A simple arrow-based rewarding neurofeedback interface reduces theta brain waves more than a rewarding neurofeedback interface based on "youtube" videos in dyslexia: A pilot study

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***Abstract*- Auto Train Brain is a mobile app that was specifically developed for dyslexic children to increase their reading speed and reading comprehension. In the original mobile app, there was only one unique neurofeedback user interface that provided visually and audibly rewarding feedback to the subject with a colored arrow on the screen. Later on, new modules are added to the app with the requests of the end-users in such a way that users can choose any "youtube" videos and start neurofeedback sessions visually and audibly. In this research, we have investigated whether the arrow-based rewarding neurofeedback interface or "youtube" videos-based neurofeedback interface is more beneficial to children with dyslexia in terms of reducing the theta brain waves at the left brain regions (FC5 - T7- P7- O1). The experiment group consists of 8 dyslexic children aged 7-to 10 (5 males, 3 females) randomized into two groups. These children had Auto Train Brain training more than 169 times at home with different neurofeedback rewarding schemes. The result indicates that the arrow-based simple neurofeedback interface reduces theta brain waves more than a rewarding neurofeedback interface based on "youtube" videos.**

Keywords—Neurofeedback, multimodality, QEEG.

I. INTRODUCTION

Even if their IQ is normal or above average, some children may struggle to learn to read quickly in the early years of school. According to DSM-V criteria, dyslexia is a subtype of a distinct learning disability that affects children for at least 6 months and cannot be related to neurological or motor disorders, developmental disorders, or intellectual disabilities[1].

In dyslexia, neurologically, there is a temporal disruption and a disconnection between the left anterior and the left posterior regions of the brain [2]. This situation affects the learning of letters and words and phonemic awareness. The increased slow brain waves in the left temporal region can be tracked in QEEG [3]. The main affected brain region due to this disconnection syndrome might be the Wernicke region [4].

Neurofeedback has been shown to help with dyslexia's disconnection syndrome. Neurofeedback has been shown to be beneficial in improving spelling, reading speed, and reading comprehension in studies [5,6,7,8]. Neurofeedback employs the brain's plasticity and operant conditioning to teach the user how to gain greater control over central nervous system activity. The user receives direct neurofeedback regarding their actual brain activation pattern, allowing them to learn to control QEEG signals voluntarily [9]. Real-time feedback of QEEG signals to oneself is a technique that allows individuals to obtain immediate feedback on their neural activity as reflected in visual and aural stimuli. It is a well-known reality that the neurons that fire together wire together [10].

Nazari used neurofeedback to decrease slow brain waves, such as delta and theta, at T3 and F7, while increasing beta-1 at T3 and F7[10]. The treatment lowered the amount of time spent reading and the number of errors made while reading. Walker and Norman [5] used various neurofeedback protocols to reduce slow brain waves, such as delta and theta at Cz, enhance beta-1 at T3, and decrease coherence in the delta and theta range, and their findings revealed at least two levels of improvement in dyslexic reading levels. Applying neurofeedback to dyslexia (delta down at T3-T4, beta down at F7 and C3, coherence training in the delta, alpha, and beta regions) was shown to be beneficial for spelling but not reading [6]. The latest research found that neurofeedback improves reading comprehension and reading speed [8].

Auto Train Brain is a mobile software that combines neurofeedback, multi-sensory learning, and special education principles [11,12,13]. Machine learning algorithms exist for diagnosing dyslexia and recommending individualized treatment plans.

In Auto Train Brain's original user interface, there was a colored arrow to give neurofeedback to the child with a visual and auditory cue. Although it was simple and unique, this user interface was proven to be beneficial to children with dyslexia to improve their condition. During its product lifecycle, new features are added to Auto Train Brain. The neurofeedback interface is also developed more. In the latest version of Auto

Train Brain, it is possible to choose the user's preferred video and start neurofeedback by providing multimodal -namely visually and audibly rewarding neurofeedback. When the subject focuses more on the video, he can see the screen more and can hear the sound of the video more.

In this research, we have collected data from the children with dyslexia during neurofeedback sessions and determined which user interface decreased Theta brain waves more [5].

II. MATERIALS & METHODS

A. Subjects & Experimental data

The neurofeedback data of 8 dyslexic children for over 169 sessions are studied in this study. The children's ages range from seven to ten (5 males, 3 females). All participants gave their informed consent before the experiment after the experimental technique was explained to them according to research ethics committee requirements. The EMOTIV EPOC-X headset is used throughout the studies. The headset's internal sampling rate is 2048 samples per second per channel. The data is filtered to remove major artifacts before being downsampled to 128 samples per second per channel. There are 14 EEG channels and two reference channels in total. Before the studies, the EMOTIV Headset is calibrated on the subjects' scalps using the EMOTIV APP, and each electrode is checked for high-quality EEG data transmission.

The participants are split into two groups at random (4 subjects in each group). One group utilized a simple neurofeedback interface based on arrows. Their goal was to change the red arrow into a green arrow while avoiding hearing any beeps. The second group used the "youtube" interface, and the subject was told that if he focused more on the video, he would be able to view it better. The individual was not given any extra information regarding the experimental technique. The approach for the experiment was randomized and double-blind.

B. Study design

Each participant has used Auto Train 169 times, has their brain waves read using the EMOTIV EPOC-X from 14 channels, and has received 30 minutes of visual and audio neurofeedback. The user interfaces for each group were different, but the neurofeedback algorithms were the same.

A recording of their QEEG is made and stored in a database. All 14-channel QEEG data is acquired during the tests in the Theta (4-8 Hz), Alpha (8-12 Hz), Beta-1 (12-16 Hz), Beta-2 (1625 Hz), and Gamma (25-45 Hz) bands for all analyses in this work. We evaluated the Theta band power values for the left hemisphere at the channels FC5, T7, P7, and O1 after collecting, averaging, and cleaning data from an EMOTIV EPOC-X headset.

III. RESULTS

It was measured that the simple "arrow" based neurofeedback interface, which rewards visually and audibly, decreases theta band power more than that of the "youtube" based neurofeedback interface, which rewards visually and audibly while watching the video at FC5, T7, P7, and O1 ($p<.001$).

IV. DISCUSSION

We have designed an experiment to test the new user interfaces of Auto Train Brain. The first neurofeedback interface is related to the "arrow" neurofeedback interface which is simply turning a red arrow into a green arrow. The second neurofeedback interface is related to "youtube" videos and neurofeedback during watching these videos.

The users of Auto Train Brain prefer the "youtube" videos more than the "arrow" interface in real life as they think it is more amusing. The results of this experiment have shown that the original "arrow" interface which is easier to control and learn was more beneficial to the children with dyslexia. The reason would be to control the "arrow" much easier than the "youtube videos" with the brain, or the content of the "youtube" videos were distracting the children to focus.
In the future, we will repeat the experiment with more participants. There may be a placebo effect and maturation effect in the experiments.

Figure -1 Auto Train Brain "arrow" interface

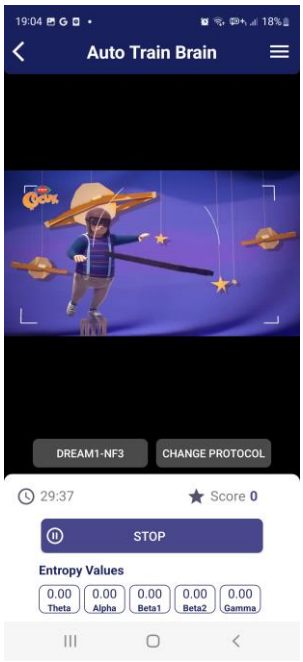

Figure -2 Auto Train Brain "youtube" interface

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Table 1. Theta band power values at the channels most important to dyslexia

Variable	Youtube neurofeedback interface N = 169	Arrow neurofeedback interface N = 169	p-Value
THETA_FC5	4.15 (± 2.11) 95% CI: [3.94 ; 4.36] Range: (0.0 ; 11.73) N = 169	2.93 (± 1.27) 95% CI: [2.74 ; 3.12] Range: (0.0 ; 6.87) N = 169	<0.001
THETA_T7	3.05 (± 2.41) 95% CI: [2.81 ; 3.29] Range: (0.0 ; 12.75) N = 169	2.14 (± 1.28) 95% CI: [1.95 ; 2.34] Range: (0.0 ; 8.34) N = 169	<0.001
THETA_P7	2.52 (± 1.94) 95% CI: [2.33 ; 2.72] Range: (0.0 ; 14.06) N = 169	1.79 (± 1.14) 95% CI: [1.62 ; 1.96] Range: (0.00917 ; 6.72) N = 169	<0.001
THETA_O1	3.72 (± 2.61) 95% CI: [3.46 ; 3.98] Range: (0.0 ; 14.51) N = 169	2.28 (± 1.07) 95% CI: [2.12 ; 2.45] Range: (0.0 ; 6.27) N = 169	<0.001