explored past papers on the experimental design of BCI training and proposed a new methodology for treating disorders under the branch of OCD spectrum disorders. The paper reviewed in the previous research methods section emphasized and recommended guidelines for four components in a BCI experimental design: environment, instructions, feedback, and training tasks. This paper proposes a methodology emphasising such components based on the study included. Though there is not much-supporting evidence of BCI's success in related mental disorders, this paper predicts that after BCI treatment, patients will be able to develop a positive thinking pattern, and symptoms of their disorder will be relieved. Overall, this paper provides a new methodology for the novel field of implementing BCI as a treatment of OCD spectrum disorders. The methodology proposed may be able to support further research in the field of implementing BCI to treat non-motor disorders and help rehabilitate OCD patients.

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