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Original Research Article

Cortical Processing of Speech in Children with Dyslexia

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ABSTRACT

Objective of the study: The present study evaluated the performance of children with dyslexia in comparison to typically developing children on speech evoked auditory late latency response. *Method:* A total number of 20 children (40 ears) in the age range of 10-12 years were taken for the study. Out of 20 children, there were 10 typically developing children and 10 children with dyslexia.
Results: Multivariate analysis of variance was carried out to compare the latency and amplitude measures of speech evoked auditory late latency response between the groups. Results revealed prolonged latencies of P1, N1, P2, and N2 ($p < 0.001$) and reduced amplitude of all peaks of speech evoked late latency responses except for wave N1 ($p < 0.05$) in individuals with dyslexia.
Conclusion: Speech evoked auditory late latency response is easily traceable in all children with dyslexia and typically developing children. However, children with dyslexia exhibited prolonged latencies and reduced amplitudes of speech evoked auditory late latency response in the present study. The deviancies appeared in the study may be attributed to the abnormal encoding of speech signal at the cortical level in children with dyslexia.

Keywords: Late latency response, Dyslexia, Cortical potential

INTRODUCTION

Auditory evoked potentials (AEPs) provide strong objective methods to assess the neural integrity of the auditory pathway from auditory nerve to cortex. Individuals with various disorders including learning disabilities have been extensively studied using various electrophysiological tests. Dyslexia is a specific learning disability that is neurological in origin. It is characterized by difficulties with accurate or fluent word recognition and by poor spelling and decoding abilities. Learning problem is one of the common educational problems seen in a number of school going children. This learning problem negatively affects a variety of behaviours, so early intervention is one of the most important steps in this regard.

In India, the occurrence of dyslexia ranges from 3% to 7.5% of children. [1] The prevalence estimate of this disability has been found to be 3 to 10 % in western literature. [2] Children with dyslexia may have auditory processing disorder and have been experimentally investigated by many researchers. [3-8] Studies on incidence of auditory processing deficits in children with dyslexics are estimated to be of 40%. [9]

Among the various electrophysiological tests, the Auditory Long Latency Response (ALLR) is the most frequently used test for assessing the cortical processing of auditory signals in individuals with learning impairment. Most of the studies have reported a prolonged latency [10-12] and reduced amplitude in these populations. [13,14] David and Ghosh [15] recorded P1, N1, P2 and N2 peaks in individuals with reading problem and results reveal an increased latency of P1 and P2 peaks when compared with normal average readers. In a similar line, Arehole [10] studied the relationship between long latency responses and learning disorders in individuals with dyslexia. Results revealed an increased P2-P1 inter-peak latency in individuals with dyslexia in comparison to normal children.

Johnson, Nicol and Kraus [6] described that the synthetic /da/ syllable has been used to study the processing of complex stimuli like speech, at the level of brainstem as well as at the level of cortex and further to study deviancies if any, in clinical population like learning disability. The response manifests as a series of brief neural events that are time-locked to the onset, offset, and the sustained information of the stimulus /da/. This tool has been used to assess binaural listening processing in children with learning disability including dyslexia. Therefore it has been suggested that the use of speech evoked ALLR in assessing such kind of processing deficits is promising to be a valid and reliable tool in such clinical population.

Speech evoked ALLR helps in assessing the capacity of auditory cortex to detect changes within the speech stimuli. [16] There are different types of speech signals which are quite useful in eliciting ALLR includes natural or synthetic vowels, syllables and words. [17-19] Hence, the recording of ALLR using speech stimuli can probe how the brain processes the signals that underlie auditory detection and discrimination. Majority of the studies have focused on recording of ALLR on click stimulus or more frequency specific tone bursts. But recording of ALLR using tone burst does not give much information about the processing or perception of speech. The P1-N1-P2 evoked neural response is heavily influenced by acoustic content of evoking signal. Hence it is important to know more about how the speech signal is processed in children with dyslexia. Therefore, the speech stimuli /da/ was used in the present study.

Studies have also shown abnormal processing of speech stimuli and normal processing for tonal stimuli in dyslexic children. [20] Tallal [21] reported that there is deficit in processing of brief, rapidly changing auditory stimulus in dyslexic individuals. Study has suggested that such children have difficulty in processing of complex stimuli especially to process through auditory mode. [22,14]

Along with the electrophysiological tests various behavioural tests are also proved to be sensitive in identifying auditory processing deficits. However, the behavioural tests are affected by different subject related factors like attention, cognitive skills etc and these tests are time consuming too. Hence electrophysiological investigations which are not affected by subject related factors and less time consuming can be an appropriate substitute for behavioural tests in certain individuals. Hence validations of the electrophysiological tests are important. Speech evoked ALLR being a recent addition to the cluster of tests that are used to study the children with dyslexia, it is imperative to understand the test results in detail. Hence the present study was carried out to understand the latency and amplitude measures of speech evoked ALLR which can be useful in the clinics for the appropriate diagnosis and rehabilitation of individuals with dyslexia.

MATERIALS AND METHODS

Participants: Two groups of participants were included in the study; control group and experimental group. Twenty participants (40 ears) from the both groups in the age range of 10-12 years participated in the study. Control group and experimental group consisted of 20 ears each from 10 typically developing children and 10 children with dyslexia respectively. The diagnosis for the experimental group was made by speech language pathologists / Psychologists at All India Institute of Speech and Hearing, Mysore, India. Participants in experimental groups were randomly selected from the Department of Clinical Services at AIISH, Mysore, India who were enrolled them. Those participants who served as control group was voluntarily show their willingness to participate in the study and they were randomly selected from different socio-economic background. All the participants had hearing sensitivity within normal limits (hearing threshold less than 15 dB HL at octave intervals between 250 Hz to 8000 Hz for air conduction and between 250 Hz to 4000 Hz for bone conduction), normal middle ear functions as per immittance evaluation, and average or above average intelligence, based on Raven's progressive matrices were selected for the study. However, those participants who were diagnosed as dyslexia with any additional associated problems such as attention deficit disorder with/without hyperactivity, chronic psychological disorder, or with any other neurological disorder were excluded from the study.

Instrumentation: A calibrated two channel diagnostic audiometer (Orbiter-922) with TDH-39 headphones and MX-14/AR ear cushion was used for air conduction thresholds. Radio ear B-71 bone vibrator was used for estimating bone conduction thresholds. A calibrated middle ear analyzer (GSI-Tympstar, version 2) was used to rule out middle ear pathology. ILO version 6 was used to record the transient evoked otoacoustic emission. Bio-logic Navigator pro (version 7.0) evoked potential system was used for recording click evoked auditory brainstem response (ABR) and speech evoked ALLR.

Test Materials: For speech evoked ALLR, a natural /da/ stimulus was recorded by an adult male speaker with clear articulation. The recording was done using unidirectional microphone connected to the computer in the sound treated room. Adobe Audition (version 2) software with a sampling rate 48000 Hz and 16 bit resolution was used. The stimuli duration was 185 msec. Recorded stimulus was then converted into wave file and loaded into the Biologic navigator pro evoked potential system for speech evoked ALLR recording.

Test Procedure: Screening checklist for Auditory Processing (SCAP) was administered on control group developed by Yathiraj and Mascarenhas, [23] to rule out symptoms of auditory processing disorders. It consists of twelve questions having the symptoms of deficits in auditory processing. The scoring was done on a two point rating scale (Yes/No). Children who scored less than 50% were considered for the control study.

Pure tone thresholds were obtained at octave intervals between 250 Hz to 8000 Hz for air conduction and between 250 Hz to 4000Hz for bone conduction (mastoid placement), using modified Hughson and Westlake procedure. [24] Tympanometry was carried out using 226 Hz probe tone at 85 dBSPL to rule out any middle ear pathology. For reflexometry, acoustic reflex measurement was performed using reflex eliciting tone of 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz ipsilaterally and contralaterally. Transient evoked otoacoustic emissions (TEOAE) were measured using click stimuli at 85 dBSPL in both ear to assess the outer hair cells functioning.

Click evoked ABR and speech evoked ALLR were recorded in both ears for all the participants using the test protocol mentioned in table 1. Participants were made to sit comfortably in order to ensure a relax posture and minimum rejection rate. Gold cup electrodes were placed after cleaning the electrode placement sites with preparing gel. Conduction paste was used to improve the conductivity of the recording signal from the generator sites. The electrodes were secured to the place by using plasters. The electrode placement was kept and followed as per the test protocol.

Test environment: The testing was carried out in an acoustically sound treated room with ambient noise levels within permissible limits as per ANSI S3.1. [25]

Test protocol: The following test protocol was used for recording click evoked ABR & speech evoked ALLR.

Table 1: *Protocol for recording click evoked ABR and speech evoked ALLR.*

Parameters	Click evoked ABR	Speech evoked ALLR
Stimulus	Click (100 µs duration)	Natural /da/ stimulus (185 millisecond)
Electrode Placement	Non-inverting - Fpz Common – A1/A2 Inverting – A2/A1	Non-inverting - Fpz Common – A1/A2 Inverting – A2/A1
Intensity	90 dBnHL	80 dBnHL
Polarity	Rarefaction	Alternating
Filter setting	100 – 3000 Hz.	1 – 30 Hz.
Repetition rate	30.1/sec	1.1/sec
Time window	10-12 ms	500 ms
No. of channel	Single	Single
No. of sweeps	1500	200
Impedance	< 5k Ω	< 5k Ω
No. of replication	2	2

Statistical Analysis: Descriptive statistical analysis of the scores in terms of mean, standard deviation and parametric tests using Multivariate analysis of variance (MANOVA) was performed using Statistical package Social Science (SPSS 16.0) software for different parameters of speech evoked ALLR. The results obtained are presented and discussed in the subsequent section.

RESULTS AND DISCUSSION

The aim of the study was to investigate cortical processing of speech using speech evoked ALLR in children with dyslexia and in typical developing children. To analyze the data, descriptive statistics and Multiple Analysis of Variance (MANOVA) were carried out for speech evoked ALLR. *Descriptive statistics* was done to find out the mean and standard deviation (SD) for all the parameters for both control and experimental groups. *MANOVA* was administered to compare between experimental as well as control group for latency and amplitude of speech evoked ALLR.

Speech evoked ALLR: In typically developing and dyslexic children, it was observed that all the peaks (Wave P1, N1, P2, & N2) of speech evoked ALLR were present in all participants. The mean and standard deviation of speech evoked ALLR is depicted in figure 1.

The mean latencies and amplitudes obtained in present study are in accordance with the previously reported studies. [26-27] It can also be observed that standard deviation is lesser for control group in comparison to dyslexic children group for all peaks except wave N2. It probably indicates heterogeneity of dyslexic children in processing of speech at cortical level in comparison to typically developing children.

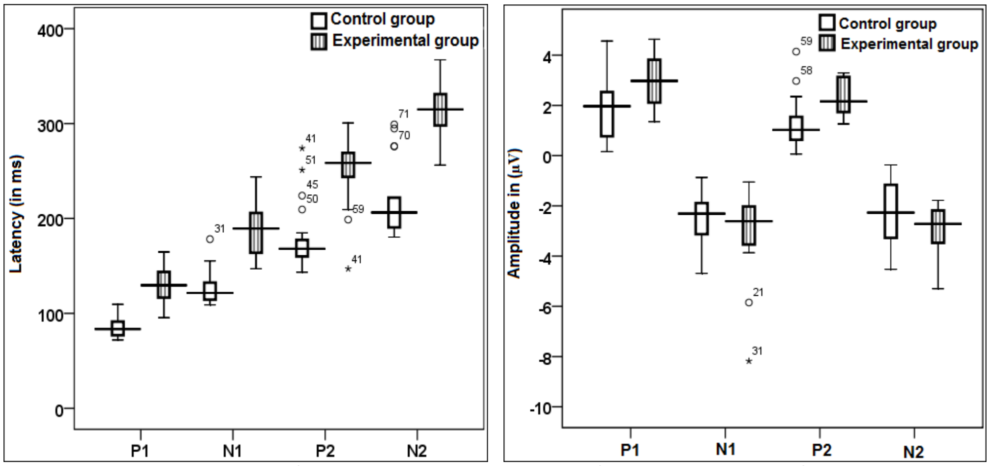

Figure 1: Mean and Standard deviation (SD) of latency and amplitude measures of speech evoked ALLR for control and experimental group

Table 2: *F-value for latency measure between control and experimental groups*

	Latency measure		Amplitude measure	
Peaks	F-value	p-value	F-value	p-value
P1	F (1,38) = 76.53	0.000***	F (1,38) = 10.94	0.002**
N1	F (1,38) = 70.68	0.000***	F (1,38) = 1.86	0.180#
P2	F (1,38) = 43.95	0.000***	F (1,38) = 14.07	0.001***
N2	F (1,38) = 84.33	0.000***	F (1,38) = 4.10	0.050*

*p<0.05; **p<0.01; ***p<0.001; #p > 0.05

MANOVA was carried out to compare the latency and amplitude measures of ALLR between the groups. Results revealed prolonged latencies of P1, N1, P2, and N2 ($p < 0.001$) and reduced amplitude of all peaks of speech evoked late latency responses except for wave N1 ($p < 0.05$) in individuals with dyslexia (table 2).

The present findings are in accordance with the earlier studies which were reported in the literature. [28,29,27] Pinkerton, Watson and McClelland [28] studied late auditory evoked potentials in children with reading, writing and spelling difficulties and the results revealed a prolonged latency and reduced amplitudes of responses. They suggested that the abnormalities in the cortical recordings represent the altered cortical functions. They also assumed that the differences in responses reflect a disturbance in selective attention which may in turn affect the reading and writing skills. Picton et al. [30] also attributed the delay in latency to short attention span in children with dyslexia.

Similarly, Byring and Jaryilehto [28] studied the late latency auditory evoked potentials in individuals who exhibits high rate of spelling errors. They also reported a prolonged latency and reduced amplitude of the peaks of late latency response. The authors assumed that a maturational delay of auditory processing which is represented as an attention disorder resulted in higher rate of spelling errors.

Purdy, Kelly and Davies [27] also studied LLR in children with learning disabilities and reported that the latency of P1 was earlier while that of P3 was prolonged. They also reported that the amplitudes of waves were lesser for children with learning impairments in comparison to typically developing children. The study concluded that the cortical processing of auditory signals is abnormal in children with learning impairment.

From the above discussed studies it can be assumed that the deviancies which were observed in the amplitude and latency values of ALLR in the present study reflect the abnormal cortical processing of auditory signals. This abnormality in the cortical auditory processing may be attributed to maturational delay of the auditory processing in individuals with dyslexia.

CONCLUSION

It can be concluded from the present study that Speech evoked auditory late latency response is easily traceable in all children with dyslexia and typically developing children. However, children with dyslexia exhibited prolonged latencies and reduced amplitudes of speech evoked auditory late latency response in the present study. The deviancies appeared in the study may be attributed to the abnormal encoding of speech signal at the cortical level in children with dyslexia. Hence speech evoked auditory late latency response may be used as a tool to differentiate between individuals with and without dyslexia.

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