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ORIGINAL ARTICLE

Fronto-Temporal N200 Event-Related Component in Dyslexic Malay Children During Audio–Visual Paired Stimuli

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ABSTRACT

Introduction: Shifted attention can be studied in paired stimuli using different experimental paradigms. Pre-existing literatures showed that children with dyslexia have difficulty in learning. Hence, there might be a relationship between learning difficulty and shifted attention. We investigated shifted attention and topographic distribution of the N200 component using audio–visual paired stimuli in an event-related potential (ERP) study among dyslexic Malay children. **Methods:** A 128 ERP net designed for children was used for the study. A total of 24 age-matched children were divided into control (n=12) and dyslexic (n=12) groups. A modified audio–visual paired stimuli paradigm was used for the ERP study. Congruent (animal-matched sound) and incongruent (animal-not matched sound) stimuli were used. All participants were instructed to press key '1' and '2' when congruent and incongruent stimuli are presented, respectively. Amplitudes and latencies of the N200 ERP component were analysed at 19 electrode locations in the 10-20 system. A topographic map was analysed for the N200 component for both groups. **Results:** There was no significant differences in the N200 amplitudes and latencies between children with dyslexia and control children at any sites. The topographic map distribution revealed that the dyslexic group had right frontal and left temporal N200 voltage distribution during the incongruent stimuli. **Conclusion:** We conclude that Malay children with dyslexia have no difficulties/intact in shifted attention. Moreover, children with dyslexia have diverted left temporal areas during auditory sound attention.

Keywords: Event-related potential, N200 component, Shifted attention, Congruence, Incongruence

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INTRODUCTION

Reading, writing, and spelling are the learning processes for human beings. In this learning process, children learn about different alphabets with their pronunciation in primary school. When the learning process is completed at the alphabet level, they learn word pronunciation and reading and writing properly at the sentence level. When this normal learning procedure is interrupted, disability might occur. Dyslexia is a learning impairment that is possibly caused by neuronal (1), genetic, and environmental factors (2). Approximately 13%–14% school children in the USA have disabilities and need special education, of which 80% have poor reading and language processing ability (3). In Malaysia, as of 2012, 165,281 school children had learning disabilities, including dyslexia; this number increases each year (4). As dyslexia is involved in the underlying mechanism of language processing in the brain in multisensory systems (5), we need to understand the neuronal mechanisms underlying this disability at an early stage for better management.

Children with dyslexia have issues such as poor spelling and reading, slow learning, poor recognition of audio–visual matching, and poor writing. (6,7). Recognition of audio–visual stimuli is important for reading. Failure of any auditory or visual system might cause dyslexia (8,9). Moreover, lack of attention on a particular stimulus can cause difficulty in reading (10). During shifted attention, we need additional attention during the switching task, and this procedure is called shifted attention (11). There is a lack of evidence related to shifted attention toward audio–visual paired stimuli in children with dyslexia at the neuronal level. Hence, we performed an attentional study using audio–visual stimuli, in which different animal pictures were used as the visual stimuli and their matching sound was used as the paired auditory stimuli, among children with dyslexia in Malaysia.

Neuronal recording during attention was successfully performed in an event-related potential study (ERP) using different audio–visual stimuli. ERP is a cheap and non-invasive method. ERP components reflect the attentional level by analysing amplitudes and latencies in different audio, visual, or sensory stimuli. 'P' refers to positive and 'N' refers to the negative peaks, while latencies are the times from stimuli to peak amplitudes of ERP components (12,13). In this regard, the N200 ERP component can reflect attention during audio–visual stimuli, which is a negative peak (N) and within the 150–250-ms time range (14,15). Participants performed better during paired stimuli (auditory stimuli paired with corresponding visual images) than during unpaired stimuli (16). Poor audio–visual neuronal synchronization has been reported in children with dyslexia (17). Lack of shifted attention has been documented during visual to auditory stimuli (18). Grapheme images and their sounds in the paired stimuli paradigm explains multi-modal sensory processing (17). An audio-visual Simon task was used in adult dyslexics that indicated poor shifted attention during auditory stimuli (19). Francisco et al., (2017) performed a study on adult dyslexics using audio-visual speech stimuli to investigate shifted attention and lack of temporal processing was found in the dyslexic group (20). A recent study investigated post-attentive integration by analysing the P300 ERP component using the audio-visual animal image and sound matched-unmatched stimuli. This study found dyslexic children have higher post-attentive integration (21). However, we used the same paradigm of them (21) but analysed the N200 ERP component to investigate shifted attention among children with dyslexia as shifted attention was never been investigated using this paradigm among dyslexic children.

Topographical distribution reflects neuronal activation and arrangement during sensory and motor functions. This provides valuable information about brain function and structure during different stimuli (22). Auditory N200 cortical distribution is usually on the frontocentral areas; however, it depends on the type of stimulation and participants (23).

In this study, we investigated audio–visual shifted attention by analysing the amplitudes and latencies of the N200 ERP component. We also studied the N200 topographic distribution using an audio–visual paired stimuli paradigm in Malay children with dyslexia.

MATERIALS AND METHODS

Study design, Ethical approval, Samples and Screening procedure

A quantitative, cross-sectional, non-interventional study with a convenience sampling method was chosen for this study. Before the ERP experiment, we procured ethical approval from the ethical committee of Universiti Sains Malaysia (USM) (USM/JEPeM18030177) and recruited the participants. We used Power and Sample size (PS) software to calculate the number of samples in control and dyslexic groups. The real difference of means (δ) between groups was 1.89 and the standard deviation (σ) was 1.56 (21). 0.8 and 0.05 were probability power and alpha values, respectively. Hence, the number of children was 12 in each group (a total of 24 children).

Children in the control group came from regular schools and children with dyslexia came from special dyslexic schools in Kelantan, Malaysia. All the children in both groups were screened based on Dyslexia Screening Instrument (DSI) scale. Score '0' was considered as the normal score for control children and score '1' was assessed for children with dyslexia in DSI. After DSI screening, an expert psychiatrist screened all the children in both groups to exclude behavioural and cognitive issues, for example, autism, attention deficit hyperactivity disorder (ADHD), etc. Mini-Mental State Examination (MMSE) (child Malay version), developmental questionnaire form, ADHD assessment checklist for parents/teachers, and gestalt test were used for this purpose. After the screening test, all children went to the ERP experiment. We received permission from all school authorities, parents, and the higher education department in Malaysia. All the children provided written informed consent with their parents. ERP experiments were conducted in the MEG/ERP room at the hospital of Universiti Sains Malaysia (HUSM).

Experimental design and paradigm

The 128-ERP net for children was used for the experiment. The stimuli were designed using E-prime 2.0 software. All participants sat in a dimly lit, sound-treated room with an ERP net fitted on their head. They were seated 80 cm away from a 22-inch LCD computer screen where all the stimuli were presented. The participants had normal vision or were corrected to normal vision. Raw data were recorded in the Net Station software. A modified audio–visual stimuli paradigm was presented as a task, adapted from Yuval et al. (16).

In this paradigm, some animal pictures followed by their matching sound were presented. Animals with their matching sounds were named as 'congruent' stimuli and animals with unmatched sounds were named as 'incongruent' stimuli. Participants pressed key '1' and '2' when they were presented a congruent and an incongruent stimuli. All the stimuli (animal pictures followed by sounds) were presented for 500 ms, with 1500 ms inter-stimulus interval. There was also a 100 ms time between animal pictures and sounds. The experimental paradigm is shown in Figure 1.

Data analysis

The first step of data analysis was performed using the Net station software. The data analysis procedure has been mentioned in some previous studies (24, 25). Filtering

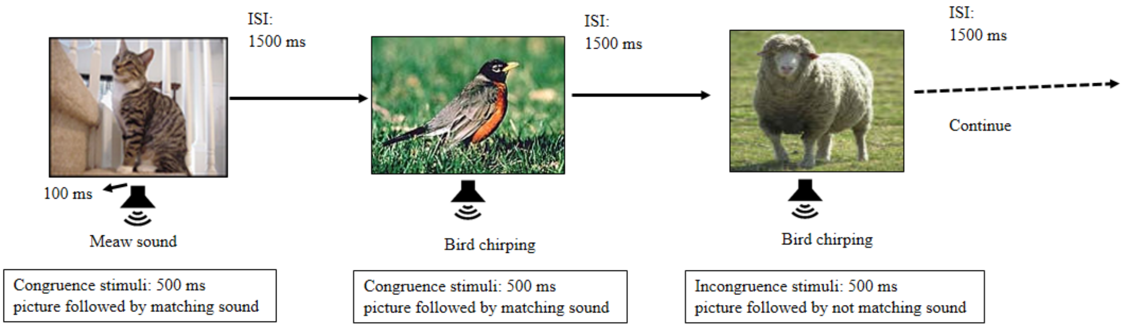

Figure 1: The experimental paradigm is shown in congruent stimuli as matching animal sound and incongruent stimuli as non-matching animal sound with 500 ms duration and 1500 ms of inter-stimulus interval

(0.03–30 Hz), segmentation (-100–600 ms), and artefact detection and removal were performed with baseline correction (-100 ms). After grand averaging, all data were subjected to statistical extraction tools to reveal the amplitudes and latencies of the N200 ERP component for the control and dyslexic groups. The topographic cortical distribution for the N200 component was assessed using the Net station software.

The second step of data analysis was performed to reveal the significance between the two groups. All data were assessed using SPSS24 software and the amplitudes and latencies of the N200 component between groups were analysed using the non-parametric Mann–Whitney test. The significance level (p) was set at ≤0.05.

RESULTS

Demographic data

The mean age (SD) of participants in the control and dyslexic groups was 10.08 (1.16) and 10.75 (1.14) years, respectively. There were 7 males and 5 females in the control group (n = 12) and 10 males and 2 females in the dyslexic group (n = 12). All participants in each group were age matched and equal in numbers. All the study participants were right handed.

Results of the N200 ERP component

The Mann–Whitney test revealed that there were no significant differences between groups in the amplitudes and latencies of the N200 component at all the 19 electrode sites. The mean differences between the congruent and incongruent stimuli for amplitudes and latencies are shown in Tables I and II, respectively.

Figure 2 shows the topographic distribution of the N200 ERP component during congruent and incongruent stimuli between the control and dyslexic groups. During congruent stimuli, N200 negative voltage activities were found in the right frontal area in both the groups. During incongruent stimuli, the dyslexic group had N200 voltage activity in the right frontal and left temporal

Table I: Mean differences of congruent and incongruent stimuli for amplitudes (in µV) of the N200 ERP component are shown at 19 electrode sites between the control and dyslexic groups

Sites	Control Mean (SD) (in µV)	Dyslexic Mean (SD) (in µV)	*p* values
Fp1	4.91 (2.73)	7.72 (3.97)	0.15
F3	4.53 (2.36)	5.26 (2.45)	0.49
F7	3.38 (1.39)	4.67 (1.80)	0.14
Fp2	5.13 (1.50)	5.60 (2.44)	0.93
F4	3.67 (0.92)	4.06 (2.46)	0.94
F8	4.71 (1.62)	5.54 (2.36)	0.32
C3	3.72 (1.67)	4.75 (2.23)	0.24
C4	3.57 (2.01)	3.86 (2.47)	0.76
T3	4.49 (2.03)	4.58 (2.15)	0.44
T4	3.66 (1.98)	4.93 (1.59)	0.11
P3	3.23 (1.66)	4.39 (1.69)	0.20
T5	4.21 (2.07)	4.10 (1.86)	0.69
P4	3.74 (1.93)	3.22 (1.97)	0.36
T6	3.74 (1.46)	5.20 (1.60)	0.08
O1	4.29 (1.45)	4.35 (2.18)	0.69
O2	4.71 (1.91)	4.78 (2.36)	0.89
Fz	4.48 (1.45)	4.93 (1.97)	0.43
Cz	3.08 (0.90)	3.83 (2.27)	0.46
Pz	4.71 (2.43)	4.39 (2.03)	0.79

Table II: Mean differences of congruent and incongruent stimuli for latencies (in ms) of the N200 ERP component are shown at 19 electrode sites between the control and dyslexic groups

Sites	Control Mean (SD) (in ms)	Dyslexic Mean (SD) (in ms)	*p* values
Fp1	204.00 (54.45)	225.33 (60.76)	0.37
F3	195.67 (47.76)	206.00 (66.44)	0.73
F7	230.67 (58.04)	188.00 (61.62)	0.12
Fp2	219.00 (44.49)	232.00 (55.33)	0.62
F4	197.33 (48.70)	213.33 (72.72)	0.49
F8	213.00 (46.68)	224.00 (56.69)	0.56
C3	186.67 (64.50)	189.00 (60.99)	0.93
C4	209.00 (50.41)	219.00 (66.98)	0.70
T3	191.00 (52.13)	182.00 (57.54)	0.75
T4	185.67 (59.50)	184.67 (47.91)	0.96
P3	183.67 (62.81)	201.67 (75.55)	0.63
T5	187.33 (67.54)	229.33 (71.97)	0.14
P4	160.67 (45.69)	152.67 (45.95)	0.68
T6	168.00 (61.38)	154.33 (46.11)	0.53
O1	170.33 (67.99)	182.00 (50.69)	0.53
O2	191.67 (63.42)	178.33 (65.61)	0.56
Fz	213.33 (37.54)	220.00 (59.46)	0.80
Cz	199.00 (60.29)	178.67 (56.91)	0.53
Pz	190.00 (58.50)	168.67 (56.11)	0.35

areas, while the control group showed activity in the frontal and occipital areas (Figure 2).

DISCUSSION

Our objective was to reveal the shifted attention during audio–visual paired stimuli in Malay children with dyslexia by analysing the amplitudes and latencies of the N200 component in an ERP study. Additionally, we studied the topographic distribution for the N200 component in both the groups. We did not find any significant differences in the amplitudes and latencies of the N200 component between the dyslexic and control groups. The topographic map showed that children with dyslexia have a right frontal-left temporal N200 voltage distribution.

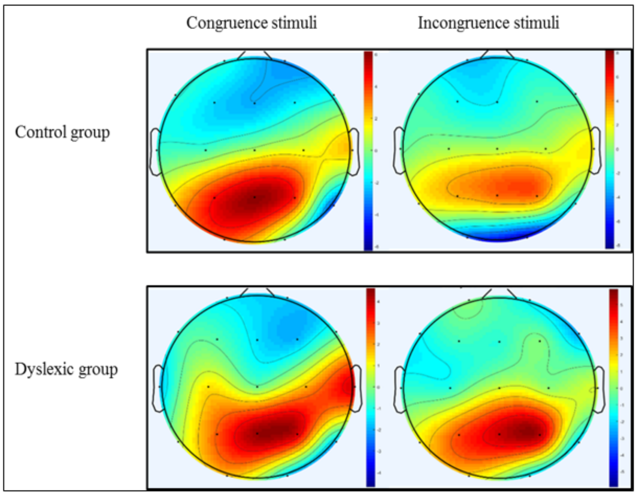

Figure 2: A topographic distribution of the N200 ERP component at 207 ms during congruent and incongruent stimuli between the control and dyslexic groups. Blue colour in colour bar indicates negative voltage activity for the N200 component.

Variable results for the N200 component have been mentioned in different studies (26, 27). The change in amplitudes, latencies, and cortical distribution depends on the experimental paradigm. Normally, higher amplitudes of the N200 component indicate higher attention (26). A study concluded that visual context can enhance auditory attention when audio–visual paired stimuli were presented to musician subjects where enlarged N200 amplitudes were found (27). This information was supported by an EEG-fMRI study, where researchers revealed that one sensory modality has beneficial influence on the other sensory modality because of the reduced top-down inhibition of secondary stimuli (28). As the multisensory system is involved in the paired stimuli paradigm, the overlapping attention theory is the only explanation if there is no enhancement of attention (29).

In our study, we used audio–visual paired stimuli and did not find any significant differences in amplitudes and latencies of the N200 component between the dyslexic and control groups at any electrode locations. Taking the explanation from above studies, no enhancement of N200 amplitude explains that the dyslexic group have overlapping attention between auditory and visual stimuli, which prevented the N200 amplitude to be higher (29). In this case, the visual sensory system was not helpful in providing any beneficial effect to the auditory sensory system (27, 28). Our results might be dissimilar because of different sets of experimental paradigms. Further studies are needed in the future to explore this matter.

Different cortical areas can be activated during presentation of different types of stimuli in the case of attention (27). In our study, both control children and children with dyslexia had right frontal area activation during congruent stimuli (Figure 2). These results explain that children in both groups used their frontal areas, which are associated with cognitive functions such as language, memory, executive function, and attention processing (30). We can say that children with dyslexia have no diversion of their attention while matching the sounds with the animals. While the children in the control group used their frontal and occipital areas to match the incongruent stimuli, children in the dyslexic group used a small area of the right frontal lobe along with left temporal areas (Figure 2). The frontal area is activated when attention is higher (30), and all children in both groups had high attention. Additionally, children with dyslexia used the left temporal area for limiting pre-automatic attentive directing to auditory stimuli processing (8). There might be an attentional inhibitory control mechanism that separately processes auditory and visual stimuli.

CONCLUSION

We investigated shifted attention and topographic map distribution using audio–visual paired stimuli in children with dyslexia in an ERP study. Children with dyslexia did not have any significant changes in N200 amplitudes or latencies compared to control children. Thus, we conclude that children with dyslexia have no impairment of shifted attention during animal sound matching (paired) stimuli. The N200 voltage activation in the topographic map distribution showed that the left temporal area processed auditory stimuli during audio–visual paired stimuli in children with dyslexia.

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REFERENCES

1. Ye Z, Rьsseler J, Gerth I and Mьnte TF. Audiovisual speech integration in the superior temporal region is dysfunctional in dyslexia. Neuroscience. 2017;356:1-10.
2. Peterson RL, Pennington BF. Developmental dyslexia. Lancet. 2012;379 (9830):1997-2007.
3. International Dyslexia Association. Dyslexia in the Classroom: What Every teacher Needs to Know. 2017. Retrieved from https://dyslexiaida.org/wp-content/uploads/2015/01/DITC-Handbook.pdf
4. UNICEF Malaysia. Childhood disability in Malaysia: A study of knowledge, attitudes and practices. (2013). Retrieved December 13, 2019, from https://www.unicef.org/malaysia/media/281/file/Childhood Disability in Malaysia.pdf
5. "What are reading disorders?". National Institutes of Health. 1 December 2016.
6. Gomez C. Dyslexia in Malaysia. International Book of Dyslexia: A Guide to Practice and Resources, 2004:158-163
7. Siegel LS. Perspectives on dyslexia. Paediatr Child Health. 2006;11 (9): 581-587.
8. Facoetti A, Lorusso ML, Paganoni P, Cattaneo C, Galli R, Umilta C, et al. Auditory and visual automatic attention deficits in developmental dyslexia. Cogn Brain Res. 2003;6 (2):185-191.
9. Franceschini S, Gori S, Ruffino M, Viola S, Molteni M, Facoetti A. Report Action Video Games Make Dyslexic Children Read Better. Curr Biol. 2013;23(6):462-466.
10. Lewandowska M, Milner R, Ganc M, Włodarczyk E, Skarżyński H. Attention dysfunction subtypes of developmental dyslexia. Med Sci Monit. 2014;20:2256-2268.
11. Johnson A, Proctor RW. Attention: Theory and practice. Thousand Oaks, CA, SAGE Publications, 2004:OCLC 645153300.
12. Light GA, Williams LE, Minow F, Sprock J, Rissling A, Sharp R et al. Electroencephalography (EEG) and event-related potentials (ERP's) with human participants. Curr Protoc Neurosc. 2010;6 (6.25):1-32
13. Woodman GF. A brief introduction to the use of eventrelated potentials (ERPs) in studies of perception and attention. Atten Percept Psychophys. 2010;72 (8):1-29.
14. Sittiprapaporn W. An effect of attention on mismatch negativity in audiovisual visual modalities. Pak J Biol Sci. 2012;15:542-546.
15. Vecchio F, Sara M. The use of auditory event-related potentials in Alzheimer's disease diagnosis Int J Alzheimers Dis. 2011:1-7.
16. Yuval-Greenberg S, Deouell LY. The dog's meow: Asymmetrical interaction in cross-modal object recognition. Exp Brain Res. 2009;193(4):603-614.
17. Sela I. Visual and auditory synchronization deficits among dyslexic readers as compared to non-impaired readers: A cross-correlation algorithm analysis. Front Hum Neurosci. 2014;8:1-12.
18. Harrar V, Tammam J, Pitt A, Stein J, Spence C. Report multisensory integration and attention in developmental dyslexia. Curr Biol. 2014;24(5):531-535.
19. Gabay Y, Shai G, Schiff R & Henik A. Visual and Auditory Interference Control of Attention in Developmental Dyslexia. Journal of the International Neuropsychological Society. 2019; 26(4): 1–11. https://doi.org/10.1017/S135561771900122X
20. Francisco AA, Jesse A, Groen MA & McQueen M. A General Audiovisual Temporal Processing Deficit in Adult Readers with Dyslexia. Journal of Speech, Language and Hearing Research. 2017; 60(1): 144–158. https://doi.org/https://doi.org/10.1044/2016_JSLHR-H-15-0375

21. Ali SA, Begum T, Reza MF, Fadzil NA, Mustafar F. Post-Attentive Integration and Topographic Map Distribution During Audiovisual Processing in Dyslexia: A P300 Event-Related Component Analysis. Malays J Med Sci. 2020;27(4):130-138. doi:10.21315/mjms2020.27.4.12
22. Patel GH, Michael DK, Snyder LH. Topographic organization in the brain: Searching for general principles. Trends Cogn Sci. 2014;18 (7):351-363.
23. Patel SH, Azzam PN. Characterization of N200 and P300: Selected studies of the event related potential. Int J Med Sci. 2005;2:147-154.
24. Reza F and Begum T. Mild cognitive impairment in mild brain injury (MBI) patients: An event related potential (ERP) and neuropsychology study. Bangladesh Journal of Medical Science. 2019;18 (3): 557-566.
25. Hasan R, Reza F, Begum T. Gender influences on colour processing: An event related potential (ERP) study. Bangladesh Journal of Medical Science. 2018;17 (4): 612-618.
26. Eimer M. The N2pc component as an indicator of attentional selectivity. Electroenceph clin Neurophysiol. 1996;99:225-234.
27. Nichols ES, Grahn JA. Neural correlates of audiovisual integration in music reading. Neuropsychologia. 2016;91:199-210.
28. Regenbogen C, De Vos M, Debener S, Turetsky BI, MиЯnang C, Finkelmeyer A. Kellermann T. Auditory processing under cross-modal visual load investigated with simultaneous EEG-fMRI. PLoS one. 2012;7(12).
29. Francisco AA, Jesse A, Groen MA and McQueen M. A General Audiovisual Temporal Processing Deficit in Adult Readers With Dyslexia. Journal of Speech, Language and Hearing Research. 2017;60 (1):144–158.
30. Chayer C, Freedman M. Frontal lobe functions. Curr Neurol Neurosci Rep. 2001;1 (6):547-552.