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# Assessment of P300 ERP Component, Cortical Scalp Mapping and Correlation With Age in Children With Dyslexia Using True and Pseudo Words in the Malay Language: A Quantitative Cross-sectional Study in Kelantan, Malaysia

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## ABSTRACT

**Introduction:** Children with dyslexia have disparate visual attention while reading varied structures of grapheme-phoneme that have different congruency. Exploring more related with attention and reading disability, we investigated the visual attention, topographic mapping and correlation of ages of children with dyslexia using ERP study. **Methods:** A quantitative cross-sectional, non-interventional study was performed with simple randomization to select participants. A total of 24 children were recruited into two groups; control (n=12) and dyslexic (n=12) groups. 128-ERP net was used for ERP experiment. Congruent (true meaningful Malay, 80%) and incongruent (meaningless, 20%) words were used for stimuli. Participants pressed button ‘1' and ‘2' when they saw congruent and incongruent words, respectively. Amplitudes and latencies of P300 ERP component were analysed at 19 electrode sites in 10-20 system. **Results:** Dyslexics evoked significantly higher P300 amplitude at T6 and shorter P300 latency at Fp1 areas compared with the control group. Moreover, pseudo word stimulations showed a high P300 voltage distribution in the prefrontal and right occipital area in the dyslexics, whereas there was more activation in the bilateral occipito-parietal areas in the controls. Significantly moderate positive correlation was found in the control group at F3, F7 and negative correlation in the dyslexic group at T4 areas for P300 latency. **Conclusion:** Children with dyslexia have higher visual attention with fronto-central topographic distribution for true Malay words and prefrontal and right occipital areas for pseudo Malay words. Age correlation results indicated that attention is directly related to the brain maturity of children.

**Keywords:** Visual attention, Dyslexia, Event Related Potential, Pseudoword, Congruence

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## INTRODUCTION

Dyslexia is a language learning-difficulty that affects approximately four to eight percent of school age children in Malaysia (1) and most children with dyslexia encounter difficulties in reading, spelling, writing, and pronouncing the words. Even though children with dyslexia have limitations in learning, they are not considered as intellectually impaired children since dyslexics usually have a normal or above normal intellectual quotient (IQ) (2). Dyslexics have limited ability to perceive orthographical symbols of language and have difficulty to identify the alphabets (3). Visual attention reduction may induce difficulties in lexical reading strategies (4), thus causing difficulty in reading irregular, unfamiliar and pseudo words (5). Dyslexics have poor visual attention to distinguish the pseudo words from true words (4–6) and lack of visual specialization for letter-processing (7). Phonological deficits (8) and impaired processing of rapid sequence stimulus (9) might interfere in visual attention processing. All these factors trigger inefficiency and difficulty of reading to unfamiliar structural words seen in pseudowords especially in the dyslexics. In recent years, there has been an increasing interest in visual attention to linguistic structures in dyslexics. Yet, the available data on visual attention among dyslexics was still limited. Besides, very few studies have examined visual attention in a different language phonemic system; specifically, in a language system such as Malay word structures. Hence, we primarily studied visual attention towards pseudo word incongruency based on Malay phonemic language by analysing the attentional mechanism of P300 ERP component and its scalp mapping distribution.

The recruitment of ERP as an electrophysiological tool in cognitive studies is highly beneficial in measuring the amplitude and latencies of targeted ERP component which represents attentional neural processing in the brain. It is non-invasive and safe with higher temporal resolution. P300 is one ERP component which is associated with rapid allocation of attention (10). Visual attention is needed in the process of reading (6). Visual attention was poor in children with dyslexia during visual blink stimuli (11).

Attention-related processes have three functional sub-components which are alerting, orienting and inhibition (12). Alerting and orientation are not highlighted in this study as we focus on the inhibition attentional process response to visual congruent and incongruent target stimulus, in this case referring to pseudoword lists (incongruent) and true meaningful word (congruent). Few studies have elaborated the visual congruency effect in visual processing using the ERP technique (13–15) but based on our current knowledge, no study has been conducted on attentional, visual neuro-mechanism using incongruent Malay words as stimulations in dyslexic population. A longitudinal lexical remediation study was conducted by Jucla et al., (2010) wherein they gave two intensive two-month visual and French orthographic training programs for a group of French children with dyslexia, later they evaluated the progress of P300 attentional process at the end of the training. They found that P300 amplitude were decreased for non-words and pseudowords in dyslexics and control subjects due to typical attentional effect when the distribution of target stimuli presentation were less frequent than the standard ones (16).

Even though there has been intensive research on P300 ERP since half a century, correlation with the developmental age has been investigated less. It has been considered that neural maturity or neuroplasticity was portrayed by the shortening of P300 latency and a robust amplitude of the same component, indicating the neural speed efficiency and neural cognitive power, respectively (17). Neuroplasticity in the white matter microstructure tract of brain grows significantly during young age and it might play an important factor in influencing reading skills (18). Tsai, Hung and Tung (2012) reported that age related changes in ERP latencies among Taiwanese children significantly regress linearly, while the amplitudes showed a significant linear increase in the P300, P200, N200 and N100 ERP components in an age range of six to thirteen years (19). However, these findings referred to auditory stimulations in the children, whereas our current study is visual, there is limited knowledge in the field of age correlations with ERP findings, especially the P300 component among dyslexics. It is presumed that age influences the attentional visual processing to orthographical symbols or words, with a limited source of developmental age and its relation to dyslexia. Hence, we investigated the effect of age factors in influencing the neural characteristics of P300 attentional mechanisms towards pseudowords in Malay wordlists.

This study presents novel evidence on the link of neural attentional processing in visual learning and semantic congruency effects (pseudoword) reflected in the P300 ERP component with their topographical mapping distributions. Besides, we further extend this study to correlate the age factor with targeted ERP components characteristics (amplitudes/latencies of P300).

## MATERIALS AND METHODS

### Study design, Ethics, Location of study and Consent

This is a quantitative cross-sectional, non-interventional study, where we collected data at a one-time point. A simple randomization process was used in control and dyslexic groups. The study protocol has been approved by Universiti Sains Malaysia (USM) Ethics Committee (USM/JEPeM/18030177) and the ERP experiments were done at MEG/ERP room of Hospital Universiti Sains Malaysia (HUSM). Written informed consents were obtained from the parents/guardian prior to the experiment.

### Sample size calculation

The sample size was calculated with Power and Sample Size (PS) software. The difference of control and children of dyslexia means was set as 0.48 (δ) and the standard deviation was 0.41 (σ) (13). Therefore, sample participants were 12 in each group, control = 12 and dyslexic =12. 10% dropout was added (2 participants) with each group. 14 in each group were the sample number with dropout. As there was no dropout in this study then the original sample number was used as 12 in each group.

### Participants

A total of 24 school age children were recruited in two groups which were consisted of 12 in control group and 12 in dyslexic group ranging in age from eight to twelve years old.

Children with dyslexia were recruited from three different schools (special class) around Kelantan state of Malaysia while healthy non-dyslexics were screened from normal stream class of three different schools in Kelantan, Malaysia, which were recognized by the Ministry of Education Malaysia, Jabatan Pendidikan Negeri (JPN). Children with dyslexia were identified based on the screening of medical reports (granted by school authorities) and based on the Dyslexia Screening Instrument (DSI) evaluated by the school teacher (20). On the other hand, all the potential healthy control subjects were screened by using DSI to ensure that they had normal development of learning, writing, spelling and reading skills. In DSI, score '0' was assessed as a normal score for control children, and score '1' was evaluated for children with dyslexia. After the DSI screening phase to select the children, they were screened by an expert psychiatrist to exclude any behavioural or cognitive issues like autism, attention deficit hyperactivity disorder (ADHD) before proceeding with the ERP experiment. For screening, the psychiatrist used the Mini-Mental State Examination (MMSE) child (Malay version), developmental questionnaire form, ADHD assessment checklist for parents/teachers and gestalt test for children.

**ERP study Procedure**

A modified stimuli of pseudo words and true words list were presented by E-Prime v 2.0 software (Psychology Software Tools, Inc, Sharpburg, Pennsylvania, USA). All words were in Malay language. Participants were seated in a dimly lit room with a 128- electrode electroencephalogram (EEG) sensor net placed on top of their head and 80 cm away from 22 inches LCD computer. All data were recorded and collected using Net-Station Software (Electrical Geodesic, Inc., Eugene OR USA). The amplitudes and latencies of P300 ERP component were analysed in 19 electrode channels using an international 10-20 EEG system.

**Experimental paradigm**

Pseudo words and true word lists in Malay language were adapted from a previous study. Total 50 Malay words (true words: 25 and pseudowords: 25) were used which were consisted of 2- 4 syllables (21). Subjects were instructed to press button '1' when presented with any word that they were clearly able to read and is meaningful (congruence) and press '2' when presented with non-meaningful or unreadable word (pseudo incongruent word). Time presentation for each word lists were 1500 ms long with 1000 ms between each word presentations (inter stimulus interval) along with random short pauses for resting (Figure 1). The true words were "Cicak, Rumah, Meriah, Pakaian, Selesai, Pelajar, Makanan, Mengapa, Kawasan, Selamat, Sambutan, Lawatan, Semangat, Arahan, Tangan, Nyamuk, Dahulu, Senaman, Cerita, Tuala, Berapa, Sesuatu, Kata, Keluarga, Sihat" and pseudowords were "Pernak, Tolabi, Gehara, Geranta, Setemes, Peralan, Menilur, Setarang, Yabikan, Keluncat, Manderang, Kidahilu, Paridata, Menkil, Kampira, Borua, Agarasu, Rasihi, Depatiku, Bahad, Menkil, Seningku, Paridata, Dangkulu, Iroma".

**Data analysis**

A band-pass filter of 0.3-50 Hz and 0.5 Hz stimulus rate were used to analyse the recorded raw data and the electrode impedance was ensured as below 50 kΩ. The data were then segmented from 100 ms before the stimuli to 900 ms after the stimuli presentation. Artefacts such as eye blinks, eye movements, and body movements were removed by artefact detection tool provided in the Net-Station Software. Then a baseline correction was made to 100 ms before stimuli and the P300 component was determined. The mean values of amplitudes and latencies of P300 ERP component were collected from statistics extraction tools of Net Station software. All data were normally distributed. Comparison of the mean differences in amplitudes and latencies were made between dyslexics and control subjects with independent T-Test using SPSS v24 software to see the significance between groups. Correlation Pearson analysis was done to measure the correlation of the subject's age with the physical characteristics of P300 (amplitudes and latencies). The alpha significant level was set ≤0.05.

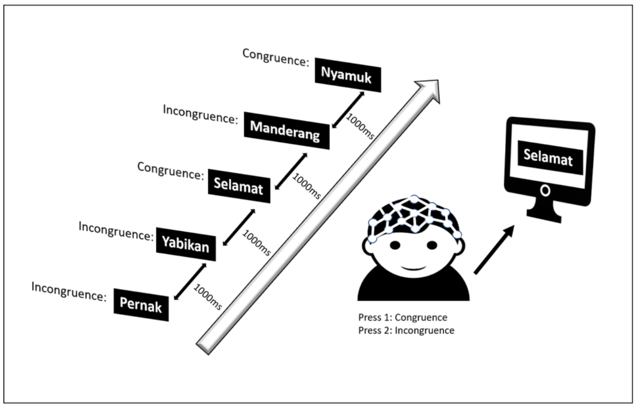


**Figure 1: Experimental paradigm was shown when true (congruence) words and pseudo (incongruence) words were used as stimuli in ERP study for 1500 ms with 1000 ms interstimulus intervel (ISI).**

**RESULTS**

**Demographic information**

Their mean ages (in year) ± SD were 10.75±1.14 years and 10.83±1.16 years, respectively. There was no significant difference in age between groups (p = 0.170). All participants in both groups were Malay and native Malay speaker. Five girls with seven boys were in the control group and two girls with ten boys were in the dyslexic group.

**Neural characteristics of P300 ERP component**

Figure 2 shows the grand average waveforms of P300 between control and dyslexic groups in 19 electrode channels (Figure 2). Dyslexic group revealed significant (p= 0.01) higher amplitude (4.51±1.70 µV) in the T6 area (Table I). Besides, they also showed significantly (p=0.04) smaller latency of P300 at Fp1 (367.67±58.82 ms) compared with the control group (448.33±110.12 ms) (Table I). Across all 19 electrode channels, 12 channels in the control group had longer P300 latencies than dyslexics who exhibited trends of longer P300 latencies than the control group.

**Scalp Mapping Topography**

Control group showed high voltage potential (red color) at bilateral occipito-parietal areas during P300 response

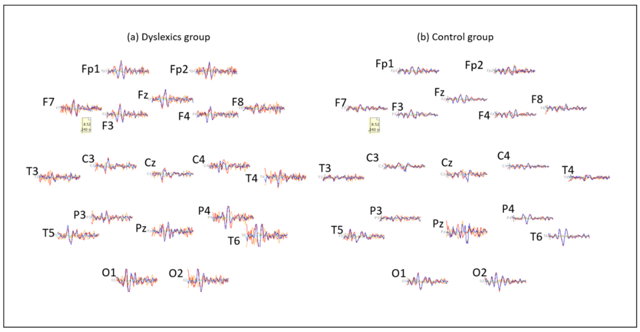


**Figure 2: Grand average waveforms of P300 ERP component were shown during true and pseudo words stimuli within dyslexics (a) and control (b) in 19 electrode areas.** Blue traces indicated true words and red traces indicated pseudo words stimuli

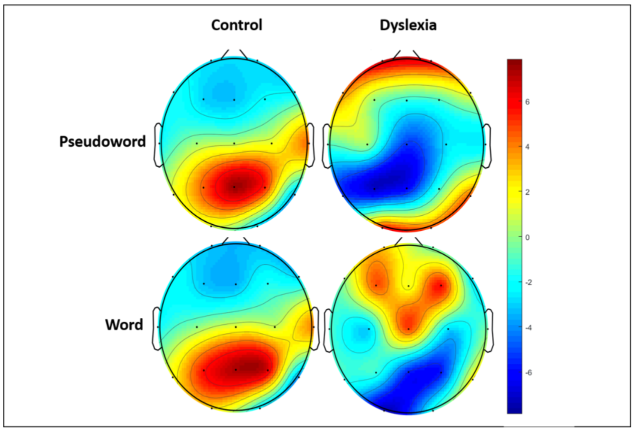


**Figure 3: Scalp topographies mapping of P300 ERP component were shown in control and dyslexic groups during true and pseudo words stimuli.** Red colour indicated distribution of P300 amplitude.

to both true and pseudo words. However, dyslexic group showed the different scalp distribution comparing with the control group. During words (true words) stimuli, P300 was elicited at the fronto-central areas and pseudo words were in the prefrontal and right occipital areas (Figure 3).

Correlation of Age with P300 amplitudes and latencies

Based on Table IIa, none of the correlation between the two groups significantly correlated across all electrodes (Table IIa). In control, two electrode channels showed significant positive correlation between P300 latencies and age. F3 and F7 moderately correlated between P300 amplitude and age factor (r=0.62, p=0.03) and (r=0.64, p=0.02). Meanwhile in the dyslexic group, T4 showed significant negative correlation between P300 latencies and age factor (r=-0.57, p=0.05) (Table IIb).

**Table I: Value of mean differences between pseudo and true words of P300 amplitudes and latencies shown in dyslexic and control groups in 19 different channel areas**

| Areas | P300 amplitude (in µV) (mean±SD) | | P300 latency (in ms) (mean±SD) | | *p-value* | |
|---|---|---|---|---|---|---|
| | **Control** | **Dyslexic** | **Control group** | **Dyslexic group** | **Amplitude** | **Latency** |
| **Fz** | 3.77±1.89 | 5.05±5.51 | 463.33±97.99 | 479±113.36 | 0.46 | 0.72 |
| **Cz** | 3.72±2.13 | 5.75±8.31 | 477±89.72 | 447±96.35 | 0.42 | 0.44 |
| **Pz** | 9.51±8.34 | 10.52±15.80 | 500.67±97.41 | 485±109.40 | 0.85 | 0.72 |
| **Fp1** | 4.61±2.14 | 6.14±5.18 | **448.33±110.12** | **367.67±58.8**2 | 0.36 | **0.04**** |
| **Fp2** | 4.47±1.95 | 6.20±5.93 | 466.67±96.55 | 451±112.55 | 0.35 | 0.72 |
| **F3** | 4.27±2.20 | 4.89±3.27 | 436.33±73.67 | 434.33±103.50 | 0.59 | 0.96 |
| **F4** | 3.77±1.17 | 5.89±5.24 | 477.67±91.44 | 464±124.09 | 0.18 | 0.76 |
| **F7** | 4.33±1.94 | 5.07±3.62 | 486.67±88.06 | 438±108.32 | 0.54 | 0.24 |
| **F8** | 4.66±2.01 | 5.22±3.11 | 506.67±96.49 | 427.67±127.52 | 0.60 | 0.47 |
| **C3** | 3.49±0.81 | 3.72±3.95 | 440±81.50 | 512±117.71 | 0.84 | 0.09 |
| **C4** | 3.59±2.14 | 4.03±3.97 | 486.67±96.08 | 470.33±90.81 | 0.74 | 0.67 |
| **T3** | 4.30±2.33 | 4.83±2.53 | 541.33±81.32 | 482.67±110.092 | 0.60 | 0.15 |
| **T4** | 3.03±1.20 | 4.07±1.61 | 508.33±101.314 | 456±106.68 | 0.09 | 0.23 |
| **T5** | 4.48±2.26 | 4.83±2.85 | 492±88.76 | 523±99.54 | 0.74 | 0.43 |
| **T6** | **2.79±1.44** | **4.51±1.70** | 443±109.86 | 499±99.40 | **0.01**** | 0.20 |
| **P3** | 3.69±1.21 | 3.82±3.42 | 490.33±85.54 | 486.33±116.92 | 0.90 | 0.93 |
| **P4** | 3.45±1.30 | 4.32±2.69 | 443.33±113.71 | 487.67±84.21 | 0.32 | 0.29 |
| **O1** | 4.77±2.16 | 6.26±4.10 | 512.33±103.52 | 518.33±69.48 | 0.27 | 0.87 |
| **O2** | 3.92±2.16 | 7.61±7.77 | 483±126.35 | 507.67±82.87 | 0.13 | 0.58 |

**Note: p≤0.05

Table II: shows the correlation between the age of control group and dyslexic group with the amplitudes (a) and latencies of P300 (b).

| Areas | (a) P300 amplitude | | | | (b) P300 latency | | | |
|---|---|---|---|---|---|---|---|---|
| | Control group | | Dyslexic group | | Control group | | Dyslexic group | |
| | *r value* | *p* | *r value* | *p* | *r value* | *p* | *r value* | *p* |
| **Fz** | 0.23 | 0.47 | -0.23 | 0.47 | -0.11 | 0.73 | 0.22 | 0.49 |
| **Cz** | 0.03 | 0.92 | 0.08 | 0.81 | 0.06 | 0.87 | -0.27 | 0.39 |
| **Pz** | 0.14 | 0.67 | 0.14 | 0.68 | -0.97 | 0.54 | -0.26 | 0.41 |
| **Fp1** | 0.23 | 0.47 | -0.20 | 0.53 | -0.22 | 0.50 | -0.33 | 0.29 |
| **Fp2** | 0.29 | 0.35 | -0.37 | 0.24 | -0.08 | 0.81 | -0.20 | 0.53 |
| **F3** | 0.24 | 0.45 | -0.07 | 0.83 | **0.62** | **0.03**** | -0.38 | 0.23 |
| **F4** | 0.11 | 0.74 | -0.07 | 0.84 | -0.06 | 0.86 | -0.24 | 0.45 |
| **F7** | 0.03 | 0.92 | 0.02 | 0.94 | **0.64** | **0.02**** | 0.16 | 0.62 |
| **F8** | 0.08 | 0.80 | 0.18 | 0.59 | -0.45 | 0.14 | -0.03 | 0.93 |
| **C3** | 0.06 | 0.86 | -0.14 | 0.67 | 0.35 | 0.27 | -0.22 | 0.50 |
| **C4** | 0.18 | 0.58 | -0.08 | 0.80 | 0.35 | 0.27 | -0.31 | 0.33 |
| **T3** | -0.13 | 0.68 | 0.24 | 0.46 | 0.45 | 0.14 | -0.04 | 0.91 |
| **T4** | 0.17 | 0.60 | 0.15 | 0.65 | 0.21 | 0.51 | **-0.57** | **0.05**** |
| **T5** | 0.08 | 0.80 | -0.09 | 0.77 | 0.50 | 0.10 | -0.34 | 0.28 |
| **T6** | -0.44 | 0.15 | 0.02 | 0.94 | 0.51 | 0.09 | 0.56 | 0.06 |
| **P3** | -0.19 | 0.56 | -0.06 | 0.85 | 0.25 | 0.44 | -0.04 | 0.90 |
| **P4** | 0.14 | 0.68 | 0.18 | 0.57 | -0.02 | 0.96 | 0.21 | 0.51 |
| **O1** | 0.05 | 0.42 | 0.02 | 0.95 | -0.43 | 0.16 | -0.46 | 0.13 |
| **O2** | -0.26 | 0.42 | 0.01 | 1.0 | 0.19 | 0.54 | -0.41 | 0.18 |

***Note: p 0.05*

## DISCUSSION

In the current study, we investigated visual attention of children with dyslexia by assessing the amplitudes and latencies of the P300 ERP component in response to lexical true Malay and pseudo words, we further expanded the study to identify the topographical mapping of scalp areas that generate voltage potential of P300 amplitude and the correlation to their ages. In the ERP study, it was found that the children with dyslexia evoked significantly higher amplitude at T6 and a smaller latency at Fp1 compared to the control healthy children. Meanwhile, mapping the result on pseudo words stimuli showed high P300 voltage distribution in the prefrontal and right occipital area in dyslexics, whereas it was more in the mid-parietal area in controls. There was no correlation between the age and P300 amplitude between the groups. Nonetheless, we found significantly moderate positive correlation in the control group at F3, F7 and a negative correlation in the dyslexic group at T4 areas for P300 latency.

### Discussion on Amplitudes and latencies of P300 ERP component

Children with dyslexia showed lower amplitudes of P300 component which indicated poor visual attention during phonological lexical decision task (22). Moreover, children with dyslexia have a deficit in applying grapheme-phoneme correspondence searching rules for orthographic (symbols) presentations with unfamiliar pseudo words, pseudo-homophones, false font showed attenuation of language processing which were examined using the P400 (15, 23) and P500 (15) ERP components. In contrast, in our study, we found significantly higher amplitude of P300 component at T6 in children with dyslexia which indicated that our children with dyslexia have high sensitivity and attention towards pseudo words that they are less familiar with (24). Alongside their reduced ability to decoded orthographical structures, leading to more attentional effort spent in pseudoword/true words task stimulation and mirroring the compensatory silent articulatory processes of the visual word task (25).

Significantly longer latencies of P300 component was found in children with dyslexia due to orthographic unfamiliarity effect (23). P300 latencies reflect higher order cognitive process such as stimulus evaluation and categorization (26). Besides these, children with dyslexia evoked shorter latencies of late ERP components indicated quick attention processing time between true and pseudo words (27). In our study we found significantly shorter latency of P300 component at Fp1 area in children with dyslexia which proved that our children with dyslexia have a good and quick visual attention which is not effected by orthographic unfamiliarity of pseudo words.

Dyslexic readers in transparent orthographics such as Turkish, Greek and German language have little difficulty in decoding words compared to English dyslexics who have more impairment in reading accuracy, phoneme deletion (28), and have a more reading accuracy problem (25). Malay true and pseudo words have different orthographical structure whereas Malay orthographical is a transparent language unlike English which is categorized as an opaque orthographical language which implies a direct and simple grapheme phonemic code. Association of our findings with a slight betterment of attentional speed processing (significantly shorter latency of P300 component), our results suggest that Malay transparent orthographic system has an effect in the speed processing to decode the orthographical structure in pseudo words and true words used in the current study.

**Discussion on Scalp Mapping**

The significantly different channel of T6 electrode is located at the temporal area of the right side of the brain hemisphere. Children with dyslexia and control children have significant differences in structural/functional areas of brains like temporo-parietal, occipito-temporal and inferior frontal regions (29). Nevertheless, there is no consensus among the studies about these regions and the significant dominance of any brain region network activation in supporting the ability to read. In our case, low activated left posterior (language system) areas were found in dyslexics, with significant attention in the right hemisphere channels (T6) refer to the possibility of hyperactivation in the right hemisphere of the brain as a way of compensating the poor attentional network on the left hemisphere during pseudoword and true word decisions task (Table 1, Figure 3). However, our current neuronal scalp mapping activation results show a different scalp activity between the control readers and dyslexics. The normal readers showed high voltage potential at bilateral occipito-parietal area during P300 response to both pseudo words and true words, with a larger activation area in the word visual stimulations. Meanwhile in the dyslexics, P300 voltage mapping distribution was high in the prefrontal and right occipital area in response to pseudo words. During true word stimuli, P300 was elicited at the fronto-central area. In the reading stage of the lexical route in decoding orthographic-phonemic (grapheme-phoneme), left ventral occipito-temporal (OT) region has presumably a crucial function in recognizing the visual orthographic whole word, which is highly linked to attentional processes and this region was under activated in dyslexics readers than the normal control readers (25). Functional Magnetic Resonance Imaging (fMRI) studies discovered that there was lack of increment in activation of the left-hemisphere language areas in adult dyslexics in response to true words and pseudo words. In fact, the right hemisphere of dyslexics were highly activated than the left (30, 31).

**Correlation age vs amplitudes and latencies of P300 ERP component**

Children ages have a positive correlation with P300 amplitudes and negative correlation with P300 latencies (19). The children ages were significantly correlated with auditory and visual latencies, but not for amplitudes (32). We could not found any significant correlation between ages of control and children with dyslexia and P300 amplitude and latency. It is known that the neural mechanisms are actively develop during brain maturity processes throughout life, explaining that the difference of amplitude between adults and children are varied in terms of amplitude size and duration of latencies. This occurrence might be due to the progression of brain cortical development that starts to mature at the age of 12 years. In this study, our subject population were in the range of eight to twelve years and the progression of the visual attentional factor is not yet robust while it is maturing.

In our correlation test among normal readers, a positive moderate correlation between P300 latency and age were located at F3 and F7. This can be interpreted that increase of age may prolong the speed of processing in the frontal area in F3 and F4 electrode channels. In an adult correlation study with an age range from 10 to 70 years with P300 latencies conducted by Shukla et al., (2000), the P300 latencies were strongly positive correlated with age while they found negative correlation in P300 amplitudes (33). P300 latency has been reported to linearly increase with the increment of age implying that the speed of mental processing slows down during aging (34, 35). Unfortunately, none of the results from established studies can be applied to explain the findings in the children with dyslexia.

A few factors might interfere with our contrast correlation findings, and it can be caused by small variation of age involved in this study which was limited to eight to twelve-year-old children, thus limiting the correlation of age factor with the physical characteristics of the P300 component. Despite the age limitation factor, our pioneering findings can act as a baseline that age factor may interplay with attentional factors in fluent control children and children with dyslexia. Furthermore, our findings suggest that the increase of age, had a potential to significantly increase the P300 latency in control readers. This is proposed based on the idea that in normal typical readers the increase in age does influence the visual attention processing speed while reading the visual true and pseudo words. Even though significant differences were confined to only 2 electrode channels in normal readers in the frontal brain region, it does enlighten us on the role of frontal brain area activation in visual attention. Fronto-parietal network is related with attentional processing of specific task demands (36) and the processing of visual attention is primarily at the prefrontal cortex allowing for the bias selection of visual features of stimulations (37), for example orthographic structures, shapes and colours. It is known that older children tend perform better in reading fluency, reading comprehension and total reading than the younger ones (38). The age development together with the reading ability was also associated with the brain maturation which influences the functional specialization in cortical regions and certain areas of cognitive abilities associated with reading skills (10, 38).

The main weaknesses of this study are (1) small sample number where large sample number can give us more reliable results and (2) location of the study: as our study area was limited in Kelantan, therefore, the sociocultural background might affect the participants' regulated words in their Malay language. We expect to extend this study to other states in Malaysia in the future. The main strength of this study is to reveal the visual attention on Malay words and pseudowords at the neuronal level which might be helpful for the teachers, community and students to process further to their learning strategies to improve their quality of life.

## CONCLUSION

We investigated the visual attention, scalp topographic distribution of the amplitude and latency of P300 ERP component in children with dyslexia using true Malay and pseudo words. Correlation was studied with age of children and amplitude and latency of P300 ERP component. We concluded that children with dyslexia have better visual attention, short speed processing with topographic distribution at the fronto-central areas for true words and prefrontal and right occipital areas for pseudo words stimuli. Moreover, brain maturity of children with dyslexia did not affect their reading process as there is no correlation of age with amplitude and latency of P300 ERP component. We proposed that higher attentional level in children with dyslexia could be a compensating factor in the neural brain network to overcome certain lacunae in the attentional processing while reading.


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