

Accepted Manuscript

Accepted Manuscript (Uncorrected Proof)

Title: Quantitative Comparison of Brain Waves of Dyslexic Students With Perceptual Type and Linguistic Type With Normal Students in Reading

Authors: Danial Fathi Khorasani¹, Mitra Rastgou Moghadam^{2*}, Mohammad Reza Saebipour³, Majid Ghoshuni⁴

1. Faculty of Education and Psychology, Birjand University, Birjand, Iran.
2. Department of Psychology, Birjand University, Birjand, Iran.
3. Department of Anatomy, Birjand University of Medical Sciences, Birjand, Iran.
4. Department of Biomedical Engineering, Mashhad Branch, Islamic Azad University, Mashhad, Iran.

***Corresponding author:** Mitra Rastgou Moghadam, Department of Psychology, Birjand University, Birjand, Iran. E-mail: m.rastgoumoghadam@birjand.ac.ir

To appear in: *Basic and Clinical Neuroscience*

Received date: 2020/12/17

Revised date: 2021/03/22

Accepted date: 2021/12/01

This is a “Just Accepted” manuscript, which has been examined by the peer-review process and has been accepted for publication. A “Just Accepted” manuscript is published online shortly after its acceptance, which is prior to technical editing and formatting and author proofing. *Basic and Clinical Neuroscience* provides “Just Accepted” as an optional and free service which allows authors to make their results available to the research community as soon as possible after acceptance. After a manuscript has been technically edited and formatted, it will be removed from the “Just Accepted” Web site and published as a published article. Please note that technical editing may introduce minor changes to the manuscript text and/or graphics which may affect the content, and all legal disclaimers that apply to the journal pertain.

Please cite this article as:

Fathi Khorasan, D., Rastgou Moghadam, M., Saebipour, M. R., & Ghoshuni, M. (In Press). Quantitative Comparison of Brain Waves of Dyslexic Students With Perceptual Type and Linguistic Type With Normal Students in Reading. *Basic and Clinical Neuroscience*. Just Accepted publication Jan. 7, 2022. Doi: <http://dx.doi.org/10.32598/bcn.2022.144.5>

DOI: <http://dx.doi.org/10.32598/bcn.2022.144.5>

Author Note

The data of this article analyzed under the supervision of Dr. Saebipour, and Dr. Ghoashouni, who are specialists in anatomical sciences and medical engineering, respectively. Also Dr. Rastgou Moghaddam, as a learning disability specialist, is the corresponding author of this paper.

All data are recorded and obtained at the Psychology Center of Birjand University. In addition, Correspondence was also obtained, such as obtaining an ethics code from Birjand University of Medical Sciences and a license (approval) from education.

The publication of this article is not in conflict with the individuals' values and interests. This article is taken from Birjand University Master's Thesis in Psychology Also, this article has not been published anywhere and if accepted, it will be published for the first time in this journal

Abstract

The aim of this study was to compare the brain wave pattern of two groups of dyslexic students with perceptual and linguistic type with normal students in reading. Method: In this study, 27 students (24 boys and 3 girls) from first to fifth grade with an average age of 8.16 and a standard deviation of 10.09 years participated. 8 students with perceptual type dyslexia, 10 students with linguistic type dyslexia and 9 normal students with reading were selected by purposive sampling method. Results: After removing noise and artifacts, the data were converted into quantitative digits using Neuroguide software and analyzed using multivariate analysis of variance (MANOVA) and univariate analysis of variance (ANOVA). Based on the results, the linguistic group and the normal group differ in the relative power of the alpha wave in the two channels Fp1 and Fp2, but there is no difference between the three linguistic, perceptual and normal groups in the absolute power of the four waves delta, theta, alpha and beta. Conclusion: The relative power spectrum of alpha band in the forehead can be significantly related to dyslexia problems as seen in the linguistic type.

Keywords: Baker Imbalance Model, Perceptual Type Dyslexia, Linguistic Type Dyslexia, Quantitative Electroencephalography

Reading is a complex cognitive skill that serves a wide range of language and vision-related areas. Disruption of communication in this network is associated with evolutionary dyslexia (Hallahan, Lloyd, Kaufman, P. Weiss, & A. Martinez, 2005). Dyslexia is a term used mainly by neurologists; But teachers call it reading problems (Walker & Norman, 2006). There are several definitions of dyslexia; According to the definition of the fifth diagnostic and statistical classification (Association, 2013) Dyslexia is a pattern of learning disorder characterized by poor speech recognition, poor coding, and poor spelling, which is not due to sensory impairment, low intelligence, or inadequate educational experience. Dyslexia occurs in all groups of children regardless of gender, social group, mental level and geographical area (Schlaggar & McCandliss, 2007). Papagiannopoulou and Lagopoulos (2016)., It is believed that dyslexia is a neurodevelopmental disorder with an unknown cause that affects between 4-7% of the population.

"Causation" is one of the most important challenges in the field of learning disabilities. Over the past three decades, the neurological approach has taken more seriously the weaknesses of children with dyslexia. According to this approach, the occurrence of this disorder is due to the malfunctions of the nervous system, especially the central nervous system (Temple, 2002).

Recent advances in imaging (magnetic resonance imaging, positron emission neurosurgery, functional magnetic resonance imaging, regional blood flow) as well as neurophysiology (recall potentials, Quantitative Electroencephalogram (QEEG), Coherence studies, magnetic resonance imaging) Today, researchers are able to look at the normal circuits involved in reading and the differences between people who have difficulty learning to read (Abdeldayem & Selim, 2005). The results of several studies have been performed on dyslexics (Casanova, Araque, Giedd, & Rumsey, 2004; Meyler et al., 2007; B. A. Shaywitz et al., 2004), It has been shown that these individuals have poor performance in the temporomandibular region. According to the study, there is a positive linear relationship between reading ability and brain activity in the left temporal lobes and lower parietal areas in the right lobe, which means that the activity of these areas also increases following the ability to read. On the other hand, the studies of (Ferrer, Shaywitz, Holahan, Marchione, & Shaywitz, 2010; B. A. Shaywitz et al., 2002), It has been shown that children with dyslexia have problems with their nervous systems; It is associated with dysfunction in the anterior cerebral cortex, parietal temporal lobes, and posterior parietal cortex. Also in the study of (Vandermosten, Boets, Wouters, & Ghesquière, 2012) The dysfunction of the left temporal lobe of the left temporal forehead was

associated with impaired phonological awareness, speech perception, and direct access to speech. Based on evidence (Galaburda, Sherman, Rosen, Aboitiz, & Geschwind, 1985; Plante, Boliek, Binkiewicz, & Erly, 1996; Rumsey, Andreason, Zemetkin, & Aquino, 1994) on functional imaging in the field of reading development, defects in specific areas of the brain, such as planometrial symmetry or poor functional angular torture, are associated with dyslexia. Based on neurological studies (Lyon, Shaywitz, & Shaywitz, 2003; Meyler et al., 2007; S. E. Shaywitz & Shaywitz, 2007; Spironelli, Penolazzi, & Angrilli, 2008) Forehead areas, parietal forehead, temporal forehead, cortex hippocampus and right hemisphere thalamus, left angular and left temporal lobe are some of the areas that have dysfunction in dyslexic people.

One of the tools for measuring the level of brain activity is the recording of brain waves by an electroencephalographic device invented to examine the function of the brain (not the structure of the banana). So far, a lot of research has been done to identify the pattern of brain waves in dyslexic people Scarlar et al.(1995, Cited in Abdeldayem & Selim, 2005) found that the Electroencephalogram (EEG) activity of dyslexic individuals showed that there was a significant difference in the higher power of tetanus band activity in dyslexics; The results of research by (Arns, Peters, Breteler, & Verhoeven, 2007) also confirmed this result. The results showed that in the dyslexic group, more slow wave activity (delta and theta) was observed in temporal and cerebral regions of the brain and increased beta 1, especially in the F7 region. According to the study, coherence (EEG correlation) in the anterior, central, and temporal regions also increased for all frequency bands. Weakening of beta strength in the central and bilateral areas in children with dyslexia It has also been reported by Gallin et al. (1986; cited in Papagiannopoulou & Lagopoulos, 2016). The difference between the beta and delta waves has been confirmed in at least two studies (Lavidor, Johnston, & Snowling, 2006; Ziegler, 2006), and others. In one study, Fadzal et al. (2012) identified the EEG signals of dyslexic and normal children in two modes: rest and writing words; Processed, analyzed and compared. Four electrodes C3, C4, P3, P4 were used to record and record EEG signals. The recorded EEG signals were filtered using a bandwidth filter with a frequency range of 8 Hz. Analysis of EEG signals showed that the frequency range of EEG signals during writing at each electrode position at a lower beta band frequency is much larger for dyslexic children than for normal reading children. The frequency range of EEG signals was 20 to 28 Hz for dyslexic children and 14 to 22 Hz for normal children. Duffy, Denckla, Bartels, and Sandini (1980) also reported an increase in alpha strength in the left hemisphere of temporal areas as well as the left ventricular areas of dyslexics. On the other hand, Butler, Breteler, Arns, Peters, Giepman, and

Verhoeven (2010) have stated that a significant increase in alpha coherence may be indicative of attention processes that improve reading.

There are anatomical studies (Galaburda, Sherman, Rosen, Aboitiz, Geschwind,1985 & Habib,2000) which show an absence of the usual left-right hemisphere asymmetry of the planum temporale in dyslexia or suggest a possible role of the left inferior frontal gyrus in speech perception and rapid auditory processing, as well as in phonological aspects of reading (Habib,2000), although no strong effects have been reported (Habib,2000). Eckert et al. (2003) found anatomical anomalies underlying the double-deficit subtype of dyslexia. Their findings suggest that impairments in a frontal-cerebellar network may play a role in delayed reading development in dyslexia.

To study the neural factors of dyslexia, functional neuroimaging has been used. However, there is not much evidence with respect to developmental dyslexia since this research has focused on (young) adults (Habib,2000). Only Shaywitz and Shaywitz (Shaywitz & Shaywitz,2002; Shaywitz & Shaywitz, 2005). used children in their neuroimaging studies in order to examine the neural systems for reading during the acquisition of literacy. These reports show a failure of left hemisphere posterior brain systems to function properly during reading (Shaywitz & Shaywitz,2002; Shaywitz & Shaywitz, 2005). The majority of studies show increased activation in the basal surface of the temporal lobe, the posterior portion of the superior and middle temporal gyri, extending into temporoparietal areas and the inferior frontal lobe during tasks requiring reading and phonological processing (Vellutino,2004). Shaywitz et al. (2002) supports these findings, however they show evidence of right hemisphere activation in the posterior temporal parietal regions. This could reflect compensatory processes or could indicate that other nonlinguistic factors are related to reading disability (Shaywitz & Shaywitz,2002; Shaywitz & Shaywitz, 2005; Vellutino,2004).

Undoubtedly, the researcher's efforts have paved the way for the identification of neuropsychological foundations of dyslexia. But most of this research seems to have neglected attention to dyslexia as heterogeneous disability. As Sophie and Rico (2002, cited by Hill & Fiurlo, 1961) have suggested, the notion of these children as a "common group by reading" may inadvertently lead to a lack of recognition of learning disabilities, possibly due to referral biases. Different diagnoses result from the tools used. These necessitate more detailed work to identify the relationships of the neuroscientific, physiological, and functional nerves between the types of dyslexia that can lead to more effective interventions for these children (Spring,

2001, quoted in Hill & Fiurlo, 1961). Significance of Attention Deficit Hyperactivity Disorder by Walker and Norman (2006), Breteler et al. (2010), Penolazzi, Spironelli, and Angrilli (2008), Arns et al. (2007), Papagiannopoulou and Lagopoulos (2016) and Fadzal et al. (2012) are emphasized.

Accordingly, the present study aims to identify the pattern of brain waves in dyslexic subgroups. For this purpose, one of the known divisions, namely the division of dyslexics into two subconscious and linguistic subgroups, has been used. This classification is provided by Bakker (1992) and his model Brasan for normal reading growth as well as explanation of dyslexia. According to this model, known as the Treadmill Baker model, primary learning is created primarily by the right hemisphere of the brain, while final reading should normally be controlled by the left hemisphere of the brain (Bakker, 1992). According to the equilibrium model, reading disorders occur when a hemisphere change occurs to control reading deviations (Dryer, Beale, & Lambert, 1999).

Baker classified dyslexic readers into two categories: type P or perceptual, type L, or linguistic. Type P or perceptual dyslexia occurs when a person in the dominant use of the right hemisphere reading strategy is unable to shift to the production of left-wing strategies in the advanced reading stages. Accordingly, the reader continues to focus on the perceptual features of the text, leading to a precise but relatively slow and divided reading reading; These types of people make a lot of time-consuming mistakes, such as repetition and self-correction. Another subcategory, the language type or L type dyslexia, occurs when a person relies largely on the language strategies of the left hemisphere in the early stages of reading development. Model L malfunctions, fast readers, but incorrect, and many nominal errors such as deletion, addition, and replacement (Dryer et al., 1999).

In the present study, in order to identify the neural dysfunction pattern in the mentioned subgroups of dyslexia (only type L and type P), quantitative electroencephalography (QEEG) dyslexia has been used. What is the difference between the three groups of dyslexic, perceptual, and normal students in reading each other in order to examine the pattern of cerebral waves?

Method

Sample

The present study is a comparative cause in terms of data collection method. The statistical population of the study included all students in grades 1 to 5 who were illiterate in special centers for learning disabilities and normal students who were studying in Birjand primary school who were studying in the academic year of 2018-19. Targeted sampling was used to select perceptual (P) and language (L) dyslexic students. In this study, of the 27 subjects studied, 24 (equivalent to 9.88%) were boys and 3 (equivalent to 1.11%) were girls. According to the information obtained from the educational level, 6 people (equivalent to 3.22%) in the first grade, 8 people (equivalent to 6.29%) in the second grade, 10 people (equivalent to 37%) in the third grade, 2 people (equivalent to 4.7%) in The fourth grade and 1 person (equivalent to 7.3%) were studying in the fifth grade.

instrument

Questionnaire 54 Tabrizi Questionnaire To collect information about the physical and mental condition of students, the 54th Tabrizi Questionnaire Questionnaire (2012) was used (Tabrizi, 2010). This questionnaire contains 11 paragraphs that include the following information These items include general information, birth, pregnancy, neurodevelopmental stages, physical health, family, child behavioral problems, educational problems, and the child's self-concept. This questionnaire is completed by the mother.

The Wechsler test of this scale was developed by Wechsler (1969) to measure children's intelligence. The Wechsler Intelligence Test is one of the most authoritative and widely used tests for assessing children's intelligence (Marnat, 1996). The validity of this test has been reported through the two-half method for general intelligence 0.97, for verbal intelligence 0.97 and for practical intelligence 0.93 (Marnat, 1996). in this study of its Persian form by Shahim (1994) It has been used to measure the intelligence of normalized children aged 6 to 13 years. The validity of this test has been reported through the two-way method for general intelligence 0.94, non-verbal intelligence 0.96; Also, the correlation of the test with academic achievement and retraining rate was reported to be 0.88 and 0.85, respectively (Shahim, 1994).

Disorders in reading and reading comprehension tests were used to identify and isolate dyslexic students. This test includes 11 Persian texts, each written on a card. Card number one is a practice card and the results are not taken into account in the calculations. 2 to 11 cards are

the main cards and both cards belong to the same base. In this way, the ability to read, understand and read the speed of students in each grade is measured by two texts.

The validity of the structure of the test in reading accuracy for pair cards (story text at the relevant basic level) between 0.6 to 0.9 and for individual cards (text of the relevant grade textbook) between 0.7 to 0.9, comprehension Content for even cards is between 0.3 and 0.6 and for individual cards is between 0.3 and 0.5 And the reading speed for even and odd cards fluctuated between 0.8 and 0.9 separately. All coefficients were significant at the $p < 0.100$ level. In order to calculate the reliability of the test, two methods of Cronbach's alpha and parallel were used. Cronbach's alpha for reading accuracy in pair cards 0.9 and individual cards 0.8, The reading comprehension score was 0.8 on even cards, 0.7 on individual cards, 0.9 for reading speed on even cards, and 0.8 on individual cards. Parallel validity in couple and individual cards in reading accuracy, comprehension and reading speed were all 0.9 (Hosseini, Pourtemad, & Heidari, 2005).

A small amount of electroencephalography was used in this study to record the brain waves of the target groups using the Mitsar amplifier, during which a special cap was placed on the patient's head. From 19 head area that dinner, F3, F7, Fp2, Fp1, O2, O1, T6, P4, PZ, P3, T5, T4, C4, CZ, C3, T3, F8, F4, FZ The waves have been recorded.

The power was calculated in the following frequency bands Delta (1-4 Hz), Theta (4-8 Hz), alpha (8-12 Hz), beta (12-25 Hz).

The brain waves were recorded in a quiet room in both open and closed eye conditions for 6 minutes at a sampling rate of 500 Hz. The mean left and right ear electrodes (E1, E2) were used as reference electrodes. Vienna EEG software was used to record brain waves and NeuroGuide™ software was used to analyze brain waves.

To process brain signals, First the brain signals In NeuroGuide software Filtered by a 1-40 Hz midpoint filter. Then in NeuroGuide software Parts of the signal that have a motion artifact, Noise of eye movements Electroencephalogram (EOG) And noise of nerve's stimulation of the muscle. contraction Electroencephalogram (EMG) Have been manually deleted. Then The power was calculated in the following frequency bands Delta (1-4 Hz), Theta (4-8 Hz), alpha (8-12 Hz), beta (12-25 Hz), have been extracted and analyzed with the help of this software.

Design

Using this method, the city center of learning disorders was first referred to. Then a list of students with reading disorders from first to fifth grade was provided to the researcher. In the next step, the parents of each of these students were contacted and they were invited to participate in the research. Poor-e-Etemad test was performed on dyslexic students who were willing to cooperate. According to the analysis of errors in this test, students whose basic errors were of the type of deletion and addition of the word, inversion, displacement, etc., under the linguistic group and students whose basic errors were mainly self-correction, repetition and pause. They were placed under the perceptual group. Since the study group in the present study was normal students in reading; An available sampling method was used to select this sample. For this purpose, a boys' school that wanted to cooperate was selected. Then, 10 first to fifth grade students were selected who, according to their teachers, were normal in reading, and in addition were willing to cooperate with the research. The criteria for entering this group other than (obtaining a low score in the diagnostic test) were similar to the criteria for dyslexic students. The mentioned groups were age equivalent. Inclusion criteria in this study include normal IQ (95-110), age range 7-11, primary school education, lack of history of mental disorders, brain injury, neurological, sensory and motor problems and reading problems related to emotional disorders.

in the registering, firstly, it is asked people to stare at a fixed point, while they are in a calm condition.. And minimize blinking and extra movements of your head, hands and feet. The subjects were then recorded in the open eye for 6 minutes. After a 3 to 5 minute break, the students were asked to return to the previously mentioned conditions and close their eyes. In closed eye mode, the recording time was 6 minutes for each child. Then all the encrypted information was stored separately in a folder for each person. Due to the small number of dependent variables (absolute and relative power of the waves) and the structure of the hypotheses and questions considered in the research, multivariate analysis of variance (MANOVA) and single-variable analysis of variance (ANOVA) were used. It should be noted that data analysis was performed using software packages, NeuroGuide, SPSS version 25, STATA version 16, MATLAB software and Excel version 2010.

Results

Comparison of the absolute power of brain waves of study groups in closed eye mode

Based on the findings of single-variance analysis and taking into account Bonfroni correction ($0.05 \div 4 = 0.0125$) was observed In all of the brain locations considered, the difference of the absolute average power of the brain wave in the three study groups at $p < 0.05$ was not significant. It should be noted that if the Bonfroni correction is ignored, in the FP2 brain location, the assumption of the equality of the absolute power averages of the delta wave is rejected ($F(2, 13.679) = 4.502$, $p = 0.031 < 0.05$). According to the Hughes Games follow-up test, difference the mean of the absolute power of the linguistic and normal groups in reading is significant ($p = 0.023 < 0.05$).

In order to confirm the previous content, according to Figure 1, it is clear that considering the Bonfroni correction, significant values (p) resulting from the univariate analysis of variance for all locations and brain waves are above the line 0.125 (blue line). Ignoring the univariate correction, it is observed that in the FP2 brain location, a significant value corresponding to the delta wave is below the 0.05 line (red line).

Comparison of the absolute power of brain waves of study groups in open eye mode

Based on the findings of the univariate analysis of variance and considering the Bonfroni correction ($0.05 \div 0.04 = 0.0125$), it was observed that in all brain locations considered, sufficient reasons to reject the assumption of equality of absolute brain power averages in three There was no study group at $p < 0.05$. According to Error! Reference source not found Figure 2 It is clear that by considering the buffering correction, the significant values (p) obtained from the one-variable analysis of variance for all locations and brain waves are above the 0.125 line (blue line).

Comparison of the relative power of brain waves in study groups

Based on the analysis, it was observed that in the open and closed eye modes for each of the delta, theta and beta waves, there is no significant difference between the study groups in terms of relative power. Also, based on the results obtained for the relative powers of the alpha wave in open and closed eyes, it was observed that in the open eye, there is no significant difference between the study groups, but in the closed eye, there is a significant difference for some brain locations between study groups. Therefore, in the following, the output and tables related to delta, theta and beta waves in open-eye and closed-eye modes and alpha wave in

open-eye mode are omitted, and only the details related to alpha wave in closed-eye mode Has been expressed.

According to Figure 3 For all brain locations, the mean relative power of the alpha wave in the normal reading group is higher than in other study groups Therefore, the significance of the differences was investigated. For this purpose, first, the natural power distribution of alpha wave was investigated using Shapiro-Wilk test. In order to facilitate the study of significant values obtained from Shapiro-Wilk tests, these values are plotted in Figure 4.

According to the findings of Figure 4, it was observed that for the FP1 brain location, the assumption of the natural distribution of the relative power of the alpha wave in the linguistic (SW(10)= 0.802, $p=0.015<0.05$) and perceptual (SW(8)= 0.790, $p=0.022<0.05$) groups was rejected. For FP2 brain location, the assumption of normal distribution of alpha wave relative power in linguistic (SW(10)= 0.808, $p=0.018<0.05$) and perceptual (SW(8)= 0.736, $p=0.008<0.05$) groups became significant. Also, for F7 (SW(8)= 0.768, $p=0.013<0.05$) and CZ (SW(8)= 0.763, $p=0.011<0.05$) brain locations in the perceptual group, the hypothesis of normal distribution of alpha wave relative power was rejected. In addition, for the P3 sites in the normal reading group (SW(9)= 0.790, $p=0.016<0.05$), the PZ in the linguistic (SW(10)= 0.822, $p=0.027<0.05$) and normal reading groups (SW(9)= 0.745, $p=0.005<0.05$) assumed the medical distribution of the relative strength of the alpha wave. For F8 brain location in the groups assuming the natural distribution of the relative power of the alpha wave in the linguistic (SW(10)= 0.839, $p=0.042<0.05$) and perceptual (SW(8)= 0.796, $p=0.026<0.05$) groups was significant.

Then, for each of the brain locations where all study groups had normal distribution, univariate one-way analysis of variance and for other locations, non-parametric Used Kruskal-Wallis test to compare the relative powers of alpha wave in the closed state. The specific output of the Levin test and univariate analysis of variance is separated by brain locations.

According to the findings of Levin test, it was observed that in all considered brain locations, there were not enough reasons to reject the assumption of homogeneity of alpha wave relative power variances in the three study groups at the level of $P<0.05$. In addition, based on the output of univariate one-way analysis of variance and regardless of Bonferroni correction, for each of the brain locations between study groups in terms of relative power of alpha wave in the blindfold, a significant difference at the level of $P<0.05$ did not exist. The

output of the non-parametric test of Croce-Wallis for brain locations is Cz, F8, F7, FP2, FP1, P3 and Pz.

According to Table 2, it was observed that in each of the FP1 (SW(2)= 6.685, $p=0.035<0.05$) and FP2 (SW(2)= 8.056, $p=0.018<0.05$) brain locations, the assumption of the same alpha wave power distribution in the study groups was rejected. Nonparametric pairwise comparisons were used to identify groups with different distributions. It should be noted that in this table, in order to control the error of the first type 0.05, adjusted significant values were used.

According to Table 3 for FP1 location, there was a significant difference in the relative power distribution of the alpha wave in the closed state between the linguistic and normal reading groups ($P=0.030<0.05$). Similarly for the FP2 locus, the assumption that the relative power distribution of the alpha wave was the same in the closed-eye state between the linguistic and normal reading groups was rejected ($P=0.014<0.05$). According to the mean scores provided, it was observed that in each of the brain locations FP1 and FP2 the relative power of the alpha wave in the blindfold mode for the normal group in reading is higher than the linguistic group.

Discussion

The aim of this study was to compare the brain wave patterns of dyslexic students in perceptual type, language type and normal reading. In this study, no significant difference was observed in the two states of closed and open eyes in absolute power, but a significant difference was observed in the relative power of alpha wave in two channels Fp1 and Fp2. Thus, in the FP1 and FP2 brain locations, the relative power of the alpha wave in the blindfold mode was higher for the normal reading group than for the linguistic group.

One of the researches that is somewhat thematically close to the present study is the research of Arns et al. (2007); In this regard, it has compared the pattern of brain wave activity in the two groups of dyslexic and normal non-adult years. For this reason, its results have been compared with the present study Comparing the results of the two studies shows the differences and similarities in which accuracy can lead to valuable points.

Difference

While according to the research of Arns et al. (2007) in the delta wave of F7, Fp2, Fp1 and T6 regions and theta wave of Fp2, Fp1 and F7 regions, there was a difference in reading and normal students, but in the present study there was a difference in absolute wave power. No brain was found between the three groups. Different age groups in the two studies may play a role in the difference in results. While in the study of Arns et al. (2007)., The age range of the sample was between 8 and 16 years, in the present study, the age of the subjects was between 7 and 11 years.

Similarities

According to the research of Arns et al. (2007) Fp1 and Fp2 are two areas in which dyslexics and normal people in reading show differences in the activity of waves (delta and theta). The importance of these two areas of the brain, Is also shown in the present research. The results of the present study showed that the relative power of the alpha wave in the closed state in the two channels Fp1 and Fp2 for the linguistic group is less than the normal group in reading. Before discussing the findings of the study, it is necessary to explain the alpha wave and the function of the prefrontal cortex.

In a study conducted by Çiçek and Nalçacı (2001) on right-handed subjects, they concluded that the alpha wavelength increased at rest and the left frontal lip alpha decreased significantly during cognitive tasks. In justification of this finding, it was stated that with increasing alpha wave, the amount of cortical arousal decreases, thus reducing the processing of data related to unnecessary external stimuli, such a strategy causes the focus to be focused on the main test and thus performance Optimally increases

An important part of the frontal lobe is the "prefrontal cortex", which is located in front of the motor cortex (Santrak, 2003). from the perspective of the neuropsychology (Brocki & Bohlin, 2004; Thorell, Lindqvist, Bergman Nutley, Bohlin, & Klingberg, 2009) Executive functions are associated with the prefrontal cortex of the brain and include the highest cognitive functions necessary for purposeful behavior. Some neuroscientists consider the prefrontal cortex to be an executive function because it is involved in reviewing and organizing thinking (Owen, 1997, quoted in Santrak, 2003). Neurological executive functions are important structures that are related to the psychological processes responsible for controlling consciousness and thinking in action. These functions regulate behavioral outputs and usually include inhibition and control of stimuli, working memory, sustained attention, planning, and

organization (Denckla, 2003). As mentioned, one of the most important executive functions is response deterrence and sustained attention. Response inhibition is the ability to think before action. This skill provides the ability to assess posture and behavior before surgery (Dawson & Guare, 2004). Students whose frontal lobe (the area that plays a key role in attention and inhibition) is damaged are easily distracted by unrelated stimuli and therefore often cannot follow certain instructions (Santrak, 2003).

Based on the Barclay Barkley (1997) inhibition model, it is assumed that the proper functioning of executive functions depends on the proper functioning of inhibition in the frontal lobe and forehead (Alizadeh & Zahedipour, 2004). Behavioral inhibition patterns state that impairment of inhibition function affects the four basic executive functions, including working memory, internal speech, reconstruction, and self-regulation of motivation and excitement, resulting in impaired self-control function (Barkley, 1997).

Conclusion

Executive functions have been at the heart of recent theories of the neuropsychological risk of children at risk of disability; specially for students with learning disabilities (reading, dictation and math) and students with attention deficit / hyperactivity disorder. Impairment of behavioral inhibition and poor control impedes effective self-management, and impulsive behaviors are a manifestation of such a situation (Alizadeh & Zahedipour, 2004).

An important point in the present study is the existence of common characteristics between dyslexic and hyperactive students; One of the common features of these two groups is weakness in executive functions (Masterpasqua & Healey, 2003). Will Cut et al (2000; quoted by Moradi, Famarzi, & Abedi, 2014) stated that dyslexia is widely associated with Attention Deficit / Hyperactivity Disorder is comorbid. According to research by Clarke, Barry, McCarthy, and Selikowitz (2002), students with ADHD have more theta ratio and lower alpha lineage in brain waves. Based on the above, it is possible that dyslexic students with hyperactivity are part of the linguistic subgroup; This statement needs to be further researched in this field

This study was associated with limitations such as low number of dyslexic girls and age limit of subjects. Therefore, it is recommended that brain scans be performed on girls at different age intervals. Research suggestions include conducting similar studies in larger samples for higher reproducibility, using task reading during EEG recording of dyslexic

students, evaluating the effectiveness of neurofeedback in forearm areas (FP1 and FP2) to increase executive performance and thus improve language dysfunction.

Accepted Manuscript (Uncorrected Proof)

Reference

- Abdeldayem, H., & Selim, O. (2005). Neuropsychological assessment and EEG evaluation of dyslexic children. *Int J Child Neuropsychiatr*, 2(2), 155-162.
- Alizadeh, H., & Zahedipour, M. (2004). Executive functions in children with and without developmental coordination disorder. *Advances in Cognitive Science*, 6(3), 49-56.
- Arns, M., Peters, S., Breteler, R., & Verhoeven, L. (2007). Different brain activation patterns in dyslexic children: evidence from EEG power and coherence patterns for the double-deficit theory of dyslexia. *Journal of integrative neuroscience*, 6(01), 175-190. DOI: 10.1142/S0219635207001404
- Association, A. P. (2013). *Diagnostic and statistical manual of mental disorders (DSM-5®)*: American Psychiatric Pub.
- Bakker, D. J. (1992). Neuropsychological classification and treatment of dyslexia. *Journal of learning disabilities*, 25(2), 102-109. <https://doi.org/10.1177/002221949202500203>
- Barkley, R. A. (1997). *ADHD and the nature of self-control*: Guilford Press.
- Barkley, R. A. (2011). The important role of executive functioning and self-regulation in ADHD. *J Child Neuropsych*, 113(21), 41-56.
- Breteler, M. H., Arns, M., Peters, S., Giepman, I., & Verhoeven, L. (2010). Improvements in spelling after QEEG-based neurofeedback in dyslexia: A randomized controlled treatment study. *Applied psychophysiology and biofeedback*, 35(1), 5-11. DOI: 10.1007/s10484-009-9105-2
- Brocki, K. C., & Bohlin, G. (2004). Executive functions in children aged 6 to 13: A dimensional and developmental study. *Developmental neuropsychology*, 26(2), 571-593. DOI: 10.1207/s15326942dn2602_3
- Casanova, M. F., Araque, J., Giedd, J., & Rumsey, J. M. (2004). Reduced brain size and gyrification in the brains of dyslexic patients. *Journal of Child Neurology*, 19(4), 275-281. DOI: 10.1177/088307380401900407
- Çiçek, M., & Nalçacı, E. (2001). Interhemispheric asymmetry of EEG alpha activity at rest and during the Wisconsin Card Sorting Test: relations with performance. *Biological psychology*, 58(1), 75-88. [https://doi.org/10.1016/S0301-0511\(01\)00103-X](https://doi.org/10.1016/S0301-0511(01)00103-X)
- Clarke, A. R., Barry, R. J., McCarthy, R., & Selikowitz, M. (2002). EEG analysis of children with attention-deficit/hyperactivity disorder and comorbid reading disabilities. *Journal of learning disabilities*, 35(3), 276-285. <https://doi.org/10.1177/002221940203500309>

- Dawson, P., & Guare, R. (2004). Overview of executive skills. *Executive skills in children and adolescents: A practical guide to assessment and intervention*, 1-126.
- Denckla, M. B. (2003). ADHD: topic update. *Brain and Development*, 25(6), 383-389. [https://doi.org/10.1016/S0387-7604\(03\)00057-3](https://doi.org/10.1016/S0387-7604(03)00057-3)
- Dryer, R., Beale, I. L., & Lambert, A. J. (1999). The balance model of dyslexia and remedial training: An evaluative study. *Journal of learning disabilities*, 32(2), 174-186. <https://doi.org/10.1177/002221949903200207>
- Duffy, F. H., Denckla, M. B., Bartels, P. H., & Sandini, G. (1980). Dyslexia: Regional differences in brain electrical activity by topographic mapping. *Annals of Neurology: Official Journal of the American Neurological Association and the Child Neurology Society*, 7(5), 412-420. <https://doi.org/10.1002/ana.410070505>
- Eckert, M. A., Leonard, C. M., Richards, T. L., Aylward, E. H., Thomson, J., & Berninger, V. W. (2003). Anatomical correlates of dyslexia: frontal and cerebellar findings. *Brain*, 126(2), 482-494. DOI: 10.1093/brain/awg026
- Fadzal, C. C. W., Mansor, W., Lee, K. Y., Mohamad, S., Mohamad, N., & Amirin, S. (2012). *Comparison between characteristics of EEG signal generated from dyslexic and normal children*. Paper presented at the 2012 IEEE-EMBS Conference on Biomedical Engineering and Sciences. <https://doi.org/10.1109/IECBES.2012.6498210>
- Ferrer, E., Shaywitz, B. A., Holahan, J. M., Marchione, K., & Shaywitz, S. E. (2010). Uncoupling of reading and IQ over time: Empirical evidence for a definition of dyslexia. *Psychological science*, 21(1), 93-101. <https://doi.org/10.1177/0956797609354084>
- Galaburda, A. M., Sherman, G. F., Rosen, G. D., Aboitiz, F., & Geschwind, N. (1985). Developmental dyslexia: four consecutive patients with cortical anomalies. *Annals of Neurology: Official Journal of the American Neurological Association and the Child Neurology Society*, 18(2), 222-233. <https://doi.org/10.1002/ana.410180210>
- Galaburda, A. M., Sherman, G. F., Rosen, G. D., Aboitiz, F., & Geschwind, N. (1985). Developmental dyslexia: four consecutive patients with cortical anomalies. *Annals of Neurology: Official Journal of the American Neurological Association and the Child Neurology Society*, 18(2), 222-233. DOI: 10.1002/ana.410180210
- Hallahan, D. P., Lloyd, J., Kaufman, J. M., P. Weiss, M., & A. Martinez, E. (2005). *Learning Disabilities (Principles, Characteristics, and Effective Teaching)*. Tehran: Arasbaran Publications.

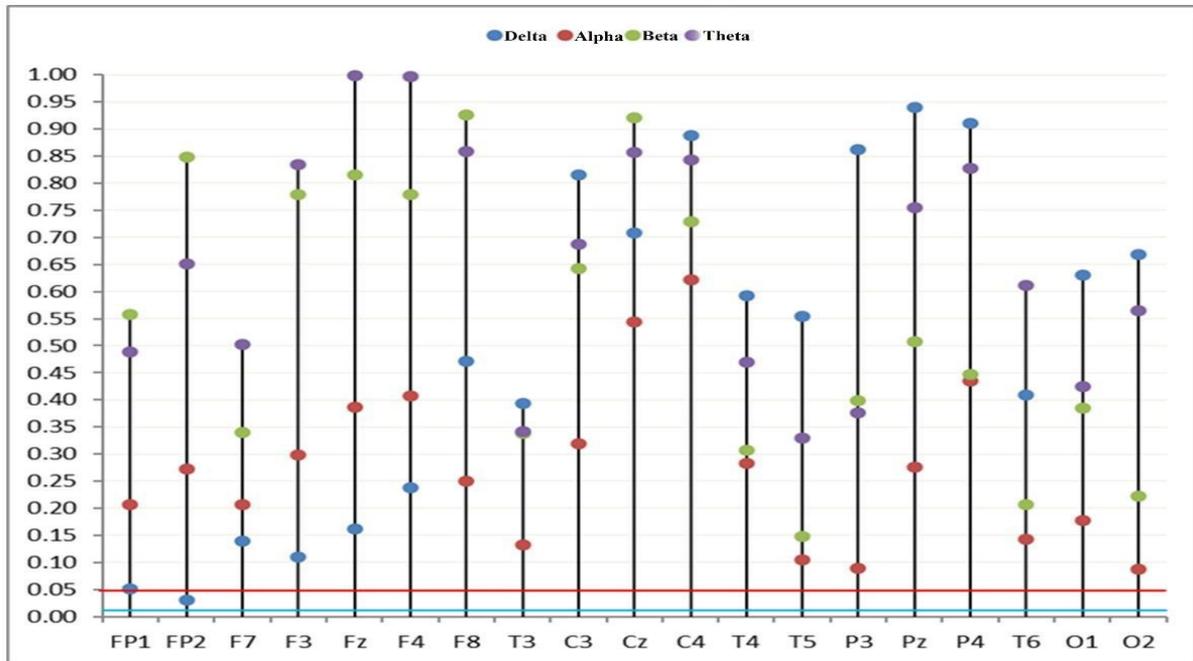
- Habib, M. (2000). The neurological basis of developmental dyslexia: an overview and working hypothesis. *Brain*, 123(12), 2373-2399. DOI: 10.1093/brain/123.12.2373
- Hill, J. b., & Fiurlo, K. A. (1961). *Psychological neurosis in school*. Tehran: Arjmand Publications.
- Hosseini, F., pouretemad, H., & Heidari, M. (2005). Comparison of phonological skills in two subgroups of perceptual and linguistic. *Advances in Cognitive Science*, 3(27), 21-15.
- Kirk, S., Gallagher, J. J., Coleman, M. R., & Anastasiow, N. J. (2011). *Educating exceptional children*: Cengage Learning.
- Lavidor, M., Johnston, R., & Snowling, M. J. (2006). When phonology fails: Orthographic neighbourhood effects in dyslexia. *Brain and Language*, 96(3), 318-329. <https://doi.org/10.1016/j.bandl.2005.06.009>
- Lyon, G. R., Shaywitz, S. E., & Shaywitz, B. A. (2003). A definition of dyslexia. *Annals of dyslexia*, 53(1), 1-14. <https://doi.org/10.1007/s11881-003-0001-9>
- Marnat, G. G. (1996). *Guide to Psychological Assessment*. Tehran: Roshd Publications.
- Masterpasqua, F., & Healey, K. N. (2003). Neurofeedback in Psychological Practice. *Professional Psychology: Research and Practice*, 34(6), 652. <https://doi.org/10.1037/0735-7028.34.6.652>
- Meyler, A., Keller, T. A., Cherkassky, V. L., Lee, D., Hoeft, F., Whitfield-Gabrieli, S., . . . Just, M. A. (2007). Brain activation during sentence comprehension among good and poor readers. *Cerebral Cortex*, 17(12), 2780-2787. <https://doi.org/10.1016/j.neuropsychologia.2008.03.012>
- Moradi, M. R., Faramarzi, S., & Abedi, A. (2014). The effectiveness of phonological games on reading performance of dyslexic male students. *Knowledge and research in applied psychology*, 15(1), 44-51.
- Papagiannopoulou, E. A., & Lagopoulos, J. (2016). Resting state EEG hemispheric power asymmetry in children with dyslexia. *Frontiers in pediatrics*, 4, 11. <https://doi.org/10.3389/fped.2016.00011>
- Penolazzi, B., Spironelli, C., & Angrilli, A. (2008). Delta EEG activity as a marker of dysfunctional linguistic processing in developmental dyslexia. *Psychophysiology*, 45(6), 1025-1033. <https://doi.org/10.1111/j.1469-8986.2008.00709.x>
- Plante, E., Boliek, C., Binkiewicz, A., & Erly, W. K. (1996). Elevated androgen, brain development and language/learning disabilities in children with congenital adrenal hyperplasia. *Developmental Medicine & Child Neurology*, 38(5), 423-437. <https://doi.org/10.1111/j.1469-8749.1996.tb15100.x>

- Rumsey, J. M., Andreason, P., Zametkin, A. J., & Aquino, T. (1994). " Failure to activate the left temporoparietal cortex in dyslexia: An oxygen 15 positron emission tomographic study": Erratum.
- Santrak, J. W. (2003). *Santrak Psychology*. Tehran: Rasa Publications.
- Schlaggar, B. L., & McCandliss, B. D. (2007). Development of neural systems for reading. *Annu. Rev. Neurosci.*, 30, 475-503. <https://doi.org/10.1146/annurev.neuro.28.061604.135645>
- Seidman, L. J. (2006). Neuropsychological functioning in people with ADHD across the lifespan. *Clinical psychology review*, 26(4), 466-485. <https://doi.org/10.1016/j.cpr.2006.01.004>
- Shahim, S. (1994). Application of Wechsler Intelligence Scale for Children in Iran. *Journal of Psychological Research*, 1(3-4), 32.
- Shaywitz, B. A., Shaywitz, S. E., Blachman, B. A., Pugh, K. R., Fulbright, R. K., Skudlarski, P., . . . Marchione, K. E. (2004). Development of left occipitotemporal systems for skilled reading in children after a phonologically-based intervention. *Biological psychiatry*, 55(9), 926-933. <https://doi.org/10.1016/j.biopsych.2003.12.019>
- Shaywitz, B. A., Shaywitz, S. E., Pugh, K. R., Mencl, W. E., Fulbright, R. K., Skudlarski, P., . . . Lyon, G. R. (2002). Disruption of posterior brain systems for reading in children with developmental dyslexia. *Biological psychiatry*, 52(2), 101-110. [https://doi.org/10.1016/s0006-3223\(02\)01365-3](https://doi.org/10.1016/s0006-3223(02)01365-3)
- Shaywitz, S. E., & Shaywitz, B. A. (2007). The neurobiology of reading and dyslexia. *The ASHA Leader*, 12(12), 20-21.
- Shaywitz, S. E., & Shaywitz, B. A. (2005). Dyslexia (specific reading disability). *Biological psychiatry*, 57(11), 1301-1309. DOI: 10.1016/j.biopsych.2005.01.043
- Shaywitz, S. E., & Shaywitz, B. A. (2008). Paying attention to reading: the neurobiology of reading and dyslexia. *Development and psychopathology*, 20(4), 1329-1349. <https://doi.org/10.1017/S0954579408000631>
- Spironelli, C., Penolazzi, B., & Angrilli, A. (2008). Dysfunctional hemispheric asymmetry of theta and beta EEG activity during linguistic tasks in developmental dyslexia. *Biological psychology*, 77(2), 123-131. <https://doi.org/10.1016/j.biopsycho.2007.09.009>
- Tabrizi, M. (2010). *Treatment of reading disorders*. Tehran: Faravan Publications.
- Temple, E. (2002). Brain mechanisms in normal and dyslexic readers. *Current opinion in neurobiology*, 12(2), 178-183. [https://doi.org/10.1016/S0959-4388\(02\)00303-3](https://doi.org/10.1016/S0959-4388(02)00303-3)

- Thorell, L. B., Lindqvist, S., Bergman Nutley, S., Bohlin, G., & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental science*, 12(1), 106-113. <https://doi.org/10.1111/j.1467-7687.2008.00745.x>
- Vandermosten, M., Boets, B., Wouters, J., & Ghesquière, P. (2012). A qualitative and quantitative review of diffusion tensor imaging studies in reading and dyslexia. *Neuroscience & Biobehavioral Reviews*, 36(6), 1532-1552. <https://doi.org/10.1016/j.neubiorev.2012.04.002>
- Walker, J. E., & Norman, C. A. (2006). The neurophysiology of dyslexia: A selective review with implications for neurofeedback remediation and results of treatment in twelve consecutive patients. *Journal of Neurotherapy*, 10(1), 45-55. https://doi.org/10.1300/J184v10n01_04
- Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades?. *Journal of child psychology and psychiatry*, 45(1), 2-40. DOI: 10.1046/j.0021-9630.2003.00305.x
- Ziegler, J. C. (2006). Do differences in brain activation challenge universal theories of dyslexia? *Brain and Language*, 98(3), 341-343. <https://doi.org/10.1016/j.bandl.2005.05.002>

Figure 1

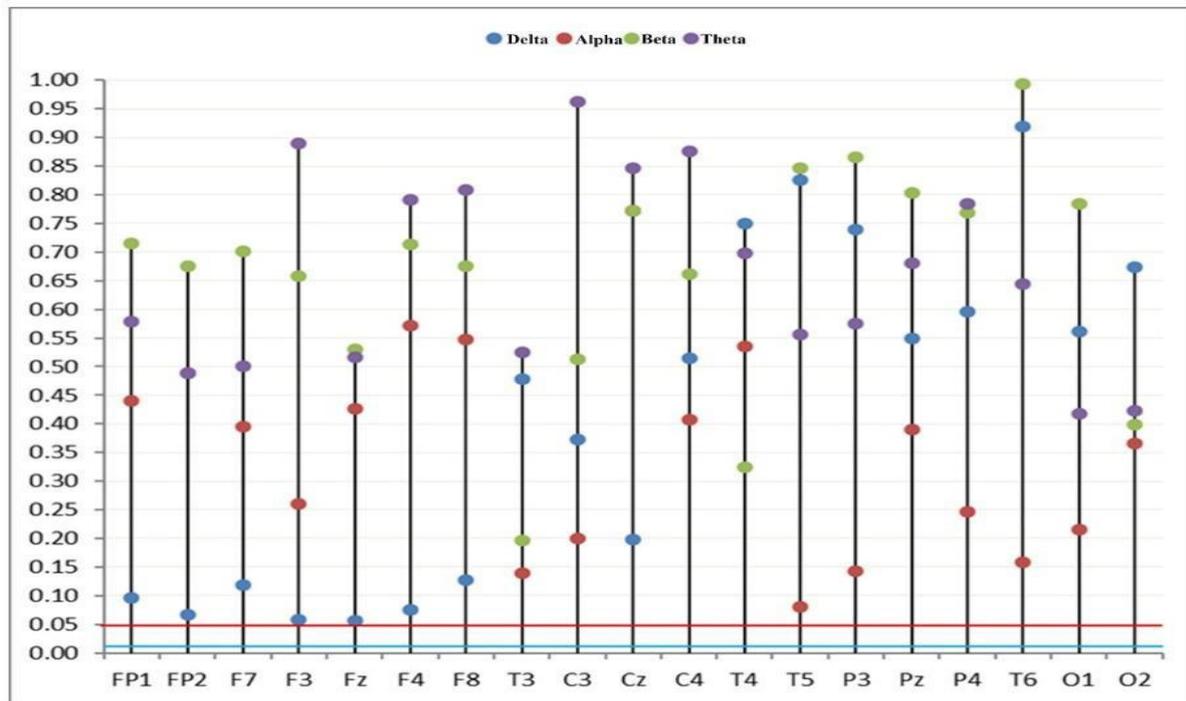
Significant level values of univariate analysis of variance by locations and brain waves in the closed state



Accepted Manuscript

Figure 2

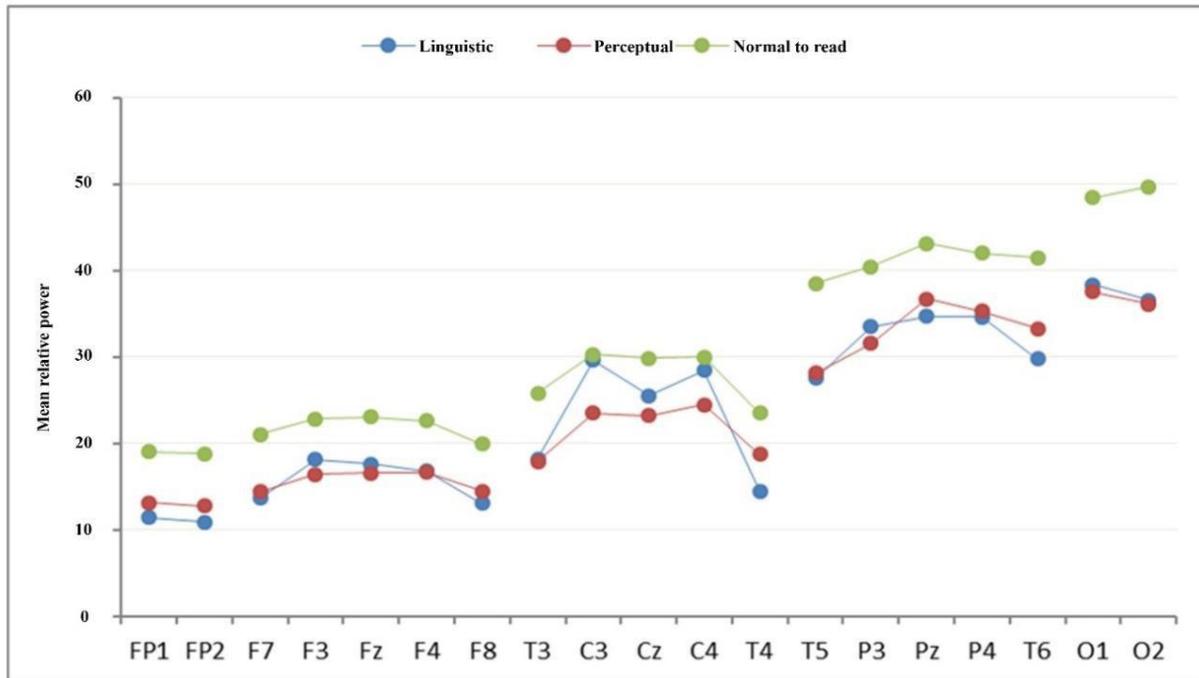
Significant level values of univariate one-way analysis of variance by locations and brain waves in the open ey



Accepted Manuscript

Figure 3

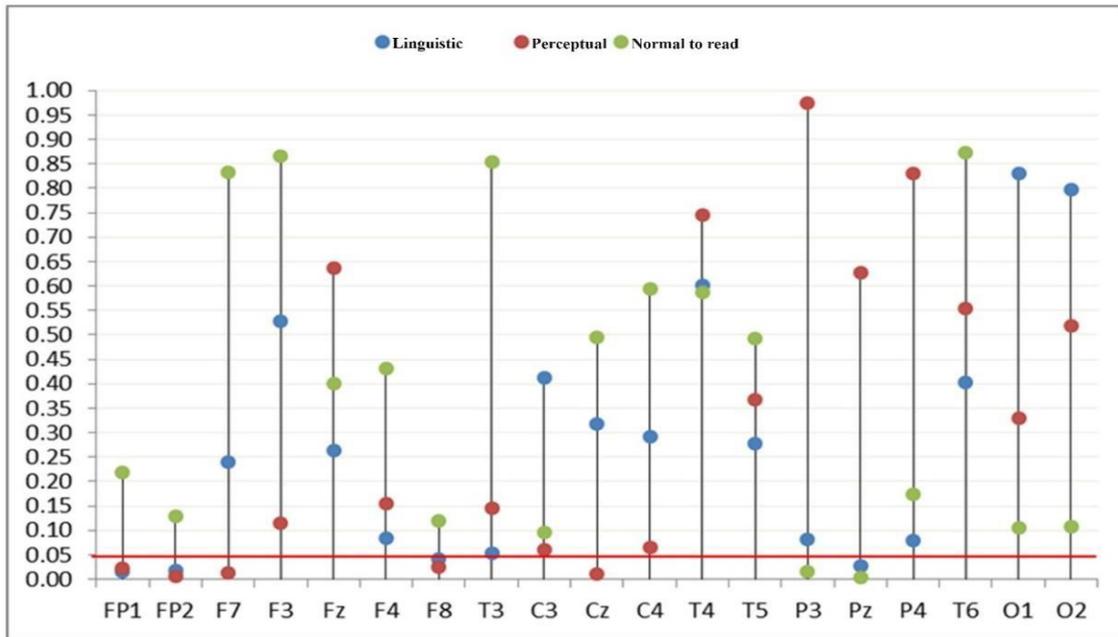
Trend of changes in the mean relative power of alpha wave by brain locations and study groups in the closed state



Accepted Manuscript

Figure 4

Significance level values of Shaper-wick test for the relative power of alpha wave by brain locations and study groups in the closed state



Accepted Manuscript

Table 1

Levin test output and univariate one-way analysis of variance for the relative power of alpha wave by brain locations in the closed state

Place	Levine test				Univariate test			
	Levine Statistics	The first degree of freedom	Second degree of freedom	Significance level (p)	F StatisticS	The first degree of freedom	Second degree of freedom	Significance level (p)
F₃	2.586	2	24	0.096	2.192	2	24	0.134
F_z	1.730	2	24	0.199	2.459	2	24	0.107
F₄	1.289	2	24	0.194	2.454	2	24	0.107
T₃	1.257	2	24	0.246	2.677	2	24	0.089
C₃	0.114	2	24	0.893	1.098	2	24	0.089
C₄	0.145	2	24	0.923	0.626	2	24	0.543
T₄	0.353	2	24	0.706	2.623	2	24	0.093
T₅	1.335	2	24	0.282	2.939	2	24	0.072
P₄	0.0001	2	24	0.999	0.946	2	24	0.402
T₆	1.790	2	24	0.189	2.010	2	24	0.156
O₁	0.039	2	24	0.962	1.806	2	24	0.186
O₂	0.188	2	24	0.905	2.248	2	24	0.127

Table 2

Outputs of the non-parametric cross-sectional Wallis test for the relative power of the alpha wave by brain locations in the ocular position

Place	group	Average ratings	Kruskal-Wallis (KW) statistics	Degrees of freedom	Significance level (p)
F_{P1}	Linguistic	9.70	6.685	2	0.035
	Perceptual	13.63			
	Normal to read	19.11			
F_{P2}	Linguistic	8.90	8.056	2	0.018
	Perceptual	14.50			
	Normal to read	19.22			
F₇	Linguistic	11.10	4.781	2	0.092
	Perceptual	12.38			
	Normal to read	18.67			
F₈	Linguistic	10.90	3.861	2	0.145
	Perceptual	13.38			
	Normal to read	18.00			
C_z	Linguistic	13.30	1.823	2	0.402
	Perceptual	11.75			
	Normal to read	16.78			
P₃	Linguistic	12.30	4.330	2	0.115
	Perceptual	11.13			
	Normal to read	18.44			
P_z	Linguistic	10.90	5.486	2	0.064
	Perceptual	12.25			
	Normal to read	19.00			

Table 3

Outputs of nonparametric pairwise comparisons for the relative power of the alpha wave to separate brain locations in the closed state

Place	group	Test statistics	standard error	Standardized test statistics	Adjusted significance level (p)
FP1	Perceptual linguistics	-3.25	3.765	-1.043	0.892
	Normal linguistics in reading	-9.411	3.647	-2.581	0.030
	Normal perception in reading	-5.486	3.857	-1.422	0.465
FP2	Perceptual linguistics	-5.600	3.765	-1.487	0.411
	Normal linguistics in reading	-10.322	3.647	-2.830	0.014
	Normal perception in reading	-4.722	3.857	-1.224	0.662