Exploring Two Alternative BCIs for Improving Alzheimer's Disease Rehabilitation

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Abstract

Neurodegenerative diseases affect the nervous system of the body, ultimately disturbing movement and or mental function where Alzheimer's disease (AD) is the most common form [1]. Brain-computer interface (BCI) is a technology that allows for an alternative method to previous rehabilitation treatments that help improve human cognitive or sensory-motor functions [2]. Due to the crippling and progressive effects of AD, it gives way for the unique utilization of BCI technology to be used for rehabilitation. A standard BCI utilizes electroencephalography (EEG) stimuli to monitor brain activity to obtain relevant information [2]. These traditional BCIs, rely heavily on instrumental learning, and the users themselves, to assist and control their brain activation [3]. The purpose of this paper is to explore alternative BCIs, such as motor-imagery and emotion-based, to explain if these two alternative BCIs can help in improving AD rehabilitation.

Introduction

Neurodegenerative Diseases and Alzheimer's Disease

Neurodegenerative diseases are an umbrella term used for diseases that affect the nervous system of the body, ultimately disturbing movement and or mental function [1]. Of these neurodegenerative diseases, AD has been classified as the most common [1].

AD is a progressive disease that gradually worsens dementia symptoms until eventual death [4]. The greatest risk factor associated with this disease is age and is the sixth leading cause of death in the United States [4]. While there is no cure, AD treatments can help slow the progressive disease down and aid in improving quality of life [4]. Actively today, there is a worldwide effort to spread awareness and support for people affected by the disease in the hope to find better ways to treat, delay onset, and prevent its development [4].

Cognitive Rehabilitation Methods for Alzheimer's Disease

The earlier you start rehabilitation treatments for AD the greater effect of slowing the progressive nature of the disease [5]. In the paper by Choi et al., they review popularized methods of rehabilitation. The three methods they introduce all involve improving the cognitive state of the patient.

The first method is cognitive stimulation to engage the patient in discussions about common everyday tasks to stimulate mental activity [5]. The method is used by generating repetitive information for the patients, reminding them of themes such as childhood and food [5]. This repetitive nature is used to create a continuity between different forms of information. This method is usually geared towards patients who are more impaired with AD [5]. Choi et al. reviewed a study that used this method and explained that those with moderate AD showed better cognitive abilities and rated quality of life more positively than compared to the other treatments they had received [5].

The second method is cognitive training which is geared toward patients who have enough decent cognitive ability so they can exercise specific cognitive functions to improve upon intact cognitive skills to slow progression [5]. The premise is based on neuroplasticity, the brain's ability to form and reorganize synaptic connections, which has shown to improve or at least maintain cognitive performance [5]. Choi et al. reviewed a study that used a software package called Neuropsychological Training that aims to focus on brain damage rehabilitation [5]. In the study, people with AD were used to target only preserved or mildly impaired cognitive areas to improve memory in dementia [5] The study showed significant improvement in overall cognition, depression, and working memory [5].

The third method is cognitive rehabilitation is a comprehensive cognitive enhancement program that includes cognitive stimulation, cognitive training, and other approaches [5]. This method offers a model of treatment that aims to stop the decline of the patient's cognitive abilities based on the interaction of the patient and their environment [5]. Choi et al. discuss that this method helps to find, learn, and practice methods of compensating so that every day cognitive demands are reduced [5].

Brain-Computer Interface

While treatments exist, an effort is still underway to find alternative ways to treat and or aid in the rehabilitation of the disease. This is where BCIs can be introduced. The main goal of the traditional BCI is to help people that have been disabled by neuromuscular disorders using EEG

stimuli to allow brain signals to be analyzed, monitored, and translated into commands which can be conveyed to represent desired actions [6]. The BCI works efficiently once the user and the BCI become compatible throughout training [7]. This training in utilizing BCI technology is a skill, and the user needs to be properly trained for control and reliable results [7]. Poor compatibility can lead to unreliable EEG patterns which stem from not correctly performing mental commands for the signal processing algorithm to identify. This training allows for the brain signals to carry encode intention from the user and allow the BCI to output decoded signals which are translated into commands by the user's intention [7].

Additional advancements in the BCI technology field allow for a wider reach of stimuli to be observed. Instead of the traditional modality, different modalities could aid in the rehabilitation of patients with AD [2]. Two alternative methods for improving AD rehabilitation that this paper will investigate are motor-imagery and emotion-based BCIs.

Literature Review

Motor-Imagery BCI

Motor-Imagery is the imagination of motor movements that results in a neural response associated with actual movement [8]. This mental execution of movement without muscle or peripheral activation leads to the same activation of the same brain areas as the respective movement [8]. In *Figure 1* the image helps to visualize the interactions that occur between the various domains of impairments that are stroke induced, and to aid their recovery during post stroke rehab [8].

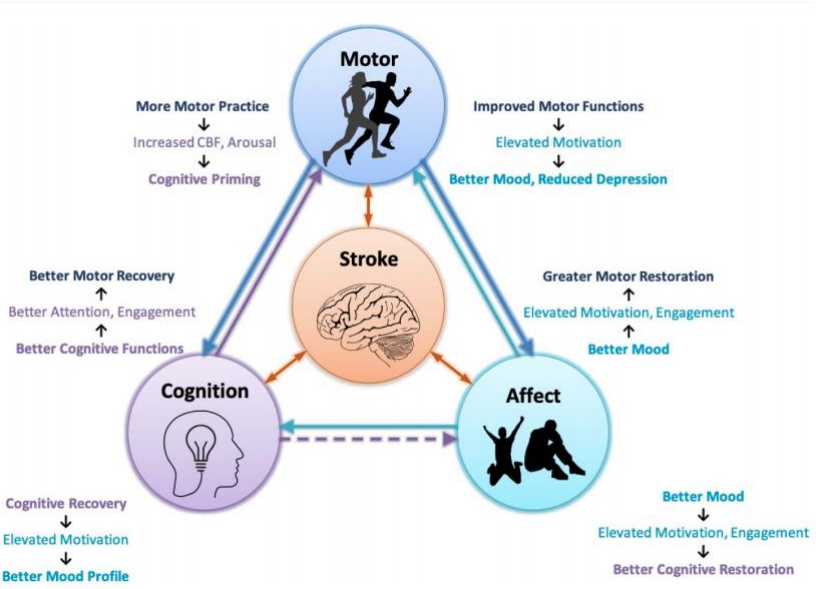

Figure 1. Image showing the connection between Post-stroke motor, cognitive, and affect deficits [8].

Mane et al. discuss an early study with eight chronic stroke patients with severe upper limb paralysis and motor-imagery BCI [8]. The study showed that patients could indeed successfully work with sensory-motor rhythms and control via magnetoencephalography (MEG) based BCI system [8]. MEG essentially provides signals with higher spatiotemporal resolution than EEG. Despite the successful regulation of the system from the patients, the study showed that the patients had no clinical improvement [8].

Mane et al. then discussed another study that showed to find clinical improvement for patients. In this study, eight chronic stroke patients participated in a motor imagery BCI mediated upper limb rehabilitation [8]. The study showed that after 12 rehabilitation sessions over 4 weeks a significant improvement in motor function of 4.9 points was observed on a Fugl–Meyer Assessment scale [8]. This successful detection of motor imagery used real-time EEG signals that used an MIT-manus robot to reward the movement of the impaired hand [8].

Additional to this study, Mane et al. also discussed results from another case study that compared the cause and effect of BCI rehabilitation and clinical improvements [8]. It showed that 60 BCI rehabilitation sessions spread over a period of 8 months yielded clinical improvement results [8]. Overall, with motor-imagery BCIs, there have been multiple controlled trials that indicate clinical gains which are on par with traditional rehabilitation methods like robotics and FES [8].

Connection to Alzheimer's Disease

This section will aim to name the relevant or affected cognitive rehabilitation methods for AD mentioned in the introduction section of this paper via motor-imagery BCIs.

Pro

Using this method of rehabilitation helps to improve cognitive training. Motor-imagery BCIs utilize a neurofeedback closed loop that constantly engages cognitive training. Neurofeedback allows researchers a new look to investigate brain function and neuroplasticity, while also allow patients to learn to control specific neural substrates to affect specific behaviors [9]. The use of the BCI engages cognitive training to directly improve neuronal plasticity which is a core cognitive development needed in AD rehabilitation.

Con

Using this method requires a certain minimum cognitive ability from the patient to comprehend and respond to the instructions that they need to carry out for the rehabilitative procedures. The older a patient is, the less effective this method would be due to the progressive aspect of AD. The older the person is, the more likely they will have lost more of their cognitive ability which would interfere with the operation of the BCI system.

Emotion-Based BCI [3]

Emotion-based BCI is a method that is open to users who do not need to actively perform cognitive tasks [3]. This importance allows for patients who are more severely challenged with their cognitive skills to benefit from this method [3].

Liberati et al. discuss in their paper a study that utilized emotion-based BCI methods [3]. The study set out to allow a patient to differ between affirmative ("yes") and negative ("no") thinking by using positive and negative stimuli respectively [3]. This was to guarantee very basic communication for immediate needs. The researchers needed to find a link between people with and without AD that would be able to help them succeed in achieving this basic communication. They found that affectivity, which is the ability to experience affects, is commonly preserved in AD, alongside non-verbal affective stimuli, such as pictures or sounds [3]. They used a classical conditioning protocol to carry out the study.

Figure 2 is showing the classical conditioning protocol for fMRI BCI associative training [3]. The first block represents 100% paired words that are associated with yes or no questions, followed by a positive or negative sound stimulus (scream or baby laugh) [3]. This is used to condition the patient to have a larger neural response so that the fMRI BCI is easier to communicate through [3]. Other blocks show a decrease in conditioning once the patient shows acceptable responses until no word pairs are used (conditioning protocol complete) [3]. This allowed the researchers to use classical conditioning to therefore allow associating a positive response ("yes") to a positive emotion and a negative response ("no") to a negative emotion [3]. This study was first tested with five healthy subjects and then with a broader sample [3].

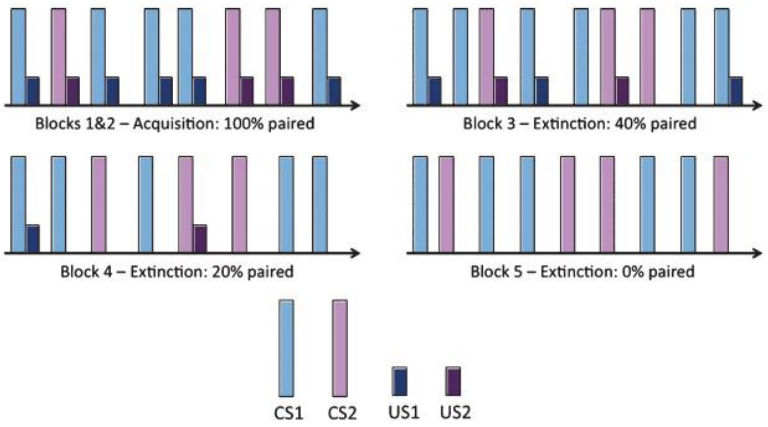

Figure 2. Classical conditioning protocol used to carry out the study [3].

Found that although very useful for research purposes, fMRI is not a portable system that is practical for communication with AD patients in everyday life. They believe that instead of fMRI results, more portable systems can be used that can be geared for the classification of mental states in AD patients [3].

Connection to Alzheimer's Disease

This section will aim to name the relevant or effected cognitive rehabilitation methods for AD mentioned in the introduction section of this paper via emotion-based BCIs.

Pro

Using this method of rehabilitation helps to improve communication with the patient, while also showing good results for conditionally training a patient. Once this method can be applied to a portable device, for practicality, the results will help patients with more severe cognitive decline communicate with their loved ones or doctors.

Con

Using this method requires the patient to be in an fMRI machine which can be not comfortable and not recommend for long periods of time. This issue also is relevant when talking about the expense of this method. Since an fMRI machine must be used, the cost of the machine yields expensive tolls. Overall, this method does not help to slow the progression of AD, even while conditionally training the patient, because it is meant for patients who have severe cognitive abilities already. As discussed, the earlier you start rehabilitation treatments for AD the greater effect of slowing the progressive nature of the disease [5].

Discussion

Overall, both alternative BCIs showed to at least improve one aspect of AD rehabilitation. Motor-Imagery BCI allows for cognitive training and neuronal plasticity stimulation. Emotion-Based BCI allows for communication with patient, good results in training patients conditionally, and method used on portable device would become practical. When comparing both, Motor-Imagery BCI edges out because its pros of cognitive training and neuronal plasticity stimulation are proven to help slow the progression of Alzheimer's Disease, which would prove to be a better rehab treatment than only communication with a patient, with conditioning. While both are great uses of BCI technology, the differences of the two shows in the application of AD rehabilitation.

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