A pilot study found that visually and vocally rewarding neurofeedback improves sample entropy in dyslexia more than vocally rewarding neurofeedback

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***Abstract*— The Auto Train Brain mobile app improves dyslexia symptoms, according to a clinical trial. There was just one unique neurofeedback user interface in the original mobile app, which gave visually and vocally rewarding feedback to the subject via a colorful arrow on the screen. Later, new modules are added to the app in response to end-user requests, such that users can choose from a variety of "youtube" videos and begin neurofeedback sessions with both visual and vocal rewards, or they can choose from a "storyteller" and begin neurofeedback sessions with only vocal rewards. In this study, we looked into whether the multimodal neurofeedback method is more effective in improving sample entropy in the gamma band in the left temporal region for children with dyslexia.**

Keywords—Neurofeedback, multimodality, sample entropy.

I. INTRODUCTION

According to the DSM-V guidelines, dyslexia is classified as a Specific Learning Disorder (SLD). SLD is a neurologically based neurodevelopmental condition that manifests itself in the form of learning difficulties and difficulties gaining academic skills below age level[1].

There is a weak connection or disconnection between the left anterior and left posterior regions of the brain in dyslexia, which presents itself in reduced reading abilities [2]. QEEG scans reveal higher slow brain waves in the dyslexic brain's left temporal area [3]. The left parietal occipital region, which is involved in visual processing, or the angular gyrus, which functions as multimodal higher-order neuron groups that combine information from unimodal visual and auditory neuron groups, maybe the most affected brain regions as a result of this disconnection syndrome[4].

This phenomenon is described by a variety of ideas. Apart from genetic disposition, the most widely recognized hypotheses. Inflammation in the brain [5] may have hindered the left lateralization and development of gray matter in the brain, causing a delay in brain maturation.

Elimination diets [6, special education [7, neurofeedback, and multi-sensory learning [8] are recognized to be the only effective strategies for reducing dyslexia symptoms.

Neurofeedback apps track the user's brain activity in real-time to help them acquire better control over their central nervous system activity. The user is given direct neurofeedback on their actual brain activation pattern, allowing them to learn to deliberately manage QEEG signals [9]. Individuals can get instant feedback on their neural activity as reflected in visual and aural stimuli via real-time feedback of QEEG signals to themselves. Learned control over a single region of the brain has been demonstrated to result in long-term changes in brain networks [10].

Auto Train Brain is a multifaceted system that combines neurofeedback, multisensory learning, and special education ideas into a single smartphone app [8]. Auto Train Brain comes with built-in machine learning algorithms.

A colorful arrow was included in Auto Train Brain's original user interface to provide neurofeedback to the youngster via a visual and audible indication. Despite its simplicity and uniqueness, this user interface has been shown to help children with dyslexia better their condition.

New features are added to Auto Train Brain throughout its product lifecycle. The neurofeedback interface is also getting greater attention. In the most recent version of Auto Train Brain, the user can select their chosen video and begin neurofeedback by receiving multimodal - that is, visually and audibly gratifying neurofeedback. When the subject concentrates more on the video, he may see the screen and hear the audio more clearly. Another game with a storyteller is available that simply delivers aural clues during the neurofeedback session.

In this research, we have collected data from the children with dyslexia before, during, and after each neurofeedback session and determined which one increased their gamma entropy more. Gamma entropy of children with dyslexia is known to be lower than that of healthy children [5].

II. MATERIALS & METHODS

A. Subjects & Experimental data

The experiment group consists of 20 dyslexic children aged 7- to 10 (15 males, 5 females) who were randomly assigned to one rewarding interface, and used it at home for more than six months. They have used Auto Train Brain (a unique application for applying neurofeedback from 14 channels) to boost their cognitive capacities several times (over 100 times).

All participants gave their informed consent before the experiment after the study ethics committee described the protocol to them. 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 neurofeedback sessions were done at the participants' homes. Before and after each neurofeedback session, 2-minute resting state QEEG signals are recorded. The participant was told in the first session that if he concentrated on the video on the application screen, he would be able to watch the movie more clearly. At other times, the participants listened to the storyteller. They can hear the story better if they concentrate. The subject was not given any additional information about the experimental method.

B. Study design

Each participant has utilized Auto Train Brain (a mobile phone application) several times, and their brain waves are measured using the EMOTIV EPOC-X from 14 channels, followed by 30 minutes of visual and auditory neurofeedback.

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, Alpha, Beta-1, Beta-2, and Gamma bands for all analyses in this work. We used the session average band powers in our sample entropy (SampEn) calculations after collecting, averaging, and cleaning data from an EMOTIV EPOC-X headset.

To evaluate irregularity at each scale, SampEn, a correlation entropy variant of Kolmogorov Sinai entropy that was well suited for analyzing brief and noisy experimental data [11], was utilized. SampEn is the logarithmic conditional chance that two sequences of m consecutive data points that are comparable (within a given tolerance r) will remain similar at the next point (m + 1) in the dataset (n), where n is the length of the time series.

The gamma band SampEn values computed from QEEG band power values before neurofeedback and the gamma band SampleEn values calculated from QEEG band power values after neurofeedback are among the 14 variables in the feature set.

III. RESULTS

It was measured that the “youtube” neurofeedback interface, which rewards visually and audibly, increases gamma entropy (average 1.61) in the left temporal region more than that of the “storyteller” neurofeedback interface, which rewards audibly while listening to music and/or audiobooks (average 1.14) during 100 sessions, and more regions in the brain are activated during multi-modal neurofeedback (Table 1).

IV. DISCUSSION

We created trials to test the new Auto Train Brain user interfaces. The first interface is for watching "youtube" videos and receiving neurofeedback while doing so. The second interface is linked to the auditory interface and neurofeedback provided by the storyteller while listening to the stories.
Because the main problem in dyslexia is visual perception and/or where visual information is combined with aural information - the angular gyrus - neurofeedback using the "youtube" interface is thought to be more beneficial in dyslexia.

It is argued that our capacity to comprehend cross-modal and multimodal data underlies much of what we refer to as intelligent behavior. In humans, those functions appear to be acquired and used more frequently between the ages of 2-4. Among the functions are some that dyslexic people commonly struggle with. Testing for the sufficiency of those functions at that young age may allow for the diagnosis of potential dyslexics. Additionally, there may be a limit to the number of concepts that can be processed at once in information processing, which could affect both multimodality and cross-modality. Educators, especially those working with dyslexic students, don't seem to generally take this constraint into account[12].

The quantity of participants in this study is a restriction. This experiment will be repeated with more dyslexic people.
The experiment also has other flaws, such as a maturation effect and a placebo effect.

Figure -1 Auto Train Brain "youtube" interface

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Table 1. qEEG average Gamma Band power values at the left temporal region for each neurofeedback rewarding interface

Variable	Youtube N = 2000	Spotify N = 2000	p-Value
AVG_GAMMA_T7	1.61	1.14	<0.001

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