Comparison of the efficacy of multi-modal neurofeedback from 5 and 14-channel EEG headset: A pilot study

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***Abstract*—It was proven with a clinical trial that Auto Train Brain mobile app increases the reading speed and reading comprehension in dyslexia with EMOTIV EPOC-X which has 14 channels. The long-term training effects of the Auto Train Brain on dyslexic children were analyzed beforehand and it was found that the gamma band entropy variance increases over time which shows the increased flexibility of the brain. The flexibility of the brain or the possibility of various/many wiring and/or connections possibly shows the increase in intelligence. In this research, we have compared the positive long-term effects of Auto Train Brain with a 5-channel EEG headset and with 14-channel neurofeedback.**

Keywords—Neurofeedback, sample entropy, Auto Train Brain.

I. INTRODUCTION

Reading is not an acquired ability like speaking or walking. A person needs to be taught the letters and phonemes of the letters and how to correctly combine the phonemes with the graphemes. 10% of the people in the world are not good at reading. According to DSM-V, dyslexia is categorized as a subtype of specific learning disability. Dyslexia is a neurodevelopmental diversity that affects children's reading skills when they start school [1]. In the first two years, it is expected that the child reaches his peer's reading speed at school, but in most cases, this may not happen incidentally without any intervention.

It is hypothesized that there is a disconnection syndrome at the temporal lobe in dyslexia[2]. QEEG measurements display the increased slow brain waves in the left temporal region of the dyslexic brain [3] and/or there may be general EEG slowing. There are subtypes of dyslexia. Some of them have defects in the visual area, some have defects in phonologic processing, and some have defects in combining the visual and auditory input in the left angular gyrus[4]. Apart from the cortex, some subcortical structures may also be affected[5].

In the literature, many different theories describe this phenomenon. The first explanation is that there is a genetic disposition, families who have dyslexia in their family tree tend to have dyslexic kids. Another explanation is that due to immune system or fatty acid deficiencies which are also genetic, chronic inflammation starts in the brain which hinders the development of the brain [6].

It is known that gluten-free diets [7], special education [8], neurofeedback, and multi-sensory learning [9] are the only effective solutions to reduce the symptoms of dyslexia.

Neurofeedback is known to reduce the effects of dyslexia. The subject's EEG data are read and shown to him in real-time. With operant conditioning, the subject gains more control of their brain [10]. The user learns to control a specific part of the brain region and it was shown that this phenomenon may alter and add weak connections which enable the subject to attend and learn better [11].

There are coherence problems and gamma band problems in dyslexia[12]. It is known that the connections between neurons are weak, and there is a deficiency in grey matter formation which also affects the working memory. Therefore, solutions that reduce the disconnection syndrome, increase coherence, and increase entropy are relevant and suitable for dyslexia.

Auto Train Brain is an advanced solution that includes neurofeedback from 14-channels, multimodal learning, and special education principles [9]. Machine learning algorithms are built-in features of Auto Train Brain.

Previous research investigated the long-term effects of 14-channel neurofeedback with Auto Train Brain. It was discovered that gamma band entropy variance was increased which shows the flexibility of the brain is enhanced.

In this research, we have compared the efficacy of 14-channel neurofeedback and that of 5-channel neurofeedback for dyslexia with Auto Train Brain.

II. MATERIALS & METHODS

A. *Subjects & Experimental data*

In this experiment, 40 dyslexic children participated providing their written consent both from themselves and from families according to the rules set by the research ethics committee. Their ages differ from 7-to 10 (34 males, 6 females). They have used Auto Train Brain (a clinically tested mobile app for applying neurofeedback from 14 channels) many times (more than 100 times) to improve their reading speed and reading comprehension.

In the experiments, EMOTIV INSIGHT2 and EPOC-X headsets are used. The EEG data was read with 2048 per secs per channel -128 per secs per channel downsampled. EEG data were converted to the frequency band data with EMOTIV's standard procedures. The frequency band data is binned as follows: Theta (4-8 Hz), Alpha (8-12 Hz), Beta-1 (12-16 Hz), Beta-2(1625 Hz), and Gamma (25-45 Hz). The artifacts were removed with a high pass filter (>100 Hz). EMOTIV APP is used for the calibration of the headsets, each electrode is soaked well and ensured that EEG data is read with top quality. The recorded channels were AF3, T7, P7, T8, and AF4 for EMOTIV INSIGHT2 and the recorded channels were AF3, F3, F7, FC5, T7, P7, O1, O2, P8, T8, FC6, F8, F4, and AF4 for EMOTIV EPOC-X.

The participants took the neurofeedback sessions with the bits of help of their families at home. During the neurofeedback training, each participant stayed at home and used it while sitting at a table. There was 40 cm between the subject and the mobile app as their families are instructed to do beforehand. The participants used the arrow neurofeedback interface of Auto Train Brain.

B. *Study design*

All subjects used Auto Train Brain (a mobile phone application) many times, for randomly chosen 20 participants, their brain waves are read using EMOTIV INSIGHT for 5 channels, for the rest 20 participants, their brain waves are read using EMOTIV EPOC-X for 14-channels and visual and auditory neurofeedback is given for 30 minutes. After the neurofeedback session, multi-sensory alphabet learning is studied for 15 minutes.

At the end of each session, session average data for each frequency band was saved to the database. During the neurofeedback session, sample entropy was calculated for each frequency band data [13]. Sample entropy is the minus of the logarithmic probability which measures the similarity of two sequences. If the two sequences of m consecutive data points, that are similar to each other (within given tolerance r), will remain similar at the next point (m + 1) in the dataset (N), then the sample entropy would be higher. N is the number of samples in the session data. Normally, sample entropy is calculated based on EEG data series, however, in our calculations, we have used QEEG data as we have not reached raw data from EMOTIV INSIGHT2 or EPOC-X.

The feature set consists of 5 variables mapped from 5 channels for EMOTIV INSIGHT, and 14 variables mapped from 14 channels for EMOTIV EPOC-X. The measures are gamma band sample entropy values calculated from QEEG band power values.

III. RESULTS

We have plotted a regression line (the x coordinate is the session numbers and the y coordinate is the variance of gamma band sample entropy for each bin). The results indicate that there was an increase in the variance of gamma band sample entropy in the long run usage of the neurofeedback, but we can not determine any continuous improvements in the gamma band sample entropies across sessions in the long run.

We have combined the 100 consecutive sessions in 10 bins. Then we calculated the variance of gamma band sample entropy in each bin. There were 10 bins. We have plotted the bin number versus the variance in the gamma band sample entropy values. The variance in the gamma band sample entropy continuously increased in the left posterior regions of the brain (T7) for both headsets.

Excluding the first 30 sessions, the regression line has R^2=0.78 (Figure 1) for a 14-channel EEG headset. Including the first 30 sessions, R^2 for the regression line is 0.50 (Figure 2). The slopes for the linear regression lines were positive in both cases.

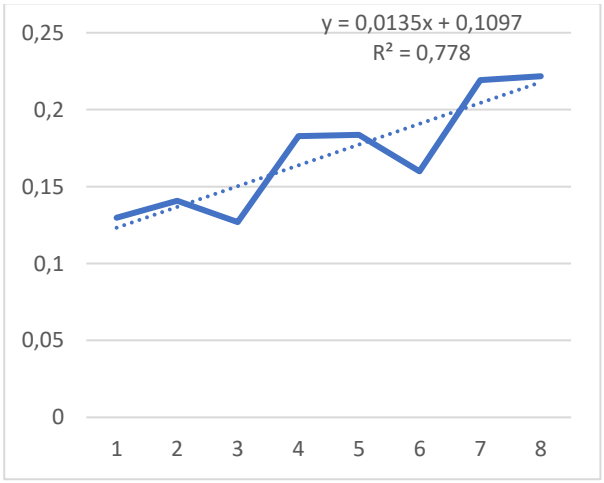

Figure 1- The increase in the variance of gamma band entropy after 30 sessions for a 14-channel EEG headset

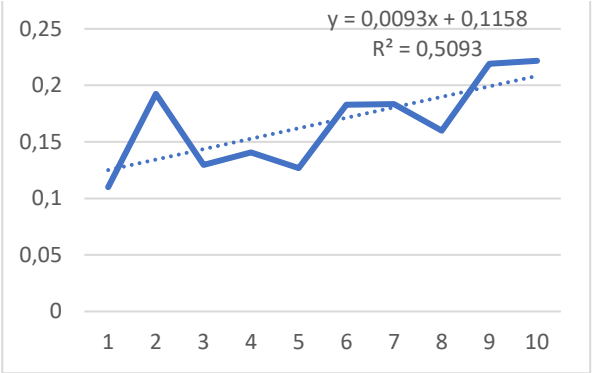

Figure 2- The increase in the variance of gamma band entropy for a 14-channel EEG headset in the 100 sessions

For a 5-channel EEG headset, in the first 40 sessions, the regression line has R^2=0.69 (Figure 3). For the next 60 sessions, R^2 for the regression line is 0.48 (Figure 4). The slopes for the linear regression lines were positive in both cases.

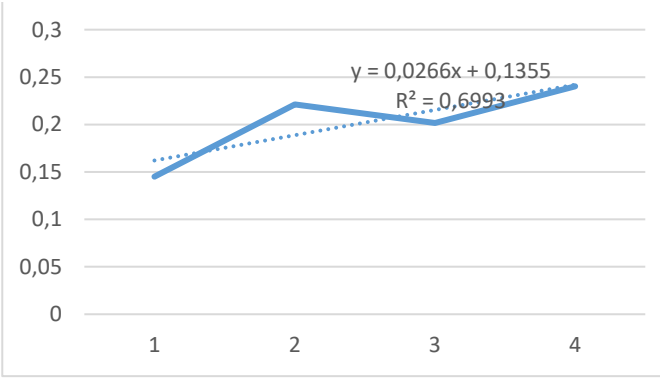

Figure 3- The increase in the variance of gamma band entropy for a 5-channel EEG headset in the first 40 sessions

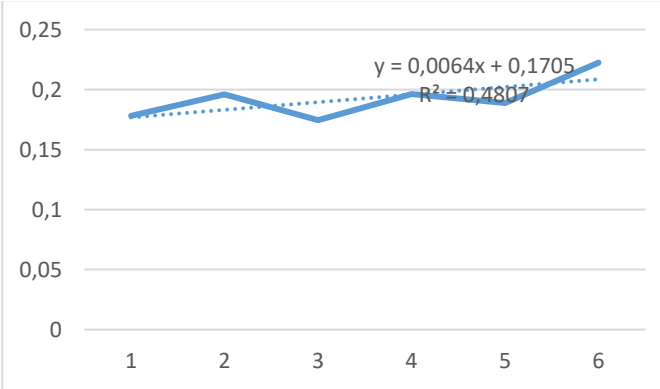

Figure 4- The increase in the variance of gamma band entropy for a 5-channel EEG headset in the next 60 sessions

IV. DISCUSSION

Auto Train Brain was proven to be effective for children with dyslexia in a clinical trial beforehand. In this research, we have investigated the long-term use and positive effects of Auto Train Brain with home's 14-channel and 5-channel EEG headsets.
In the first 20 sessions of the usage, the variance of the sample entropy in the gamma band increases rapidly with 14-channel neurofeedback. With 5-channel neurofeedback, the number of sessions necessary for this increase is twice; in 40 sessions the gamma band entropy variance reaches the peak and the adaptations start in the brain.

We hypothesize that many metabolic changes take place in the brain and the body of these children when adapting and learning neurofeedback, and the learning effort is high in the first month. After the 20 sessions for 14- channel neurofeedback and after the 40 sessions for 5-channel neurofeedback, the variance of the sample entropy in the gamma band is reduced and we hypothesize that the pruning and the new cell formation started in the brain. Thereafter the variance in the gamma band entropy increases in the rest of the sessions. There are 2 more pruning phases in the rest of the sessions for both headsets.

The results indicate that flexibility increased after 100 sessions of usage of Auto Train Brain with both headsets. It requires the double amount of time and sessions to increase the flexibility of the brain with 5-channel neurofeedback. The families who use 14-channel neurofeedback can see the positive effects in the child's daily life much sooner.

Nazari[14] has applied neurofeedback to 6 dyslexic children and he has not noted any notable changes in the power bands, however, he has noted the normalization of coherence of the Theta Band at T4- T4, delta band at Cz- Fz, and Beta band at Cz-Pz, Cz- Fz and Cz-C4. He has concluded that the significant changes in coherence indicate the integration of sensory and motor areas and explain the improvements in reading skills and phonological awareness.

Coben showed that coherence neurofeedback improves reading scores by 1.2-grade levels for reading disabilities[15].

The limitation of this research is the number of participants. We will repeat this experiment with more dyslexic people.
The other limitations of the experiment are that there is a maturation effect and the placebo effect.

Figure -1 Auto Train Brain "youtube" interface

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