Relationship between Speech Identification Scores and Auditory Evoked Potentials in Children with Learning Disability

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Abstract

The main aim of the study was to correlate the SIS scores with the AEPs recorded from children with and without learning disabilities having normal hearing. A comparison was also made between the AEPs recorded using different stimulus in three different stimulus conditions. In the process two groups of subjects were taken, 10 children with learning problem and 10 children without learning problem. Routine audiometric tests such as pure tone audiometry, speech audiometry and immitance testing was carried out to rule out the presence of hearing loss in children from both the groups. ABR and LLR were recorded for the speech stimulus /da/ in three different conditions (quiet, 0 dB SNR and +3 dB SNR). ABR wave V latency was and N1, P2 latency and the amplitude of the N1-P2 complex of ALLR were noted for the analysis. The results showed that wave V latency was prolonged for both the groups in the presence of ipsilateral noise. Within the two signal to noise ratio conditions no significant difference was noted. Group wise comparison revealed no significance difference for all the conditions although; the clinical group had longer wave V latency in all the conditions. No significant difference was observed in the N1 and P2 latency across the three conditions in both the groups. Comparison between the groups revealed that there was a significant difference in the N1 latency for all the three stimulus conditions, and P2 latency for 0 and +3 dB SNR conditions. The clinical group had prolonged latency of N1 and P2 in all the conditions. The amplitude of the N1-P2 complex in the two groups was different across the three stimulus conditions, but failed to reach a significant level. The presence of noise reduced the SIS scores for both the groups and the effect was more for the clinical group. However, there was no one-to-one correlation could be obtained between the SIS and AEP recordings. In conclusion, AEPs are sensitive to differentiate between children with learning problem from those without learning problem, especially in conditions with background noise. Although, the ABR wave V latency is not a sensitive measure, the latency of N1 and P2 of ALLR may be a sensitive measures to identify a with learning problem.

Introduction

The role of an audiologist is to identify and rehabilitate individuals with hearing problem. Some of these problems may be very obvious and easy to identify such as a severe-to-profound hearing loss, or the presence of a conductive hearing loss. The major challenge is faced when one has to identify hearing problem which are subtle in nature such as the presence of central auditory processing disorder (C) APD, or auditory neuropathy.

There are various behavioral tests which have been developed to identify different auditory processes like gap detection test which assesses the temporal integrity and dichotic CV test which assesses the binaural integration deficits are few to name. There is a surfeit of literature available to prove the sensitivity and specificity of these tests. Most of these tests are time consuming, during which there is high possibility for the child to get distracted or

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lose his attention. It is also possible that some children may not understand the complex instructions in which case the testing would be difficult. In Indian context, where many languages are spoken it is difficult to develop a test in each language. Also, for children less than 7 years of age there is lack of normative data available. In case the normative data is available, a wide range of scores makes it difficult to identify a child with auditory processing disorder.

The prevalence of central auditory processing deficit is more in children with learning disability. The National Joint Committee on Learning Disabilities (NJCLD, 1990) defines the term learning disability as: "a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning or mathematical abilities. These disorders are intrinsic to the individual and presumed to be due to the Central Nervous System Dysfunction" (NJCLD, 1990).

There have been many studies done to evaluate the usefulness of auditory evoked potentials (AEPs) in discriminating children having learning problem with those having no learning problem. Majority of these studies have recorded AEPs using speech as a stimulus as it represents the signals encountered in daily living situation. The studies have shown that in the auditory brainstem responses the latency of wave V, and the wave V slope latency and amplitude are sensitive measures to differentiate between children having learning problem from those having no learning problem (Wible, Nicol, & Kraus, 2005; Cunningham, Nicol, Zecker, & Kraus, 2001). In the auditory late latency responses it is the amplitude of the N1-P2 complex, which is sensitive to identify children with learning problem (Putter-Katz et al, 2005; Purdy, Kelly, & Davies, 2002; & Cunningham et al, 2001).

Behavioral measures of speech intelligibility show that children with learning problem have poorer speech perception ability than the children without learning problem. This difference in the perception is enhanced in stressful environmental conditions like listening in the presence of background noise, degrading the perception abilities of children with learning problem even more (Wible, Nicol, & Kraus, 2005; Cunningham et al, 2001). Various studies have been done using AEPs to tap the exact nature of deficit responsible for degrading speech perception in children with learning problem. None of the study has been able to identify the exact deficit (Song, Banai, & Kraus, 2008; Russo, Nicol, Musacchia, & Kraus, 2004; & Cunningham et al, 2001).

Need for the study

Learning disability (LD) is a very heterogeneous group; it has many subgroups. Some children having LD may exhibit auditory processing deficits, while some may not exhibit auditory processing. There are various tests which enable us to differentiate the kind of deficit the child has. Most of these tests are subjective in nature and require complete attention and concentration of the child. The results of the tests would be invariably affected by the variables such as the attention span of the child, his/her willingness to co-operate in the testing. The child might be wrongly diagnosed as having LD based purely on these subjective tests if the above mentioned variables are not controlled. Hence, there is a need for an objective test which will help us in accurately diagnosing these children.

In literature there are many studies done to find the neurophysiological responses i.e., auditory evoked potentials (AEPs), in children without a learning problem and in children with learning disability. Majority of these studies have been done under quite background conditions and not in adverse listening conditions (Wible, Nicol, & Kraus, 2005). The learning disabled population performs well in quite situations; whereas the major problem faced by them is in adverse listening situations (Russo et al, 2004; Cunningham et al, 2001). Hence these study over estimate their performance. AEPs for speech stimuli in adverse conditions could be sensitive in identifying auditory processing deficits, as most often this population does not exhibit abnormality in quite conditions.

As both the speech perception abilities and the AEPs are affected in the learning disabled group to a larger degree than compared to normals there is a need to relate the both.

Aim of the study is to:

1) Know whether the latency of ABR wave V vary in different stimulus conditions and also between the two groups.
2) Know whether the latency of N1 and P2 waves vary in different stimulus conditions and also between the two groups.
3) Also to know whether the amplitude of the N1-P2 complex differ in different conditions and also between the two groups.
4) Find a relationship between the latency of the ABR wave V, ALLR waves N1 and P2 latency with the SIS scores obtained in different conditions independently for both the groups.
5) Find a relationship between the amplitude of N1-P2 complex with the SIS scores obtained in different conditions independently for both the groups.

Method

Subjects

A total of 20 subjects were taken for the study. They were divided into two groups. Group I consists of children with learning disability who served as the clinical group; and group II consists of children with no learning disability who served as the control group.

Clinical Group: A total of 20 ears from '10' children in the age range of 7 to 15 years, who were diagnosed as having learning disability by an experienced speech language pathologist; and psychologist was taken. All the children had normal hearing sensitivity.

Selection criteria: Subjects who met the following criteria were taken:

- All the subjects had pure tone thresholds within 15 dB HL at octave frequencies from 250 Hz to 8000 Hz for air conduction and between 250 Hz and 4000 Hz for bone conduction.
- All the subjects had good Speech Identification Scores (above 90%) in quiet.
- All of them had 'A' type tympanogram with acoustic reflex threshold within normal limits, indicating a normal middle ear function.
- No relevant otologic history was reported by the subjects.
- No history of any observable medical or neurological impairment.
- All the subjects were diagnosed as having learning disability by an experienced speech and language pathologist and or psychologist, based on the Early Reading Skills test results (Loomba, 1995).

Control Group: A total of 10 ears from '10' children in the age range of 7 to 15 years, whose language skill was adequate to their age were taken. All of them had normal hearing sensitivity.

Selection Criteria

- All the subjects had pure tone thresholds within 15 dB HL at octave frequencies from 250 Hz to 8000 Hz for air conduction and between 250 Hz to 4000 Hz for bone conduction.
- All the subjects had Speech in noise (SPIN) scores 70% and above at 0 dB SNR.
- 'A' type tympanogram with acoustic reflex threshold within normal limits was obtained from all the subjects, indicating a normal middle ear function.
- No relevant otologic history was reported by the subjects.
- No history of any observable medical or neurological impairment was noticed.
- A checklist developed by WHO (1999, cited in Singhi, Kumar, Malhi, & Kumar, 2007) was administered on all the children to rule out the presence of any learning impairment.

Speech in noise scores (SPIN)

SPIN test was done in two different conditions having speech stimulus at 40 dB above the SRT level. The type of noise used was the speech noise. A standardized word list developed by Vandana (1998) was used as the stimulus.

The conditions in which SPIN scores obtained were:

- ✓ SIS at 0 dB SNR
- ✓ SIS at +3 dB SNR

AEP recording

All the subjects participated in the study were made to sit comfortably on an arm chair. They were asked not to move their head or blink their eyes while AEP recording to avoid muscle artifacts. They were also instructed to be awake throughout the AEP recording as it might affect ALLR recording. All the three electrode sites were cleaned and the intra electrode impedance of 5 kΩ and inter electrode impedance of 3 kΩ was maintain.

Table 1: Parameters used to record ABR

STIMULUS PARAMETERS		ACQUISITION PARAMETERS	
Stimulus type	Speech stimulus (/da/)	*Mode*	Monaural stimulation
Stimulus duration	40 msec	*Electrode type*	Disc electrode
Stimulus rate	9.1/sec	*No of channels*	Single channel
Polarity	Alternating	*Analysis window*	60 ms
Number of Sweeps	1500	*Filter settings*	100 Hz – 3000 Hz
Intensity	65 dB SPL for both the subject groups	*Notch Filter*	On
Transducer	ER-3A insert receiver	*Replicability*	Twice for all the 3 conditions
Ipsilateral masking	i) without noise ii) with 65 dB SPL WBN (0 dB SNR) iii) with 62 dB SPL WBN (+3 dB SNR)	*Electrode montage*	Ground: non test ear mastoid (M_i) Inverting: test ear mastoid (M_i) Non inverting: forehead (Fpz)
		Gain	1,00,000 times
		Artifact rejection	40 µV

Table 2: Parameters used to record ALLR

STIMULUS PARAMETERS		ACQUISITION PARAMETERS	
Stimulus type	Speech stimulus (/da/)	*Mode*	Monaural stimulation
Stimulus duration	40 msec	*Electrode type*	Disc electrode
Stimulus rate	Speech: 1.1/sec	*No of channels*	Single channel
Polarity	Alternating	*Analysis window*	500 ms with pre stimulus recording of 50 ms
Number of Sweeps	300	*Filter settings*	1 Hz – 30 Hz
Intensity	65 dB SPL for both the subject groups	*Notch Filter*	Off
Transducer	ER-3A insert receiver	*Replicability*	Twice at all the 3 conditions
Ipsilateral masking	i) without noise ii) with 65 dB SPL WBN (0 dB SNR) iii) with 62 dB SPL WBN (+3 dB SNR)	*Electrode montage*	Ground: non test ear mastoid (M_i) Inverting : test ear mastoid (M_i) Non inverting : forehead (Fpz)
		Gain	50,000 times
		Artifact rejection	80 µV

ABR and LLR were recorded at 65 dB SPL. This level was chosen because according to Olsen, (1998) normal conversational level is between 55-65 dB SPL. For ABR the Wave V latency was noted. For the LLR the N1, P2 latency and N1-P2 complex' amplitude were identified and marked. More emphasis was given on these two components of the LLR waveform as the N1 amplitude was found to be more affected by noise (Putter-Katz et.al, 2005).

Waveform Analysis

Both the ABR and LLR waveforms were stored for further analysis. Later the waveforms were recalled and analyzed. The waveforms were shown to three experienced audiologists. Their task was to identify the presence or absence of a response for both ABR and LLR for all the stimuli conditions. When there was an agreement regarding presence of response between the three audiologists the latencies of Wave V of ABR, N1, P2 of LLR and the amplitude of N1-P2 complex for LLR were noted. The prominent peaks of the response were then correlated to the behavioral SPIN results in both the groups.

Results

The SIS scores and the AEP data obtained for the different conditions and from both the control (children with no learning problem) and the clinical (children having learning disability) groups were tabulated. They were then compared to check if there was any statistically significant difference in the data obtained between the two groups. The data was also analyzed to compare the differences amongst the three stimulus conditions in each group separately. The final part of the analysis was to correlate the SIS scores with the AEP results obtained from each of the three conditions separately. The details of the mean and standard deviation of different AEP parameters are shown in table 3 and table 4.

Auditory brainstem Responses

Wave V latency was shorter for control group than the clinical group for all the conditions. However, they have failed to reach a statistically significant level. The amount of Wave V latency shift is same for both the groups in all the three conditions. Maximum shift however occurred at 0 dB SNR (table 3).

Table 3: Mean and SD for Wave V latency for both the groups obtained at three conditions

Condition	**Group**	**Mean (in msec)**	**SD**
ABR with-out noise	*Normals*	6.81 (N=7)	.54
	LD	7.07 (N=11)	.44
ABR at 0 dB SNR	*Normals*	7.58 (N=7)	.92
	LD	7.73 (N=11)	.67
ABR at 3 dB SNR	*Normals*	7.27 (N=7)	.70
	LD	7.57 (N=11)	.45

A Mixed ANOVA's (condition 3 x groups 2) were done to examine the significant interaction of ABR wave V latency. The result revealed that there was a significant difference in the Wave V latency across the three conditions [F (2, 32) = 21.605, p<0.001]. Further analysis was done using Bonferroni's Post Hoc Test which revealed that there was a significant difference in the latency in without noise condition with that of 0 and +3 dB SNR. Within the 0 and + 3 dB SNR condition there was no significant difference. No significant difference between the groups [F (1, 16) = 1.155, p>0.05] was seen. It also did not reveal any significant interaction between the group and within the condition on the wave V latency [F (2, 32) = 0.27, p>0.05].

Auditory Brainstem Response in the control group and the clinical group

The latencies were compared across the stimulus conditions using Friedman's test for the control group and using repeated measure ANOVA for the clinical group. Both the tests revealed a significant difference in the latency across the three stimulus conditions [÷^{2} (2) = 10.571, p<0.005]. For pair wise difference Wilcoxon's test (for control group) and Bonferroni's post hoc test (for clinical group) was done which revealed that there was a statistically significant difference in the wave V latency in the condition with no noise as compared to the conditions with noise (both 0 and 3 dB SNR). The comparison of the latencies in the two conditions with noise revealed no significant difference.

Auditory Late Latency Responses

Significant difference in the N1 latency between the groups in the three stimulus conditions was present, whereas for P2 latency no significant difference was seen in presence of noise at both 0 and + 3 dB SNR. However, the amplitude of N1-P2 complex did not differ statistically between the groups in anyone of the stimulus conditions.

Table 4: Mean and SD values for N1, P2 latency and N1-P2 amplitude of ALLR obtained in both the groups at different stimulus conditions

		Control Group			Clinical Group		
	Condition	Without noise	0 dB SNR	+ 3 dB SNR	Without noise	0 dB SNR	+ 3 dB SNR
N1 Latency	*Mean*	153.85	145.71	152.57	191.12	204.43	195.75
	SD	39.50	35.10	28.48	35.51	35.94	29.17
P2 Latency	*Mean*	233.33	236.33	215.66	266.57	279.42	276.85
	SD	42.95	52.72	37.16	43.89	34.92	42.96
N1-P2 Amplitude	*Mean*	7.265	6.00	4.90	5.60	5.48	2.23
	SD	2.38	2.62	6.01	3.23	1.68	3.95

A Mixed ANOVA's (condition 3 x groups 2) were done for each of the ALLR components to check for the main effect across the three stimuli conditions, and between the groups. The results indicated that there was a significant difference in the latencies of both N1 and P2 between the two groups [F (1, 21) = 13.077, p<0.05] and [F (1, 18) = 7.723, p<0.05] respectively. There was no significant difference in the latencies of N1 and P2 across the three stimulus conditions [F (2, 42) = 0.063, p>0.05] and [F (2, 36) = 0.642, p>0.05] respectively. Also there was no interaction between the groups and the conditions for both N1 and P2 latency [F (2, 42) = 1.131, p>0.05] and [F (2, 36) = 0.915, p>0.05] respectively. For N1-P2 amplitude there was no significant difference between the groups [F (1, 19) = 0.148, p>0.05], or across the three stimulus conditions [F (2, 38) = 0.575, p>0.05]. Along with this interaction effect was also absent between groups and stimulus condition [F (2, 38) = 1.112, p>0.05].

Late Latency Response in the control group

The N1 and P2 latency was almost similar in all the three stimulus conditions. The amplitude however was maximum in the condition without any noise and minimum for 3 dB SNR condition. Friedman's test was done to check for significance difference, if any, in the latencies of N1, P2 and the N1-P2 amplitude of ALLR across the three different stimulus conditions. No statistically significant difference in the N1 and P2 latency was seen across the stimulus conditions. A similar result was also observed for the N1-P2 amplitude across the three conditions.

Late Latency Response in the clinical group

Slight differences were observed in the latency of N1 and P2 across the three conditions. The latency is least in the condition with no noise and is maximum for the 0 dB SNR condition. The amplitude of the N1-P2 complex was maximum in the absence of noise and least at 3 dB SNR. The results of the repeated measure ANOVA showed that there is no significant effect in the N1 [F (2, 30 = 1.153, p>0.05], P2 [F (2, 26 = 0.582, p>0.05] latency and N1-P2 [F (2, 28 = 0.135, p>0.05] amplitude across the three stimulus condition. Thus the presence or absence of noise had no significant effect on any one of the ALLR components.

Speech Identification Scores (SIS)

The SIS obtained without ipsilateral noise is 100% in the control group. The clinical group had 99.5 % scores in the absence of ipsilateral noise. In the presence of noise the SIS deteriorated for both the groups. However, SIS obtained in the clinical group was more severely affected than the control group.

Mixed ANOVA (condition3 x groups 2) was done to check for the main effect of the stimulus conditions and also between the two groups. The mixed ANOVA results revealed a significant difference [F (2, 56) = 63.867, p<0.001] in the SIS scores across the three conditions. Bonferroni's test was carried out further for pair wise comparison between the conditions. The results showed that the SIS obtained in all the stimulus conditions was significantly different from each other. There was a significant difference in the SIS scores between the two groups [F (1, 28) = 16.421, p<0.001], where the scores were higher for the control group than the clinical group. An interaction effect was also found between the SIS obtained in three stimulus conditions and, the two groups, which was statistically significant [F (2, 56) = 9.474, p<0.001].

Correlation of Auditory Brainstem Response and Late Latency Response to SIS scores

All the subjects in the control group had 100 % speech perception scores without ipsilateral noise, because of which it was not possible to do a statistical test to find the correlation between AEP parameters and the SIS scores. For the clinical group Spearman's correlation test was done which showed that no particular trend was followed by the AEP parameters and the SIS scores in different condition. No significance correlation between the AEP parameters and the SIS scores across the stimulus conditions in the clinical group were obtained.

Discussion

Auditory brainstem Responses (ABR)

The wave V latency was prolonged for the control group in the condition with ipsilateral noise. Within the two conditions of noise however there was no significant difference. Similar results have been quoted by Cunningham et al. (2001), who found that in the presence of background noise the latency of wave V increases for children with no learning problem. Russo et al. (2004) found that in the presence of background noise, brainstem encoding of speech is disrupted. In particular, noise interferes with the onset response. In the majority of normal subjects they evaluated the onset response was severely degraded, while in 40% of subjects it was completely abolished. They concluded that the onset portion of the response is more susceptible to degradation in the presence of noise rather than the sustained portion.

The results obtained in the present study add on to the existing studies which reveal that in the presence of noise the ABR wave V latency is affected. The lack of difference in the wave V latency between the two condition of noise; 0 and + 3 dB SNR; can be attributed to the fact that the noise degrade the onset response hence resulting in almost equal shift in wave V latency.

The clinical group also had significant difference in the latency in the presence and absence of ipsilateral noise. Within the two noise conditions (0 and + 3 dB SNR) however, no significant difference was observed. Johnson, Nicol, and Kraus, (2005) also reported similar findings. They found that the children with learning problem exhibited delayed peak latency of the wave V indicating poor synchrony to transient events. They also report that environmental stresses such as noise and rapidly presented stimuli further negatively influence the neural encoding of linguistic information in children with learning problem. Wible, Nicol, & Kraus, (2004) reported that the brainstem processing of speech sound rather than being completely different for children with a learning problem, is to some extent similar in both children with and without a learning problem.

The possible reason for the deficits observed for the clinical group in the current study cannot be attributed to an overall deficit in neural synchrony. The prolongation of the wave V latency seen for the clinical group is comparable, although to a higher degree, to what has been observed for the control group under stressful situations. Hence, it can be said that the deficits which are seen for the clinical group can also be observed in the control group under stressful environmental conditions such as in the presence of background noise. Based on this it can be concluded that the children with learning disability rather than having a deficit in neural synchrony have abnormal representation of specific neural activity (Johnson, Nicol, Zecker, & Kraus, 2007).

Group wise comparison revealed no significance difference in the wave V latency for both the groups for all the conditions although; the clinical group had longer wave V latency in all the conditions.

The trend followed by both the groups were similar having shortest latency for the condition without ipsilateral noise and longest for condition with 0 dB SNR. These results are in support of the previous studies done (Johnson, Nicol, & Kraus, 2005; Johnson et al. 2007), which also reported that although the wave V latency is prolonged in children with learning disability as compared to children with no learning problem, the difference is not statistically significant. The lack of any statistical difference between the two groups can be because of a smaller number of samples collected. Another reason can be the heterogeneity of the LD group. Thus, it can be concluded that ABR for speech stimulus, with or without noise ipsilaterally, may not be efficient to identify abnormal auditory processing in individuals with learning disability.

Auditory Late Latency Responses (ALLR)

There was no significant difference in the N1 and P2 latency across the three stimulus conditions in the control group. The results are similar to those stated by Cunningham et al. (2001); Wible, Nicol, and Kraus, 2002; and Wible, Nicol, and Kraus, (2004). They reported that in the presence of noise there is no change in the latency of the ALLR peaks in children having no learning problem. However, the SNRs used in the studies were different where the Cunningham et al. (2001) and Wible, Nicol, & Kraus, (2004) used 0 dB SNR, while Wible, Nicol, & Kraus, (2002) used +15 dB SNR.

Contradictory studies have also been reported in the literatures. It has been reported that with the addition of noise there is an increase in the latency of the ALLR components (Whiting, Martin, & Stapells, 1998; Martin, Kurtzberg, & Stapells, 1999).

It is possible that the noise does not affect the firing of the neurons in the cortex to the extent it effects the firing of neurons at the level of brainstem. Another reason can be the fact that the cortical response requires lesser degree of synchronous firing than the brainstem response, and the presence of background noise does not compromise the synchronous firing to that great an extent (Cunningham et al, 2001).

In the clinical group no significant difference was observed in the N1 and P2 latency across the three stimulus conditions. These results are similar to those stated by Cunningham et al. (2001); Wible, Nicol, & Kraus, (2002, 2004) who report that in the presence of noise there is no change in the latency of the ALLR peaks in children with learning problem. The reason for the insignificant difference in the latencies could be the same as that mentioned for the control group.

Comparison between the two groups revealed that there was a significant difference in the N1 latency for all the three stimulus conditions, and P2 latency for the condition with 0 *and +3 dB SNR noises. The clinical group had prolonged latency of N1 and P2 for all the conditions.* The results of the present study are in contradiction to those done by Cunningham et al, in 2001, who reported no difference in the latency of any of the ALLR components for the two groups in the presence and absence of noise. The reason for the differences in the findings of the present study with that of the previous authors can be because of the fact that the learning disabled group is a heterogeneous one (Cunningham et al, 2001; Wible, Nicol, & Kraus, (2002, 2004). Some of them show results which are similar to those observed in children with no learning problem whereas, the others show a significance deviance. It is possible that the children taken for the present study might have been fallen under the second category thereby varying the latency significantly.

The amplitude of the N1-P2 complex in the control group was different across the three stimulus conditions, but failed to reach a significant level. Similar results were showed by Cunningham et al. (2001) and Wible, Nicol, & Kraus, (2004) who found that there is a reduction in the amplitude at 0dB SNR compared to no noise condition for children having no learning problem. However, Wible, Nicol, & Kraus, (2002) found a significant reduction in the amplitude at +15dB SNR compared to no noise condition for children having no learning problem.

In the present study no significant difference in the amplitude of N1-P2 complex was found although there was a reduction in the response amplitude in the conditions with ipsilateral noise. The lack of significance can be because of a smaller sample size. Another reason can be the way in which the amplitude was measured. The above reported studies all measure the RMS amplitude of the cortical response, whereas in the present study the peak-to-trough amplitude of the N1-P2 complex was taken.

In the clinical group there was a reduction in the amplitude of the N1-P2 complex in the conditions with ipsilateral noise (0 and +3dB SNR). However, it failed to reach a significant level. Cunningham et al. (2001); and Wible, Nicol, and Kraus, (2002, 2004) have also shown similar results for children with learning problem. They found a reduction in the amplitude of the N1-P2 complex in condition with ipsilateral noise when compared to no noise condition. The possible reason for the reduction in the amplitude of the N1-P2 complex can be attributed to asynchronous firing of the neurons responsible for the generation of cortical responses in stressful conditions such as presence of background noise (Wible, Nicol, & Kraus, (2004).

The amplitude of the N1-P2 complex showed no significant difference between the two groups across either of the three stimulus conditions. This is in consonance with the previous findings of (Wible, Nicol, & Kraus, (2004). They found that the introduction of background noise had a similar effect of reduction in the response amplitude for children with and without a learning problem. It can be suggested that in the children with a learning problem, the poor cortical representation of speech sounds in the presence of noise cannot be attributed to an abnormal decrease in overall response activity. Rather, it is possible that the activity associated with the neural encoding of speech sounds is being distributed differently over time across the responses recorded in noise in the children with learning problem (Wible, Nicol, & Kraus, (2004).

It can be concluded from the above discussion that the N1, P2 latency of ALLR can be used to identify auditory processing disorder in children with learning disability. However, amplitude is not a sensitive parameter for both with and without ipsilateral noise to identify an auditory processing disorder.

Speech Identification Scores (SIS)

The control group had 100 % scores in quiet. The control group had hearing sensitivity within normal limits and did not have any other abnormality, which resulted in good SIS in quiet.

The presence of noise reduced the SIS scores for the control groups. Within the two conditions of noise, 0 and + 3 dB SNR, the scores were more severely degraded at 0 dB SNR condition. This supports the literature that in adverse listening situations even children with normal language skills perform poorly (Elliot, 1979). Bradlow, Kraus, & Hayes, (2003) stated that as the listening condition becomes more adverse (from -4 to -8 dB SNR) the speech perception deteriorates even further. The reason for reduction in SIS scores in 0dB condition than +3 dB can be because the poor SNR affects the speech processing to a greater extent than at higher SNR.

In the condition with no ipsilateral noise the clinical group also had higher SIS scores than in the conditions with noise. The scores were significantly poorer in the condition with ipsilateral noise (0 and +3 dB SNR). This is consistent with the previous studies which report that children with learning disability have poorer speech perception abilities (Chermak, Vonhof, & Bendel, 1989). The poorer performance for the clinical group in the conditions with ipsilateral noise as compared to no noise condition can be because of a similar phenomenon as that seen for the control group.

On comparing the performance between the two groups it was found that the control group had significantly higher scores in all the conditions as compared to the clinical group. In the presence of noise the SIS scores reduced significantly more for the clinical group. Within the two conditions of noise, 0 and + 3 dB SNR, the scores were more severely degraded in the 0 dB SNR condition for both the groups. Similar results have been quoted by Bradlow, Kraus, & Hayes, (2003). There is considerable literature reporting that children with learning disability perform poorer than the children with no learning problem in the presence of background noise (Chermak, Vonhof, & Bendel, 1989; Bradlow, Kraus, & Hayes, 2003) and the findings of the present study are in analogous to them.

Cunningham et al. (2001) and Johnson, Nicol, & Kraus, (2005) have shown that in quiet there in no significant difference in the speech perception of children with and without a learning disability. The reason they report is that the quiet condition is an ideal listening situation which does not strain the auditory system. Hence, it is not possible to detect the subtle auditory deficits present in the children with learning disability in quiet conditions.

Correlation between the AEPs and Speech Identification Scores (SIS)

In order to categorize the cause of the learning disability an attempt was made to correlate the AEPs measured in the present study with the SIS scores obtained in each condition. *No correlation was found between the ABR wave V latency and the SIS scores in one any of the condition for both the groups*. There is dearth of information regarding the correlation between the SIS scores with that of wave V latency. The reason could be that the wave V is not very sensitive to the differences in the processing of speech sounds in the control and the clinical group. Another reason can be that the synthetic speech stimulus might not accurately represent the brainstem processing for speech.

The clinical group showed no correlation between the ALLR response parameters and the SIS scores for the three conditions. Very less information is available to support or contradict the current findings. However, literature is available measuring the JNDs (Cunningham et al, 2001) and its correlation with the cortical responses. They found that children with poorer JND had more reduction in the RMS amplitude of the response as compared to children with better JNDs. It is also possible that the brief duration of the stimulus (40 msec /da/) used here is not sufficient to assess the cortical response adequately.

Conclusion

It can be concluded form the present study that AEPs are sensitive measure to differentiate between children with a learning problem from those without a learning problem, especially in conditions with background noise. Although, the ABR wave V latency is not a sensitive measure, the latency of N1 and P2 of ALLR are sensitive measures. Hence, the N1 and P2 latencies are useful in identifying auditory processing deficits in children with learning disability. These parameters are sensitive to auditory processing disorders in both conditions with and without background noise. Also, when testing in adverse listening situations both 0 and +3 dB SNR are equally sensitive in identifying an auditory processing disorder. The results of the study also suggest that there is need not be a one-to-one relation between the AEP findings and SIS at different SNRs.

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