Convolutional Neural Networks: Brain Computer Simulations for Potential Non-Invasive Schizophrenia and Psychiatric Treatment as alternative to medication

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***ABSTRACT*—Deep Learning Neural Networks (DLNN), drawing inspiration from the brain's learning capabilities, may potentially provide treatment solutions alternative to medication. Recent advancements in Convolutional Neural Networks (CNN) and Electroencephalography (EEG) have shown promise in accurately diagnosing conditions like depression, anxiety, and schizophrenia. Additionally, DLNN could be applied to identify brain regions suitable for electrical stimulation or suppression including Electroconvulsive Therapy (ECT) as non-invasive treatments for psychiatric disorders, minimizing side effects of medication. The paper evaluates current progress in DLNN for psychiatric diagnosis and proposes a novel approach to treatment for schizophrenia.**

Keywords—Electroencephalography (EEG), Convolutional Neural Network (CNN), Deep Learning (DL), Computational Cognitive Treatments, Schizophrenia, Brain Computer Interfaces (BCI)

I. INTRODUCTION

Schizophrenia is a psychotic disorder categorized by a variety of combinations of positive and negative symptoms, differentiated by an absence of normal activities (e.g. emotional processing) or presence of abnormal activities (e.g. hallucinations). There are certain shortcomings to modern day treatment and research in schizophrenia. Though a popular form of treatment, several studies evaluate the consequences of using oral medication which primarily reduces positive symptoms but worsen negative symptoms. [6][2] Though both positive and negative symptoms within schizophrenia are devastating, the removal of only positive symptoms leave patients in more depressive states of asocial characteristics and alogia (poverty of speech). Additionally, use of these medications for treatment has a substantial risk in increasing anxiety, depression, and psychosis [19] which has also been seen as a push for substance abuse to reach euphoria because of "sedative" characteristics.

Modern research has shown to use neural networks and deep learning techniques for classification and diagnosis of schizophrenia and related psychotic disorders using EEG, functional Magnetic Resonance Image (fMRI), and other brain activity measuring equipment [7][28][25][11]. By analyzing the database of brain activity of healthy and schizophrenic patients, we can more effectively view common areas of disruption brought by the disorder.

According to an evaluation by Sergio et al. [25], we see that the disorder comes from a failure of the connectivity in neural circuits. They further suggest modulating brain connectivity to train patients to individually reconnect their networks as a form of treatment. This was tested through FMRI-BCI (utilizing neurophysiological brain signals) in a methodology that works in the form of self-regulation training to manipulate patients' brain activity to be depicted in the fMRI readings. This suggests Brain Computer Interface's (BCI) potential to build efficient neural connectivity, modifying and manipulating the brain to exhibit certain activities is possible. My study in particular finds classifications through EEG and neural network models with the use of electroconvulsive therapy (ECT) to activate similar brain activity for psychological disorder treatment.

ECT, normally used as a final resort when medicine is non-effective in mood disorders, shows promising evidence of treatment potentially useful in psychotic disorders, though there are only a few studies

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conducted on this topic [12]. These models and algorithms along with other brain activity measuring tools (fMRI, Position Emission Tomography (PET)) could potentially be used for spatial recognition. This application would theoretically locate areas with unusually high/low activity to bring psychiatric patients to an equilibrium without the use of medication. The advantages of medication avoidant therapy would diminish the severe side effects that neutralizes positive symptoms, but further strengthens negative symptoms.

Overall, this paper is separated by two sections: a review of current research on the use of CNN to diagnose schizophrenia, and a proposal of using such networks with other brain computer interface technologies as a form of non-invasive treatment.

II. RELATED STUDIES

A. Understanding Schizophrenia

As a difficult disorder to understand, there are social stigmas revolving around schizophrenia and other psychotic disorders. In media and popular culture representation, it portrays psychotic disorders as sinister, dangerous, and potentially fatal to those near schizophrenic patients. However, plenty of evidence has been discovered to find that individuals with this disorder suffer more from the violence and abuse in clinical or home settings. The disorder's prevalence, different than society's assumptions, arise from a range of risks including genetics, brain abnormalities, and birth factors [4][5], rather than negative intentions. However, the direct underlining cause has been yet to be claimed, leading to difficulties in diagnosis and treatment. There are leading theories of the causes of this disorder, focusing on the Dopaminergic Hypothesis, and the Glutamatergic Hypothesis. These two hypotheses argue over the excess of dopamine in the brain and irregular N-methyl-D-aspartate (NMDA) receptor signaling, respectfully [2][29]. A particular interest goes towards "the disconnection hypothesis," described as the dysconnectivity of neural circuits and "disruption of reinforcement of adaptive behavior, consistent with disintegrative aspects of schizophrenia" as noted by Friston [10][25].

B. Current Treatments in Psychiatry and Schizophrenia

The purpose for searching for newer forms of treatment is due to the lack of effective and consistent methods within psychotic disorders, mainly revolving around oral medication and cognitive behavioral therapy (CBT), often combined [4]. As introduced earlier, common shortcomings of treatment in these disorders circle back toward to unpleasant side effects, chances of treatment resistance, and worsening or lack of effectiveness in negative symptoms [29]. Side effects themselves may be enough persuasion to push patients away from medication as it may involve other issues including weight gain and disturbances in glucose, lipids, insulin, and cholesterol. Physical health deterioration may cause further difficulty in treating the main issue of psychotic disorders [4].

C. DL in Psychiatry and Schizophrenia

Research in AI has been exponentially increasing, especially through NN with notable works in facial recognition, social media, and in our specific interest, healthcare. To briefly review the concept of a NN, it begins with an input layer, and ends with our output layer, with hidden layers consisting of nodes in between. These hidden layers were modeled by how our brain's neural circuits are connected and thus can be trained by adding weights on specific nodes tied to other nodes in different layers [14].

NN in psychiatry treatment is currently a developing research field, but there has been certain progress in diagnosing disorders [7]. There are still concerns with the difficulty of training these models and having a large dataset to reach the desired output, with notable issues with back-propagation. Back propagation is an algorithm technique to use the actual output with the desired output to alter the weights to reach our necessary output. This implies certain uncertainties as error-prone algorithms could instead return to brute-forcing outputs to how we manipulate them [7]. However, even with the limitations neural networks raise, we have found significant progress through extensive training, "closing the gaps between theoretical models and biological evidence" [15]. In schizophrenia research with NN, results have shown to have an accuracy of around 81-99% [28][25][20] (*Further reading on existing studies can be found in* [25]). CNN is a NN but with more effective results in spatial resolution such as images or brain activity shown through EEG, fMRI, etc. Though diagnostic models do provide an advancement in finding at risk patients or patients who need diagnosis, we are deprived of actual technologies that provide better promise as treatment than oral medication. Most studies have all used the data set from Olejarcyzk and Jernajczyk's study consisting of 14 healthy subjects and 14 schizophrenic patients, into a CNN. Previous findings show great promise, but the small data pool pushes for further study with larger datasets [20]. There are also other limitations running the CNN. As most DL algorithms do, CNN has large computational cost as the hidden layers increase. Andrew et al. strengthens the limitation that there is a lack of sufficient datasets that lead to imbalanced data pools

that require over and under sampling. They also insist that more research on AI in mental health should be conducted and that priority should remain on human compassion and treatment for the meantime. Regardless, there are multiple calls in the hope for advancement in utilizing AI in mental healthcare fields.

III. METHODS

In terms of an individual take on this topic, I have also utilized 28 total subjects recorded with the standard 19 electrode EEG, and two other datasets, from Roach and Moscow State University [21][19][3].

Using MATLAB (R2023a, The Mathworks, Inc., Natick, MA) and EEGLAB, a MATLAB library specialized towards EEG data by University of California at San Diego, I proceeded to include the necessary channel locations for the standard 10-20 EEG cap of 19 nodes, as utilized from Olejarcyzk and Jernajczyk's dataset [7]. This raw EEG dataset was then converted and filtered through the EEGLAB's filtering process. Due to time limitations in modeling out epochs with the current dataset, the plan to develop a similar CNN diagnosis algorithm was pushed for future developments of this study. Nevertheless, I skipped the epoching process and proceeded with developing individual Independent Component Analysis (ICA) on each subject, as this process still evaluates the entire EEG activity without sectioning time windows. ICA works by separating mixtures of signals into workable subcomponents, easing the process of analyzing the complete brain activity. In this case, we are viewing each of the 19 electrodes' activity separately for spatial resolution purposes.

The figures represent the conducted ICA in one subject of each study group. Visually, we can see differences between the healthy subject and schizophrenic patient. High activity would be depicted in red, and low in blue. However, it is difficult to reason any conclusions from visual analysis on each Independent Component (IC) labels for the 28 patients evaluated amongst each other. Further studies in the future expect to provide a polished algorithm for both diagnosis and treatment techniques.

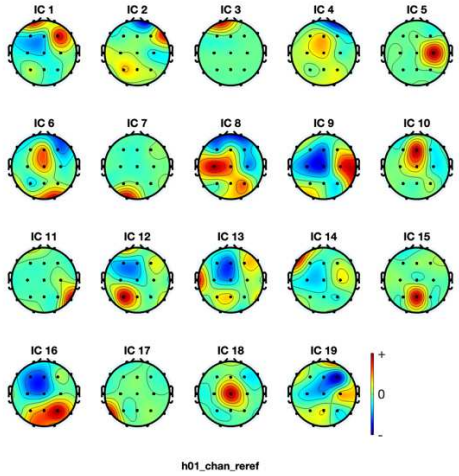

Fig. 1: IC Labeling on Healthy Subject 1 [21]

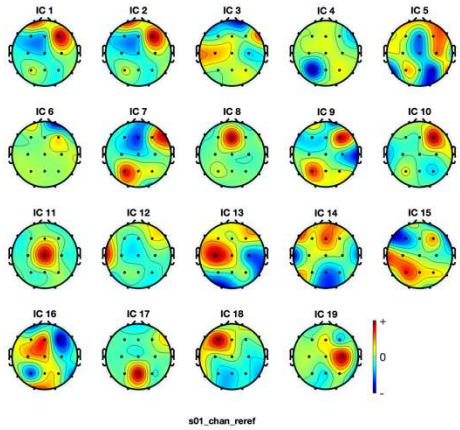

Fig 2: IC Labeling on Schizophrenic Patient 1 [21]

IV. DISCUSSION

There are relatively few studies revolving the future of BCI in psychiatry. Sergio et al. proposes there are promises in using modern advancements, specifically fMRI-BCI technology as forms of treatments for psychotic disorders such as schizophrenia [25]**.** Their methodology consists of training patients to self-regulate and manipulate their brain activity to be read by fMRI readings [25]**.** A shortcoming in Sergio et al.'s suggestion is that though training of self-regulation may provide immediate results, patients with psychotic disorders who experience positive symptoms such as hallucinations may have difficulty in reorganizing their current symptoms within the moment [25]. As it is commonly recognized that schizophrenia lowers quality of life, including a prevalence of avolition, it is difficult to expect much individual progress without outer assistance [12]**.** There also exists the evidence that self-regulation may be interfered with by factors, shown through a

negative correlation with self-regulating and negative symptoms in the duration of illness [25]. If the larger prevalence of negative symptoms inhibits the fMRI-BCI methods, it may be beneficial to investigate increasing BCI studies on schizophrenic patients.

Papanastasiou et al. delves into the utilizing EEG neurofeedback with BCI through virtual environments and video-game based learning, which shows promise in improving subjects' attention within user-friendly terms in fields of [learning, memory, and attention], [spatial and visuospatial skills], and [collaboration, communication, and social skills]. This proposal eases the burden of independent pressure to regulate connectivity by adding assistive tools [22]. Most studies of visual environments were conducted on children with attention deficit hyperactivity disorder and dyslexia, with favorable results in diagnosis and improvement of symptoms [22][23]. It is also significant to include that there was an additional review on developments of understanding brain signals in children with autism spectrum disorder, providing a communication bridge. However, they conclude that there are difficulties in creating a universal BCI system available to each and all persons due to "brain signal variability," with an estimate of about 50% of individuals that will not respond to BCI technologies [13][22]. A different study conducted by Dutta et al. on obsessive-compulsive disorder also found success in using BCI training to detect and plans to further improve cognitive control with it [9]. Overall, there seems to be a consensus that there needs to be further testing to ensure reliability in diagnosis and treatment.

The hypothesis that schizophrenia circulates from decreased neural connectivity, raises questions of potential paths in different technology: the use of Electroconvulsive therapy (ECT) and CNN findings of brain activity. As previously noted, ECT was originally a method for managing psychotic disorders [12]. There was an evaluation that ECT was found to be recommended for patients with a difficult number of negative symptoms along with those who are drug resistant with depression and anxiety. With an understanding of the small number of studies, there is still strong evidence of the effectiveness of the use of ECT for schizophrenia. (Please see [12] for the complete review of these findings.). Additionally, Deep Brain Stimulation, a similar method of stimulating brain signals like ECT, but extremely invasive, is also being investigated for potential uses in treatment after reported success in treating Parkinson's disease and other treatment resistant disorders [16][18]. Further studies may be necessary to evaluate alternative methods to develop non-invasive, stimulative aids other than ECT for better accessibility. With these conclusions, I hope to utilize the CNN algorithm to locate common areas of irregular brain activity and apply ECT and other emerging technology to further stimulate neural activity related to psychotic symptoms.

V. CONCLUSION

With the rise of concern and understanding of mental disorders, there is an increasing urgency for the development of reliable treatment that minimizes probability of other side effects or issues arising, as recognized in oral medication and potential proposals. Schizophrenia in modern day society still faces difficulty in providing accurate treatment options.

From an extensive review, I find that there exists the need for a larger form of studies before we move to apply DL in our development of mental disorders. BCI technologies have provided strong proof on the effectiveness of treating psychiatric disorders, but the lack of prevalent studies in treatment other than diagnosis add uncertainty in pushing this form of treatment as competition to medication. Steering away from medication will allow for those with harsh side effects their right to live "normally." Future developments of this study hope to expand on further testing and studies on effective treatment options applying CNN to trained brain stimulative methods in psychiatry.

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