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EEG neurofeedback for dyslexia treatment: Limitations and future directions

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Abstract. This study reviewed recently published scientific literature on the use of EEG neurofeedback for dyslexia treatment. Dyslexia is characterized as severe difficulty in spelling, reading, learning, memorizing as well as sequential activities. Traditional program designed to teach reading enhancement are mostly less effective or require intensive therapy over long periods of time. This research aim is to determine whether learning disabilities among dyslexic's children can be improved by electroencephalography neurofeedback therapy. Some suggestive discoveries have been reported on the effectiveness of neurofeedback training to enhance learning performance. Due to the limitation in terms of sample size and single-band training protocol in neurofeedback research for dyslexia treatment, the association between neurofeedback training and improvement in learning disability has yet to be established. This review highlights several suggestions to help and accelerate future research.

1. Introduction

Dyslexia is a common neurological issue where children with normal physical and mental capability experience problem in their reading. The difficulty is constantly identified with a language-based disorder. These learning disabilities include troubles with reading, speaking as well as written language. Children who experience the ill effects of dyslexia much of the time perform poorly in reading fluency, phonological mindfulness, single word interpretion, and spelling [1].

Around 5-10% of children in western societies is experiencing dyslexia [2]. In Malaysia, there was 5% dyslexia case or in the proportion of 1:20 reported among school children. This finding is supported by [3] whom observed that 7% out of 2000 standard two Malay pupils are found to have a phonological reading issue. Afterward, [4] found that 27.5% out of 40 preschools had dyslexic symptoms and 15% were distinguished as having high risk of dyslexic symptoms.

If dyslexic issue is not evaluated well in the early period of education, the children will end up frustrated by the hard time in figuring out how to read, and different issues may emerge. For a long-term impact of dyslexia, the children may have absence of certainty, unmotivated and dependably show negative practices. Moreover, the children may feel reluctant to participate in tutoring session.

As the outcome, the children may open to the danger of flopping out from school if the issue is ignored. A newspaper article [5] announced that 75% of convicts in Malaysia were dyslexic. The investigation appeared if dyslexic issue is not assessed well, it is not just influencing the individual youngsters, yet additionally will makes issues the nation.

Advancement of innovative technologies in diagnostic equipment helps specialists and researchers in diagnosing dyslexia in children most effecient. Contribution of most recent brain imaging methods, for example, electroencephalography (EEG), functional magnetic resonance imaging (fMRI) and magnetoencephalography (MEG) gives finding regarding the variations from the norm of capacity and structure of cerebral in individuals with dyslexia. In any case, intervention of advances technologies in treatment of dyslexia are constrained. At present, dyslexia are treated only through education, yet this customary program require intensive therapy over a long period of time.

Neurofeedback (NF) treatment is a way to overcome the drawbacks of conventional program in term of reducing the intervention period. NF is a non-invasive strategy of improving psychological aptitudes dependent on operant molding. NF is an inert strategy, which show impacts after giving a standard treatment for adjusting the target EEG pattern for a specific period. NF treatment permits to control certain brain pattern related with certain cognitive process. EEG is commonly and generally utilized in NF strategy because of its low cost, adaptability, convenience, and robust feature of time resolution. Nevertheless, hemoencephalography (HEG) [6], functional magnetic resonance imaging (fMRI) [7,8], low-resolution electromagnetic tomography (LORETA) [9], slow cortical potential neurofeedback (SCP-NF) [10], low energy neurofeedback system (LENS) [11] and live Z-score [12] are likewise accessible choice for NF.

Previous studies on EEG-NF have been proposed for treatment of various dysfunctions including Attention Deficit Hyperactivity Disorder (ADHD) [13], anxiety disorders [14], epilepsy, addictions [15], brain injury [16], depression and learning disorders [7]. However, despite multiple promising case report, study on the effects of NF on learning disabilities especially dyslexia are very limited. Since EEG-NF promise a good result in treating disorders, thus efficacy of EEG-NF on dyslexia is essential to be further explored.

The remaining portion of the paper is organized as follows. Section 2 explains the compilation of methods used by the literatures on efficacy of neurofeedback for dyslexia treatment. Section 3 describes the challenges and limitations while Section 4 discusses the suggestions for future direction. Finally, conclusions are drawn in Section 5.

2. Methodology

Generally, a workflow of EEG neurofeedback intervention was described as shown in Figure 1. Firstly, the brain activity was recorded either during rest or while the individual performs a task. Secondly, the EEG recording was compared with normative data. Then, a feedback either through auditory or visual display was established. The aim is that the feedback notifies the individual on an intuitive level to modify brain activity in somehow that gives positive reinforcement.

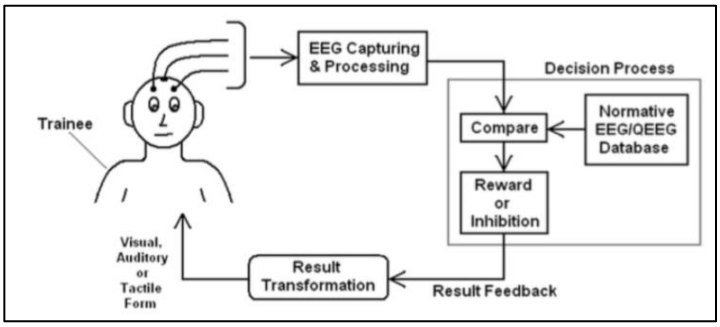

Figure 1. Basic workflow of neurofeedback intervention [17]

A few studies reported the use of EEG neurofeedback in dyslexia children (refer Table 1). A variety of protocols have been used during neurofeedback training with mainly targeted left frontal and temporal region of the brain. Across published studies, an improvement in spelling, reading and attention activity has been assessed to show the positive results of neurofeedback for dyslexia treatment.

Table 1. Summary of neurofeedback therapy studies on dyslexia

Protocol	Electrodes position	Sample Size	Number of sessions	Research Topic	Outcome	Reference
Theta/Beta ratio^{+} Coherence Alpha^{+} Coherence Beta^{-} Coherence Delta^{+}	F_Z and C_Z T_4 - T_6 C_Z - P_Z F_1 - F_Z	12	30-35	Learning and reading.	Improvement in reading speed and comprehension.	[2]
Delta^{+} Coherence Alpha^{+} Coherence Beta^{+} Coherence Delta^{+}	T_6 F_7-FC_3 F_7-C_3 T_3–T_4	19	20	Reading and spelling.	Improvement in spelling but no improvement in reading.	[18]
Delta and Theta^{-} Beta^{+}	T_3 and F_7	6	20	Reading and phonological awareness.	Improvement in reading and phonological awareness.	[19]
Delta and Theta^{-} Beta^{+}	T_3 and F_7	6	20	Attention and working memory.	Improvement in attention and working memory.	[20]
Delta and Theta^{-} Beta^{+}	F_7 T_3	4	20	Reading and spelling.	Improvement in spelling, accuracy and comprehension reading.	[21]

$^{+}$ Reward.
$^{-}$ Inhibition.

3. Limitations

Currently, the researchers have been able to successfully develop a classifier that can differentiate brain pattern between dyslexic and normal individuals. Besides, some NF protocol were found to help in improving dyslexia's children in their reading and spelling ability. However, the main problem is the fact that these studies were limited to small sample size which doesn't reflect to the real population. Furthermore, some of these studies missed proper control group that would undergo a fake EEG-NF training.

4. Future Directions

Most of available studies used single EEG band protocols for EEG-NF. Only one [2] used multi-band protocols that aimed to change the ratio of amplitudes of employed bands. Evaluation of the other combination of multi-band to increase the efficiency of neurofeedback is worth to exploring.

5. Conclusions

To date, large scale studies with conclusive evidence of EEG neurofeedback for dyslexia treatment is yet to be established. However, there are evidences of improvement on individual case-by-case basis. EEG neurofeedback gives an intervention approach suitable to overcome the drawbacks of traditional educational treatment for learning disabilities.

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