

# *Auto Train Brain increases the variance of the gamma band sample entropy in the left hemisphere in dyslexia: A pilot study*

Günet Eroğlu

Mühendislik ve Doğa Fakültesi, Işık University

İSTANBUL

**Abstract**—It was proven with a clinical trial that Auto Train Brain mobile app increases the reading speed and reading comprehension in dyslexia. We have analyzed the long-term training effects of the Auto Train Brain on dyslexic children. We have collected QEEG data from 14 channels from 21 dyslexic children for 100 sessions and calculated the Sample Entropy in the gamma bands for the left posterior brain (T7, P7, and O1). Although the gamma band values fluctuate and no permanent increase in the gamma band values is detected after Auto Train Brain training at T7, P7, and O1. The variance of gamma-band sample entropy increases as the neurofeedback session number increases. We have concluded that the Auto Train Brain increases the flexibility of the left brain in dyslexia.

**Keywords**—Neurofeedback, sample entropy, Auto Train Brain.

## I. INTRODUCTION

According to DSM-V, dyslexia is categorized as a subtype of specific learning. Dyslexia is a neurodevelopmental diversity that affects the reading skills of children when they start school [1]. The problems emerge when the child starts school and if the necessary interventions will not be taken, they may last during their lifetime.

In dyslexia, neurologically, there is a weak connection or disconnection between the left anterior and the left posterior regions of the brain which manifests itself in lower reading abilities [2]. QEEG measurements display the increased slow brain waves in the left temporal region of the dyslexic brain [3]. The main affected brain regions due to this disconnection syndrome might be the left parietal occipital region related to visual processing or angular gyrus which functions as multimodal higher-order neuron groups that combine the information coming from unimodal visual and auditory neuron groups[4].

Many theories describe this phenomenon. The most commonly accepted theories are apart from genetic disposition. There may be a brain maturation delay due to inflammation in

the brain [5], which slowed down the left lateralization and development of the gray matter in the brain.

It is known that elimination diets [6], special education [7], neurofeedback, and multi-sensory learning [8] 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 operational conditioning, the subject gains more control of their brain [9]. 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 [10].

Dyslexic people find it difficult to learn the associations between graphemes and phonemes and learning methods with visual and auditory cues increase memory and writing abilities [11]. If more than two senses, namely visual and auditory, are involved in the learning of orthographic tokens and phonemes, learning becomes permanent and memory is improved.

A multi-sensory method example (Orton Gillingham) decreases the reading disability of dyslexic people [12]. Some dyslexic people have problems with visual abilities and perceptual learning may be improved with practice [13]. Problems with dyslexia may be in unimodal visual recognition parts of the cortex, or mostly in the higher order neuron hierarchies which are responsible for combining the visual and auditory signals. Dyslexic people may find it difficult to go from one modality to another. This delayed attention shifting would be reported either in visual [14,15,16] or in auditory modalities [17] or cross-modal attention processes [18]. Therefore, any dyslexia software increase the abilities of visual, auditory, and cross-modal attention processes.

Auto Train Brain is an advanced solution that includes neurofeedback, multimodal learning, and special education principles [8]. Machine learning algorithms are built-in features of Auto Train Brain.

In this research, we collected data from the children with dyslexia during 100 neurofeedback sessions and determined

whether there were any improvements in the gamma band sample entropy. [5].

## II. MATERIALS & METHODS

### A. Subjects & Experimental data

In this experiment, 21 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 (15 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 EPOC-X and EMOTIV-EPOC+ 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(16-25 Hz), 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 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, their brain waves are read using EMOTIV EPOC-X or EMOTIV EPOC+ from 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 [19]. 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 EPOC-X.

The feature set consists of 14 variables mapped from 14 channels. 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 a bin. 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, P7, and O1) that are mostly affected by dyslexia.

Excluding the first 30 sessions, the regression line has  $R^2=0.78$  (Figure 1). 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.

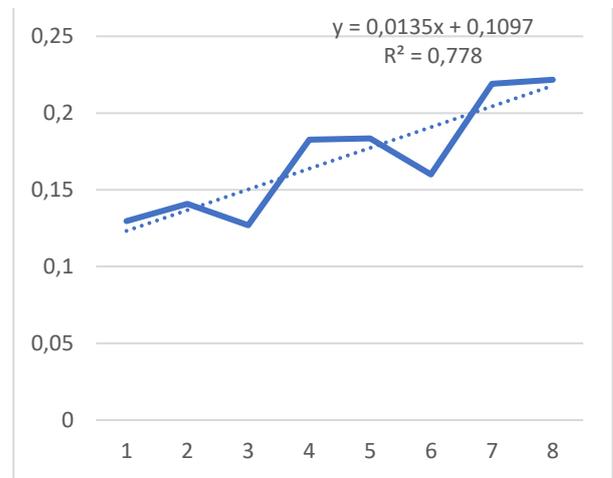


Figure 1- The increase in the variance of gamma band entropy after 30 sessions

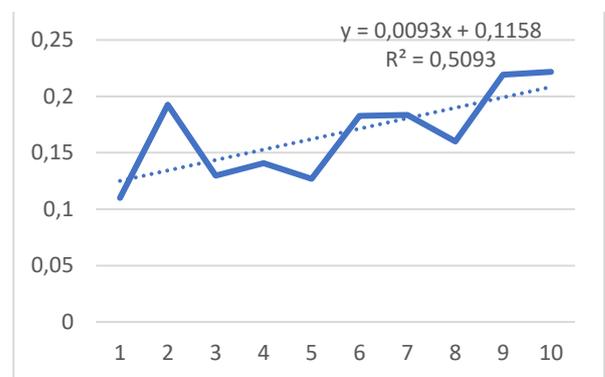


Figure 2- The increase in the variance of gamma band entropy after session 1

#### 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 at home.

In the first 30 sessions of the usage, the variance of the sample entropy in the gamma band increases rapidly. We hypothesize that many metabolic changes take place in the brain and in the body of these children when adapting and learning neurofeedback, and the learning effort is high in the first month. After the 30 sessions, 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 after 30. There are 2 more pruning phases in the rest of the sessions.

The results indicate that the human brain spends more effort in the learning phase than in the following periods. After the adaptation and learning, there is a pruning phase and learning continues with some variations included. The flexibility of the left hemisphere for dyslexic children is increased after 100 sessions of usage of Auto Train Brain. These children and families are happy to use Auto Train Brain at home. They see the positive effects in their everyday life and they have increased their reading by at least 2 levels.

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.

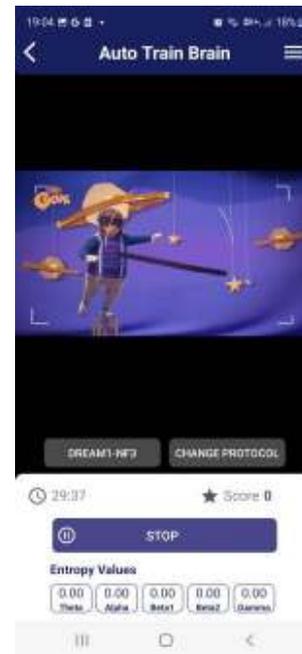


Figure -1 Auto Train Brain “youtube” interface

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