EFFECT OF NOISE ON BIOMARK IN INDIVIDUALS WITH LEARNING DISABILITY

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Abstract

Several studies have reported poor temporal processing and speech-in-noise problems in children with learning disability (LD) (Chandrasekaran, Hornickel, Skoe, Nicol & Kraus, 2009; Hayes, Warrier, Nicol, Zecker & Kraus, 2003). Electrophysiological techniques such as speech ABR have been used (King, Warrier, Hayes & Kraus, 2002; Russo, Nicol, Zecker, Hayes & Kraus, 2005) to determine the auditory processing deficits in children with LD. The present study utilised BioMARK to find out the differences in speech sound processing in children with LD, in quiet and noise. Fifteen children in the age range of 8 to 12 years were selected for the study which included 5 children with LD and 10 typically developing children. All the 15 participants had a normal peripheral hearing sensitivity and they underwent BioMARK response testing with 40 ms /da/ stimulus. The stimulus was presented in quiet as well as in presence of white noise (+30 dB SNR) ipsilaterally. The peaks were marked as wave V, A, C, D, E, F, and O. The waveforms were converted into ASCII codes and processed using Brainstem Toolbox on Matlab vR2009B (Skoe & Kraus, 2010). Amplitudes of the formant of fundamental frequency, first formant and higher frequency were obtained and compared. Results showed a significant difference ($p<0.05$) in latency of the peaks V, A, D, E, F and O, of BioMARK in children with LD as compared to typically developing children. This was true for both quiet and noise conditions. Also, a significant difference ($p<0.05$) in the amplitudes of various formants was found in noise condition for children with LD and typically developing children. So, it can be concluded that there is a problem in decoding of information in presence of noise which is more pronounced in children with LD. Hence, other management strategies along with environmental modifications should be employed.

Keywords: *Noise, Learning disability.*

Speech perception in daily life places a lot of demands on the auditory system. For an accurate representation of the speech, rapidly changing spectral information and its separation from background noise is absolutely necessary. Usually, most of the individuals are able to face and get through these challenges easily. However, there are groups of population who find it extremely difficult to understand speech in presence of noise. One such group consists of individuals with learning disability (LD). LD, according to the Individuals with Disabilities Education Improvement Act (2004) is a disorder which may involve deficits in basic psychological processes required for understanding or for using spoken / written language. These problems may manifest themselves as deficit in academic abilities. Several researchers have documented poor auditory processing in children with learning problems (Cestnick & Jerger, 2000; Farmer & Klein, 1995; Hari & Kiesila, 1996; Nagarajan et al., 1999; Tallal & Piercy, 1974). One of the major auditory processing problems in these children has been listening in background noise (Bellis, 1996; Breedin et al., 1989; Chermak & Musiek, 1997; Cunningham, Nicol, Zecker & Kraus, 2001; Katz, 1992; Katz et al., 1992).

Researchers have reported an effect of noise on brainstem (King et al., 2002) as well as cortical responses (Martin et al., 1999; Whiting et al., 1998; Wible, Nicol & Kraus, 2002). In few cases, there have been reports of a presence of neurobiological abnormalities leading to auditory processing deficits (Cunningham et al., 2001; Nagarajan et al., 1999; Temple et al., 2000) while in others the cause has been unknown. Many investigators have attributed the poor reading skills in children to their inability to perceive in presence of noise (Godfrey et al., 1981; McBride-Chang, 1996; Reed, 1989).

To overcome the dreadful effects of noise on speech comprehension, several researchers (Bellis, 2003, Chermak & Musiek, 1997; Ferre, 2006) have suggested a delivery of signal at a higher signal-to-noise ratio (SNR). This is expected to benefit these children in classroom conditions where SNR is poor. The American

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(ASHA) (2005) recommended an SNR of +15 dB in classroom conditions.

There are many behavioural tests that can help in obtaining the auditory processing status of an individual but since many of these tests are not modality specific and are cognitively based (Cacace & McFarland, 2009), it becomes difficult to rely on their results, especially in children. On the other hand, there are electrophysiological tools which do not require much participation from an individual.

The present study was aimed at understanding the differences in typically developing children and children with LD in handling rapid speech signals using a BioMARK response. The study also aimed to compare the BioMARK responses between the two groups in presence of ipsilateral white noise at a higher SNR (+30 dB SNR) than recommended by ASHA (2005) for classroom situations.

Method

Participants

Ten typically developing children (20 ears) and 5 children with LD (10 ears) in the age range of 8 to 12 years were selected for the study. All the 15 participants had a pure tone air conduction and bone conduction threshold within 15 dB HL, from 250 Hz to 8000 Hz and 250Hz to 4000Hz, respectively. All of them had a type A tympanogram with acoustic reflex thresholds ranging from 80 to 100 dB HL and speech identification scores greater than 90% in both ears. It was ensured that all participants had normal Intelligence Quotients between 90 to 110 as measured on Raven's Coloured Progressive Matrices (Raven, 1956). Children with LD were selected based upon the diagnosis of a speech language pathologist.

Instrumentation and environment

A calibrated dual channel audiometer (Orbiter 922, GN Otometrics, Taastrup, Denmark) was used for testing pure tone air conduction, bone conduction and speech identification testing. Headphones used for this purpose were TDH-39 housed in Mx-41/AR cushions and bone vibrator was Radioear B-71. A calibrated immittance meter (GSI Tympstar; Grason Stadler, Eden Prairie, MN) was used for testing the middle ear function. A 'Biologic Navigator Pro' evoked potential instrument was used for recording click evoked auditory brainstem response (ABR) and BioMARK response. All evaluations were carried out in an acoustically treated two-room sound suite fitted to ANSI S3.1 (1991) standards.

Stimuli

For a click ABR, a click stimulus of 100 µs was utilised while for a BioMARK response 40 ms /da/ stimulus recommended by King et al. (2002) was used. This stimulus was available in the 'Biologic Navigator Pro' evoked potential instrument.

Procedure

After obtaining the demographic details of the participants, they were subjected to pure-tone air conduction, bone conduction testing, speech audiometry and acoustic immittance measurement. Further, the participants underwent the click ABR and BioMARK testing according to the protocol provided in Table 1. The pattern of testing followed from click ABR testing, to BioMARK testing in quiet to BioMARK testing with an ipsilateral white noise. This white noise was provided ipsilaterally through the evoked potential system at 50 dB SPL in a way so that signal to noise ratio is maintained at 30 dB SNR.

Table 1: *Protocols for click ABR and BioMARK testing*

	Stimulus	Click ABR	BioMARK /da/
Stimulus parameters	Duration	100 µs	40 ms
	Intensity	80 dB SPL	80 dB SPL
	Polarity	Alternating	Alternating
	Repetition rate	11.1/sec	9.1/sec
	No. of stimuli	2000	3000
	Analysis time	10 ms	74.67 ms (15 ms pre-stimulus, 59.67 ms post-stimulus)
Acquisition parameters	Filters	100 - 3000 Hz	100 - 3000 Hz
	Electrode placement	Non-inverting (+ve): vertex; inverting (-ve): Test ear mastoid; ground: Non-test ear mastoid	Non-inverting (+ve): vertex; inverting (-ve): Test ear mastoid; ground: Non-test ear mastoid
	Transducers	Biologic Inserts	Biologic Inserts

Two recordings for each waveform were obtained to ascertain the reliability and these waveforms were 'weighted added' using the BIOLOGIC system software. On this waveform, the peaks were marked as V, A, C, D, E, F and O. The identification of peaks was carried out by two audiologists (other than the authors). Further, these waveforms were converted into ASCII codes using the AEP to ASCII conversion software. These ASCII codes were further processed in the Brainstem Toolbox developed by Skoe and Kraus (2010) using Matlab vR2009B. This helped in obtaining the fast fourier transformation (FFT) of the waveforms. FFT led to obtaining the spectral amplitude at the fundamental frequency (F0) 103-120 Hz, first formant (F1) 455-720 Hz and second formant (F2) 720-1154 Hz.

Analyses

Both the groups were compared for the latencies of the peaks as well as the spectral amplitude obtained in both quiet and noise conditions. Descriptives (mean and standard deviation) were obtained for both the groups for both the ears. Mann Whitney U test was carried out to know the differences between the two groups in terms of latencies and amplitude with and without the noise. Wilcoxon test was performed to know the differences within the group in terms of latencies and amplitude, with and without the noise.

Results

The mean and standard deviations for the latencies of wave V, A, D, E, F, O were obtained as depicted in Table 1. Wave C was not considered for further statistical treatment as it was absent in 22 out of 30 ears tested.

The mean latencies as observed in Table 1 reveal that there is a delay in latency of all the peaks in children with LD group as compared to the typically developing children. It can also be noticed that with an introduction of noise with the stimulus, there was a shift in latencies of all the peaks. This happened for both the groups but slightly more for children with LD group for wave V, A and D.

Table1: *Mean and standard deviations of the latencies of wave V, A, D, E, F and O for the typically developing and children with LD group across the quiet and noise conditions*

Wave		Condition							
		Quiet				Noise			
		Typically developing		Children with LD		Typically developing		Children with LD	
	Ear	Mean (ms)	S.D.	Mean (ms)	S.D.	Mean (ms)	S.D.	Mean (ms)	S.D.
V	Right	6.66	0.14	7.66	0.42	7.86	0.47	8.80	0.39
	Left	6.60	0.09	7.98	0.36	7.55	0.52	9.05	0.24
A	Right	7.35	0.17	8.28	0.48	8.68	0.31	9.92	0.45
	Left	7.36	0.12	8.56	0.14	8.65	0.54	10.32	0.51
D	Right	22.64	0.23	25.22	0.78	23.94	0.31	28.62	0.56
	Left	22.60	0.25	26.96	1.36	22.60	0.26	29.36	1.87
E	Right	30.83	0.19	35.26	1.28	32.31	0.76	35.26	1.28
	Left	30.83	0.20	38.30	0.63	30.83	0.20	38.30	0.63
F	Right	39.39	0.18	41.23	0.94	39.39	0.18	41.23	0.94
	Left	38.37	3.12	42.72	1.41	38.37	3.13	42.72	1.41
O	Right	47.62	0.20	52.86	2.41	47.63	0.20	52.86	2.41
	Left	47.60	0.12	51.64	2.54	47.60	0.12	51.64	2.54

Further inferential statistics were also carried out. Mann Whitney U test was done to know if there was any difference between the groups in both quiet and noise condition. It was found that the LD group was significantly different ($p<0.001$) from the typically developing children both in quiet and the noise condition. In Figure 1(a), it can be seen that for both the ears there is a delay in latency for the children with LD for all the peaks, in quiet condition. In figure 1(b), a similar trend can be appreciated for the noise condition. Wilcoxon signed ranks test revealed that there was a significant difference ($p<0.05$) in the latencies of all the peaks with introduction of noise. This was true for both the experimental and control group.

The amplitudes of Fo, F1 and higher frequency (HF) were obtained from processing the ASCII codes of waveforms into Brainstem Toolbox. These amplitudes were further compared for both the groups and conditions as depicted in Table 2. Mann Whitney U test also revealed a difference between the two groups for the amplitude for Fo, F1 and higher frequency.

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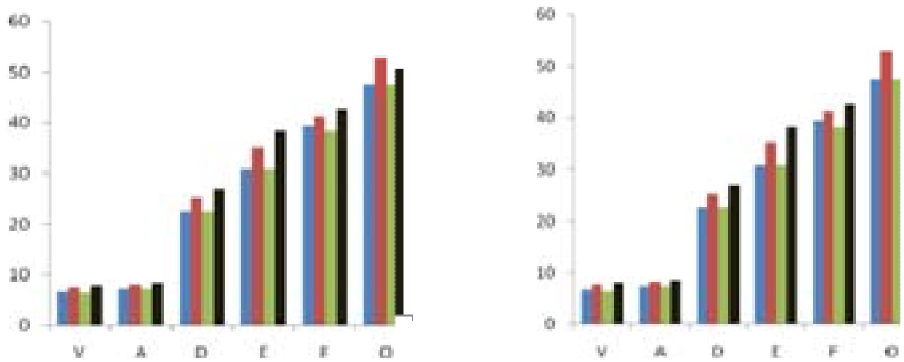

Figure1: *Comparison of latencies of the BioMARK response peaks across experimental and control group in (a) quiet condition (b) noise (+30 dB SNR)*

Table 2: Depicting the amplitude (in µV) for the various frequencies across the different groups and conditions

Frequency	Ear	Typically developing		Typically developing		Typically developing (+30dB SNR)		Typically developing (+30 dB SNR)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Fundamental	Right	5.39	0.98	4.83	1.02	5.20	1.02	2.48	1.06
frequency (Fo)	Left	4.81	1.11	2.97	0.96	4.78	1.02	2.25	1.02
First formant	Right	1.12	0.45	0.96	0.43	1.11	0.33	0.33	0.28
(F1)	Left	0.99	0.53	0.78	0.29	0.97	0.58	0.24	0.22
Higher frequency	Right	0.31	0.13	0.22	0.11	0.32	0.15	----	----
(HF)	Left	0.22	0.12	0.20	0.19	0.19	0.11	----	----

This difference was persistent among the groups for both the conditions. As it can be observed from Table 2, there is a regular decrease in the amplitude of Fo, F1 and higher frequency from control to experimental group and quiet to noise condition. Wilcoxon signed ranks test was carried out and it was found that there was a significant difference ($p<0.05$) in amplitude in quiet and noise in both the groups. The decrease in amplitude was observed in both the groups but in children with LD, low amplitudes were noticed for Fo and F1 while the amplitudes at higher frequencies were too low to be recorded.

Discussion

Previously, there have been reports of slow temporal processing and poor speech-in-noise perception in children with LD (Bellis, 1996; Ferre, 2006; King et al., 2002; Russo et al., 2005). Both brainstem and cortical evoked potentials have been utilised in the past to know the difference in auditory processing between children with LD and typically developing children. In the present study, through BioMARK speech ABR responses, it has been found that there is an increase in latency of all the peaks of speech ABR in children with LD. These results are in consonance with those of the (Cunningham et al., 2001; King et al., 2002) who also noted a delay in latency for speech ABR peaks. This has been attributed to the temporal processing deficit in the children with LD.

Although, a number of studies have investigated nature of speech ABR in quiet conditions, there is a dearth of literature studying the effect of ipsilateral noise on speech ABR. The present study found a further increase in latency of the peaks of speech ABR. It was found that noise affected the typically developing children too, but its effect on children with LD was much more. After analysing the amplitude of Fo, F1 and F2, it was found that there was a great reduction of amplitude in children with LD in both quiet and noise (+30 dB SNR). The amplitude for higher frequencies was distorted to the maximum extent in this group. Comparatively, the group with typically developing children did not have a significant reduction in amplitude at all the formant frequencies at +30 dB SNR. This shows that children with LD are more prone to the hazardous effects of noise.

In order to overcome the effects of noise and enhance the auditory processing, several investigators (Bellis, 2003; Chermak & Musiek, 1997; Ferre, 2006) have recommended an increase in SNR to be provided in classroom conditions. ASHA (2005) has recommended +15 dB SNR to be used in classrooms. In this preliminary study, it is evident that even at +30 dB SNR, children with LD could not benefit much. Hence, other management strategies to improve the auditory processing in such individuals should be undertaken. Direct remediation activities (Bellis, 1996) like noise desensitisation training (Katz & Burge, 1971; Maggu & Yathiraj, 2011) can be promising in this regard.

Conclusions

From the findings of this preliminary study, it can be concluded that children with LD exhibit problems in speech sound processing. This problem is aggravated in the presence of noise. A higher SNR might not be an exact solution for this population. Hence, other management strategies should also be utilized.

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