SPEECH ELICITED ABR: AN EXPLORATORY STUDY IN NORMALS AND IN CHILDREN WITH LEARNING DISABILITY

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**A dissertation submitted in part fulfillment for
the degree of M. Sc. (Audiology),
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MYSORE- 570006.**

MAY - 2005

Dedicated to the two people who unveiled the mysteries of Audiology to me..

Kartik, for leading me to it & Vanaja ma'am for guiding me … through it !!!

CERTIFICATE

This is to certify that this dissertation entitled **"SPEECH ELICITED ABR: AN EXPLORATORY STUDY IN NORMALS AND IN CHILDREN WITH LEARNING DISABILITY"** is the bonafide work in part fulfillment for the degree of Master of Science (Audiology) of the student with **(Reg. No. A0390008).** This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any university for the award of any other degree or diploma.

Place: Mysore
Mav 2005

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CERTIFICATE

This is to certify that this dissertation entitled **"SPEECH ELICITED ABR: AN EXPLORATORY STUDY IN NORMALS AND IN CHILDREN WITH LEARNING DISABILITY"** has been prepared under my supervision and guidance.

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DECLARATION

This dissertation entitled **"SPEECH ELICITED ABR: AN EXPLORATORY STUDY IN NORMALS AND IN CHILDREN WITH LEARNING DISABILITY",** is the result of my own study under the guidance of **Dr. C. S. Vanaja,** Lecturer, Dept of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any university for any other Diploma or Degree.

Place: Mysore. **Reg. No. A0390008**

May 2005

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CHAPTER I

INTRODUCTION

Learning problems is one of the very common educational handicaps seen in a number of school going children. In India it has been found that the percentage of children found to have dyslexia ranges from 3% to 7.5% (Ramaa, 2000).These learning problems encompass a variety of deficits ranging from subtle difficulty in reading to complex auditory processing disorders. To minimize the degree of their difficulties, early intervention of their problems is one of the most crucial steps.

A large number of these children have a lot of problem in processing of complex stimuli, which are difficult to process either visually or auditorily. The ASHA task force on central auditory processes consensus development (1996) stated that a processing disorder of some form is presumed to result from the dysfunction of process and mechanisms dedicated for audition & for others, it may stem from some general dysfunction, such as an attention deficit or neural timing deficits that affects performance across modalities. The hypothesis that the children with specific learning disability have auditory processing disorder has been experimentally investigated by many studies. Though a majority of studies in literature report that a subgroup of children with learning disability have auditory processing deficit, there is no consensus regarding the nature of the auditory processing disorder. Tallal (1980) described a deficit in dyslexics involving processes of brief rapidly changing auditory stimulus. The findings that dyslexics are mainly impaired in processing stop consonants which are characterized by brief and rapid spectral changes support the role of temporal processing in speech perception deficits of dyslexics.

Auditory processing of an individual can be assessed through either behavioral tests or electrophysiological tests. Behavioral tests mainly aim at cutting down the external redundancy and assess for the processing of modified auditory stimuli. Each of these tests assess one or more of the auditory processes like retention, auditory linguistic integration, sequencing, attention, vigilance, etc. Different behavioral tests include tests like, Staggered Spondaic Word Test (Katz & Ivey, 1994), Competing Sentence Test (Willeford & Burleigh, 1994), Pitch Pattern Sequence (Pinherio, 1977), etc. On the other hand electrophysiological tests assess for the underlying physiology. Auditory evoked potentials (AEPs) provide powerful objective methods of assessing the neural integrity of the pathway from auditory nerve to the cortex (Hood, 1997). Using theses techniques, it is possible to follow the course of brains activity in time with precision of tens of milliseconds and thus obtain knowledge not only of the end product of processing but also of the sequence, timing, and stages of specific processes (Tapio, Leppanen and Lyytinen, 1997).

A majority of the electrophysiological studies carried out on learning disabled population have used cortical potentials to understand the auditory processing. Prolonged latencies (Guruprasad, 2000; Leppanen & Lyttinen, 1997; Radhika, 1997; Arehole, 1995; Jirsa and Clontz, 1990; Dawson, Finely, Philips & Lewy, 1989; Byring & Jaryilehto, 1985) and reduced absolute amplitudes (Pinkerton, Watson & Mc Clelland, 1989; Jirsa and Clontz, 1990) for $P_{1,}$ N_1, P_2 and N_2 waves have been reported in children with learning disability.

Many investigators have explored MMN as an index of auditory dysfunction in children with dyslexia. MMN has been established as a reliable tool to evaluate perceptual problems in children with dyslexia. Kujala (2002) stated that MMN is a useful tool of sound discrimination ability in children with dyslexia. Baldeweg et. al (1999) reported that in children with learning disability, MMN and discrimination performance correlated with the degree of impairment of phonological skills. Schulte and Korne (1998) used MMN to compare the discrimination of speech and non speech stimuli in dyslexics and control adolescents. It was found that tonal MMN did not vary across subjects. However syllables elicited smaller MMNs in dyslexics than controls. Further Kujala and Naatanen (2001) reported that in dyslexic children, the change in the reading skill measures with training correlated with the change in amplitude of MMN.

These different physiological tests have indicated that in this population with learning disability, processing at the level of auditory cortex is deviant, when compared to normals (Warrier, Jhonson Hayes, Nicol & Kraus, 2004; Kraus & Nicol, 2003; Cunningham et.al., 2002; Wible, Nicol & Kraus, 2002; Cunningham, Nicol, Zecker & Kraus, 2001; McGee et.al.2001; Kraus et.al, 1996). However, not much information is available on parallel grounds to evaluate the processing at a lower level like the brainstem.

More recently, auditory brainstem responses are being explored to various speech stimuli including transient bursts and transition of formants that are extracted from either a synthesized or naturally spoken speech syllable (Reddy, Kumar & Vanaja, 2004; King, Warrier, Hayes & Kraus, 2002). These stimuli have been used to study the processing of complex stimuli like speech, at the level of brainstem, and further to study deviancies if any, in clinical population like learning disabled. The use of auditory brainstem responses to speech stimuli in assessing such kind of processing deficits is promising to be a valid and reliable tool in such a clinical population. This has been a big breakthrough in the field of electrophysiological testing, where ABRs were conventionally recorded using simple non speech stimuli such as clicks or tone bursts. Jewett, Romano & Williston, (1970) first definitively described far field scalp recorded auditory brainstem responses, using broadband stimulus like click. Later frequency specific auditory brainstem responses were evoked using tone bursts. Ever since, ABR has always been used as a very reliable tool for threshold estimation and differential diagnosis of cochlear and retrocochlear lesions. However, this conventional ABR fails to highlight any difference between normals and individuals with learning problems. Researchers have observed that when a speech stimulus was used instead of a conventional click stimulus to evoke ABR, these processing deficits could be assessed better (Wible, Nicol & Kraus, 2005; King et.al., 2002).

In spite of availability of several other tests, ABR is used routinely in the clinical assessment, due to its inherent advantages over most of the other behavioral and electrophysiological tests. Among the various electrophysiological tests, the maturational factor of ABR gives it greater consideration. Brain stem structures mature by 18 to 24 months of age, unlike the other cortical structures, which mature only by 11 to 15 years of age (Sharma, Kraus, McGee & Nicol, 1997). The objectivity of ABR makes it more advantageous over other behavioral tests. This objectivity of ABR is greatly credited over behavioral tests, especially while evaluating difficult to test population. Apart from theses cardinal features, characteristics like its ease of testing, time effectiveness and resistance to subject variables like attention or sleep make ABR one of the most valid electrophysiological test with maximum potential, validity and reliability.

Need For the Study

Brainstem structures mature by 18 to 24 months of age (Eggermont & Salamy, 1988; Folsom & Wyne, 1987; Fria & Doyle, 1984; Galambos, Hicks & Wilson, 1984; Gorga et al. 1987; 1969; Jacobson, 1985, Lauffer & Wenzel, 1990). Usually with the conventional click elicited ABR, no age effects are seen with respect to parameters like latency, morphology and amplitude, unlike higher cortical potentials which mature only by 11 to 15 years of age (Sharma, Kraus, McGee & Nicol, 1997). However, all these studies have used non speech stimuli. There is a need to investigate whether there is any maturational effect in school going children with speech elicited ABR.

A few reports are available with respect to auditory brainstem responses evoked using different speech stimuli like transitions and bursts. Reddy, et.al. (2004) have used speech bursts to evoke ABRs in normal adults where as King et.al. (2002) evoked ABRs using formant transitions in normal children. However there is no comparative study which compares the responses yielded by these different stimuli in the same individual.

There is a dearth of literature postulating the significance of speech elicited ABR to highlight processing deviancies in clinical population. Khaladkar, Kartik and Vanaja (2005) have reported that speech burst ABR shows deviancies in processing, in individuals with sensorineural hearing loss who are characterized by processing problems. If such a protocol were developed and found useful, very young children as well as infants can be tested without their co-operation and those at a risk of developing learning disability (characterizing auditory processing problems) at a later stage in life can be identified and subsequently rehabilitated much earlier than they conventionally are, i.e. even before their problem becomes significant in school, in an attempt to minimize the degree of their handicap. King, et.al, (2002) have elicited ABR using transitions of speech stimuli and have reported that ABRs evoked using transitions could identify processing deviancies in clinical population, when conventional click evoked ABR failed to do so. These findings were replicated and supported by Russo, Nicol, Mussachia and Kraus, (2004). There is a need to evaluate speech evoked ABR in clinical population like learning disabled and to investigate what type of speech stimulus highlights these processing deficits better. No investigators have studied the usefulness of speech burst elicited ABR in identification of learning disabled.. It would also be informative to investigate which of the two speech stimuli, speech bursts or transitions is more sensitive in identifying auditory processing disorder.

Aims of the Study: The aims of the present study were as follows:

- To investigate if any maturational changes with regard to speech evoked ABR exist in school going children.
- To evaluate the brainstem responses evoked using different speech stimuli in normal children and in children with learning disability. Responses were also compared for all the three stimuli, both within the group and across the groups.
- To evaluate the efficacy of the two speech stimuli in identification of processing deficits in children with learning disability..

CHAPTER II

REVIEW OF LITERATURE

In the last few decades, there have been a number of extremely encouraging experimental studies in the area of learning disability. A review of these studies reveals heterogeneity, in the characteristics, causes and associated deficits. Results of various investigations have revealed that there is a subgroup of children with learning disability having auditory processing deficit. In a review of ten studies, the incidence of auditory processing disorder in children with learning disability is estimated to be 40% (Ramus, 2003).

Warrier et. al. (2004) investigated the physiological mechanisms that contribute to abnormal encoding of speech in children with learning problems. They compared speech evoked cortical responses recorded in a noisy background to those recorded in quiet in normal children and in children with learning problems. Results of their investigation indicate that almost one-third of learning impaired children exhibited cortical neural timing abnormalities, such that their neuro-physiological representation of speech sounds became distorted in presence of background noise. However, the RMS amplitude in these children did not differ from normals, indicating that this result was not due to difference in response magnitude. Also, learning impaired children who participated in a commercial auditory training program exhibited cortical timing improvement and also showed improvement in phonological perception.

A number of earlier investigators have reported increased latencies (Vanaja & Sandeep, 2004; Guruprasad 2000; Leppanen & Lyytinen, 1997; Radhika, 1997; Byring &

Jarjilehto 1985; Satterfield, Schell, Backe & Hidaka 1984; Dawson, Finely, Philips & Lewy, 1989; Jirsa & Clontz 1990; Arehole, 1995;) and reduced absolute amplitudes (Pinkerton, Watson & McClelland, 1989; Jirsa & Clontz, 1990; Leppanen & Lyytinen, 1994) for P1, N1, P2 and N2 waves in this population with learning disability.

Cunningham, Nicol, Zecker and Kraus, (2000) evaluated the maturational progression of speech evoked P1/N1/N2 cortical responses over the life span. They attempted to determine, whether responses are distinctive in clinical populations experiencing learning problems and elucidate the functional significance of these responses. The results revealed that the maturational patterns in the group of children with learning problems did not differ from normal group. However, P1/N1/N2 parameters were significantly correlated with standardized tests of spelling, auditory processing and listening comprehension in children with learning problems. These studies highlight the abnormalities in cortical processing in children with learning disability.

Cortical dysfunction in individuals with learning disability has also been reflected in MMN recordings. Bradlow et. al. (1999) investigated behavioral discrimination of /da/ vs. /ga/ and its neurophysiologic correlate using MMN. It was observed that varying the formant transition duration from 40 ms to 80 ms did not result in improved behavioral response, but there was enhancement of MMN response. The results suggest that the presence of MMN does not indicate that stimuli can be discriminated behaviorally. However, it is difficult to have normal behavioral discrimination in subjects with absent MMNs. Kraus et. al. (1996) also investigated the correlation between impaired behavioral discrimination of a rapid speech change /da/ and /ga/ and its attention independent neurophysiologic measure, MMN. They reported that some children's discrimination deficits originate in auditory pathway before conscious perception and have implications in differential diagnosis and targeted therapeutic strategies for children with learning problems and attention disorders. Similar results have also been reported by other investigators. Vanaja and Sandeep (2004), investigated MMN responses to different contrasts are abnormal in a group of children with learning disability. It was observed that processing of both speech and non-speech sounds are affected in children with learning disability, although number of children showing abnormality for speech stimuli was greater. Further, they reported that perception of place of articulation is most affected and manner of articulation is least affected in children with learning disability

Abnormal cortical evoked potential have been reported even in children at risk for familial dyslexia by Maurer, Bucher, Brem and Brandeis, (2003). They investigated the differences in frequency and phoneme mismatch negativity between kindergarteners with and without risk for familial dyslexia. The results indicated that the mismatch response was attenuated to frequency deviance and less left lateralized to phoneme deviance. Similar results have been reported in earlier literature also .Leppanen, Richardson, Pinko, Eklund, Guttorm, Aro and Lyytinen (2002) measured event related brain responses to consonant duration changes embedded in pseudo words applying an oddball paradigm in 6 month old infants with and without high risk of familial dyslexia. Pseudo word tokens with varying /t/ duration were presented with an interval of 610 msec between the stimuli. The results revealed that infants at risk due to a familial background of reading problems process auditory temporal cues of speech sounds differently from infants without risk, even before they learn to speak.

Thus the review of literature shows that the MMN and P1/ N1 /N2 parameters are affected in children with learning problems. This group of population has reduced behavioral discrimination as well. Their performance further deteriorates, in presence of noise. However, there is a dearth of studies investigating early responses (ABRs) in such population.

Speech evoked ABR in normals

It has been observed that there are faithfully reproducible peaks lying within the latency of early evoked responses, which can be recorded using speech stimuli. These peaks have been considered as reliable peaks in normal individuals for speech evoked ABR (King, Warrier, Hayes and Kraus 2002).They were the first group of researchers who attempted to evoke auditory brainstem responses using formant transitions of synthesized syllable /da/. They used a time window of 60 ms, so as to permit occurrence of responses other than early responses if any. They carried out their study on a group of 33 clinically normal children in the age range of 8 to 12 years. The stimuli were presented through insert earphones at an intensity of 80 dB SPL, with a repetition rate of 11.1/sec. The non inverting electrode was placed at Cz, with inverting electrode on the mastoid and the forehead being the common. In all the responses that were obtained, 3 peaks were found to be consistently present. These 3 peaks were named peak A, C and F. These 3 peaks were found to be faithfully reproduced in all children. It was also observed that these 3 peaks fell in different latency regions and could be classified accordingly. Peak A occurred, approximately at a latency of 7 msecs to 47 msecs (group mean), which was considered as ABR. However, peak C occurred, on an average at latency of 17.7ms being considered as FFR and peak F at 39.5ms. These peaks were then used for comparison with clinical population. These findings were further validated by Russo, Nicol, Musacchia and Kraus (2004). They described brainstem responses to speech syllables in quiet and in noise. They analyzed the transient response of brainstem with measures of latency, amplitude, area and slope. The sustained components (FFRs) on the other hand were analyzed using measures of RMS, Fo and F1 amplitude. Their study revealed that measures of transient and sustained components of the brainstem to the speech syllables could be reliably obtained with high test retest reliability in quiet. However, background noise disrupted the transient components but sustained components were unaltered.

Subsequently in another study, Reddy, Kumar and Vanaja (2004) attempted to study speech evoked ABR using burst portion of naturally produced speech syllables. They used 4 different speech stimuli to extract burst i.e. /t/, /th/, /p/, /k/ and compared responses across stimuli. The results of their study indicated that overall wave morphology of ABR evoked by speech bursts was similar to that of clicks. Amongst all, ABR evoked by /t/ and /th/ had better morphology. All the 5 peaks in the response could be easily identified. It was also deserved that there were robust VI and VII peaks with better morphology than of a click. With respect to latency measure, it was observed that the latency of ABRs evoked with click stimuli was shortest, followed by that of /k/, /t/, /th/ and /p/.

Speech evoked ABR in clinical population

Sensorineural hearing loss**:** Attempts have been made to investigate whether speech evoked ABR is more deviant than click evoked ABR in subjects with sensorineural hearing loss. Khaladkar, Kartik and Vanaja (2005) used speech evoked ABR to study the processing of speech stimuli in adults with sensorineural hearing loss. It was observed that when compared to click evoked ABR, speech evoked ABR showed more deviant results. They correlated latency values for both click and speech bursts with speech identification scores. It was observed that there is a negative correlation between latency of waves and speech identification scores and this correlation value was higher for speech burst stimuli when compared to clicks with respect to the amplitude measures. Once again there was a significant difference in the amplitudes of responses evoked by click and speech burst ABR with the amplitude being lesser for speech burst ABR when compared to click evoked ABR. This difference in amplitudes was attributed to the difference in the spectral envelope of the two stimuli.

Learning Disabled Population: Auditory brainstem responses elicited by speech stimuli are being recently explored to identify processing deviancies in children with learning problems. King, Warrier, Hayes and Kraus (2002) studied ABR and cortical responses to synthesized syllable /da/. Cortical responses were obtained in quiet and in presence of noise (0dB signal to noise ratio). Using the criterion of mean ± 1SD, 20 out of 54 children with learning problems had delayed latencies for peak A, to /da/, even though they had normal wave V latency to ABRs evoked by click stimuli. All of the children with learning problem with delayed ABR latencies also had delayed latencies for peaks C and F. In contrast of the 34 subjects with learning problems with normal ABR latencies for /da/, all but 2 subjects also had normal latency values for the peaks C and F. Their findings indicated that the children who had delays in brainstem latencies are the same children who have latency delays in FFR. No cortical latency and amplitude differences were seen between children with learning problems with normal and delayed onset latencies to /da/. However, for cortical responses, when quiet to noise correlation were detained; Children having learning problems with delayed brainstem onset latencies to /da/ had significantly lower correlations than children with learning problems with normal onset latencies.

In another similar study, Wible, Nicol and Kraus (2004) reported atypical brainstem representation of onset and formant structures of speech sounds in children with language based learning problems. Children were chosen for this study based on measures of reading, spelling and syllable discrimination. Their investigation showed that in response to the onset of the speech sound /da/, wave V-Vn of the auditory brainstem response had significantly shallower slopes in children with learning problems, suggesting longer duration and small amplitude. For the measures of FFR the amplitude of activity over the 229 to 686 Hz range which corresponds to the first formant of the /da/ stimulus was diminished in children with learning problems, while the activity at 114Hz representing the fundamental frequency /da/ was no different between the groups. Normal indicators of auditory peripheral integrity suggest a central neural origin of these differences. These data suggest that poor representation of crucial components of speech sounds could contribute to difficulties with higher level language processes.

Wible, Nicol and Kraus, (2005) have investigated the correlation between brainstem and cortical auditory processes in normal and language impaired children.

They used AEPs to investigate brainstem and cortical responses to synthesized syllable /da/. The duration of the wave V-Vn of ABR and effect of noise on correlation between cortical responses to repeated stimuli was studied. It was observed that the group of children with learning problems demonstrated abnormal encoding of speech sounds on both individual measures of brainstem and cortical processing. These individuals had prolonged wave V-Vn duration and degradation of responses in presence of noise. The LP group as a whole failed to demonstrate relationship, between brain stem and cortical measures, which were strongly evident in normal children, with exception of three-fourth children having learning problems, delineating different subclass of auditory language based learning problems.

It is thus evident that a variety of electrophysiological tools have been explored to study the processing deficits in children with learning problems. Initially, LLR and MMN were used to investigate such processing deviancies. Recently, speech elicited ABR is being scrutinized for its efficacy to highlight the processing deficits in clinical population like learning disabled, which a conventional click evoked ABR fails to. These studies have used transition portions of speech syllables to elicit ABR. (King et.al, 2002) or burst portions of speech syllables. None of the present studies compare speech elicited ABRs across various speech stimuli. The present study is such an attempt to evaluate the efficacy of different speech stimuli to evoke ABR to identify processing deficits in children with learning disability.

CHAPTER III

METHOD

Participants: Two groups of subjects were included for the study. Experimental group comprised of 10 children formally diagnosed as having learning disability on measures of standardized test of Early Reading skills by an experienced speech and language pathologist. This diagnosis was made external to and independent of the present study. Children were in the age range of 8 to 12 years and had no history of otological or neurological pathologies. Control group comprised of 20 age matched children with good scholastic performance. All the children had normal hearing sensitivity (thresholds less than 15dBHL in the frequency range of 250 Hz to 8 kHz) and normal middle ear functioning.

Instrumentation: The present study was carried out using the following instruments:

- A dual channel OB922 clinical audiometer (version-2) was used to carry out the pure tone and speech audiometry.

- A calibrated GSI Tympstar middle ear analyzer was used for tympanometry and reflexometry.

- IHS smart EP, version 2.39 (Intelligent Hearing systems, Florida, USA) was used to record and analyze ABRs. Eartone 3A insert earphones were used to deliver the stimuli.

Materials: The following stimuli were used to evoke ABR:

Stimulus 1: extracted burst portion of 2.74ms duration of naturally produced syllable /t/ by an adult male speaker.

Stimulus 2: extracted transition portion of 27ms duration of syllable /t/ by an adult male.

Stimulus 3: acoustic click of duration of 100µs.

Procedure: Otoscopy was done on all subjects to rule out any visible pathology of external or middle ear. Pure tone audiometry was done to establish the audiometric thresholds from 250 Hz to 8 kHz for air conduction, and 250Hz to 4 kHz for bone conduction for the experimental group. Tympanometry and reflexometry were performed to rule out any middle ear pathology in the experimental group.

Auditory brainstem responses were evoked using the protocol mentioned in Table 1. Prior to evoking ABRs, the subjects were made to sit in a reclining chair in an electrically shielded and acoustically treated room. ABR recordings were made from a Cz electrode placed centrally on the scalp which served as the non inverting electrode. The forehead served as the ground and the inverting electrodes were placed on the right and left mastoids (recorded from channel C and channel D). The subjects were instructed to not to pay attention to the stimuli and they were instructed to relax and be seated comfortably with minimal movements to minimize the effects of subject artifacts.

Table 1

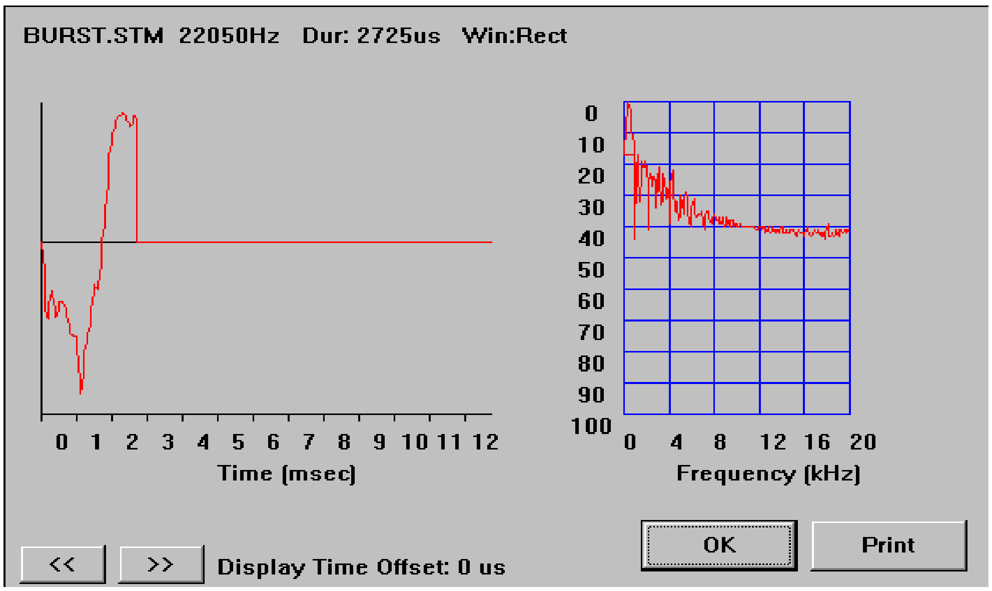
Protocol for recording ABR

Parameter	Speech stimuli		Non speech stimulus
	Stimulus 1	Stimulus 2	Stimulus 3
Polarity	Alternating	Alternating	Alternating
Transducer	Insert earphones	Insert earphones	Insert earphones
Intensity	60dBnHL	60dBnHL	60dBnHL
Repetition rate	30.1/s	30.1/s	30.1/s
Filter setting	100Hz-3kHz	100Hz-3k Hz	100Hz-3kHz
Analysis time	15ms	15ms	15ms

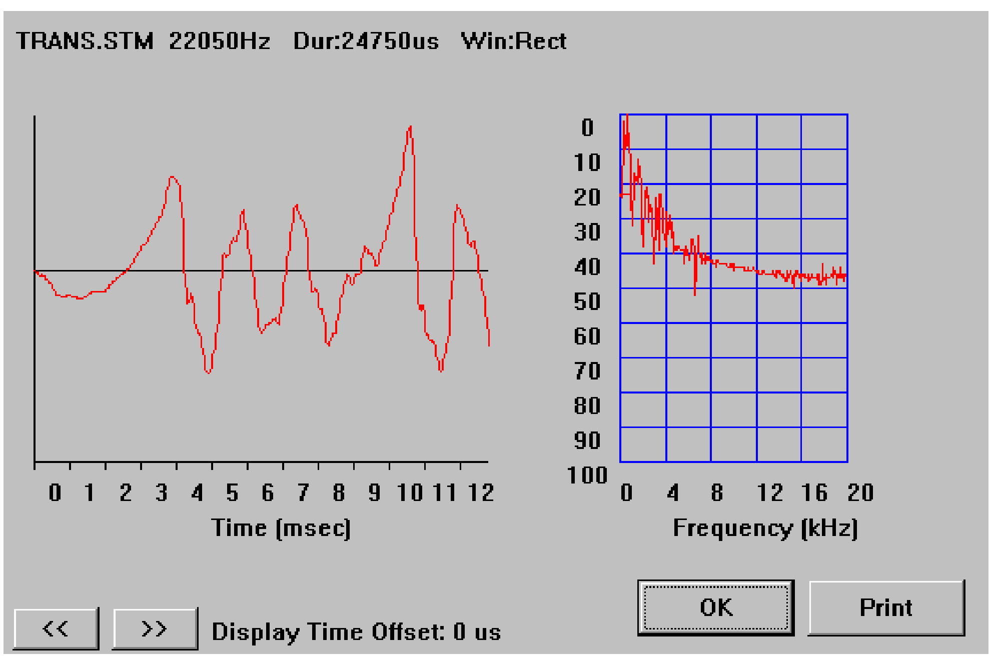
Figure 1

Stimulus waveforms for burst (1a) and transition portion (1b) of |ta|.

1 (a)



1 (b)



CHAPTER IV

RESULTS AND DISCUSSION

In the present study, the most prominent peak obtained with maximum amplitude was considered for analysis. It was considered as the V peak for the click evoked ABR as it was the most robust peak (Jewett et.al.1970). For speech burst also it was considered as the V peak s, as the morphology of the obtained peak was similar to that of V peak in click evoked ABR (Reddy et. al. 2004). However the most prominent peak for transition evoked ABR was considered as peak A (King et.al.2002).

The latency and amplitude values were compared across the three stimuli-acoustic click, burst and transition. Latency and amplitude measures were compared across age groups, in normal subjects to see if any significant differences existed across ages. Comparisons were also made for each of the stimulus, across normals and children with learning disability, to investigate if any significant differences were present between the groups.

The two statistical measures used for the study included independent sample t-test and ANOVA . ANOVA was carried out to investigate the effect of stimuli on latency and amplitude of ABR. The effect of age group on latency and amplitude of ABR was also investigated using ANOVA. Tukey's post hoc test was carried out whenever ANOVA showed a main effect. Independent sample t-test was used to evaluate any significant differences between the experimental and control groups, for each parameter. All the statistical analysis was performed using SPSS package (version 10.0).

I. Comparison of Auditory brainstem responses across stimuli in normals

Latency Measures: Table 2 shows the mean and standard deviation for the latency measures obtained for all three stimuli-clicks, speech burst and transition in normal children for both the ears. It is evident from Table 2 that for both the ears, latency of the response evoked by the click stimulus is the shortest. Also the standard deviation for the click evoked ABR is the least. Among the two speech stimuli, the latency of the responses, evoked by these two stimuli is longer than the click stimulus for both the ears.

Table 2

Mean and SD for latency measure (in msec) across stimuli in normals

Right Ear				Left Ear		
Stimulus	Click	Burst	Transition	Click	Burst	Transition
Mean	5.78	6.34	6.69	5.74	7.46	6.80
SD	0.29	0.31	0.41	0.43	0.60	0.48

To delineate the main effect of the stimulus on the latencies, ANOVA was performed. It is clear from the table that there was a main effect of the stimulus on latency. Further, to investigate the significant differences across the stimuli. Tukey's post hoc test was carried out. It is evident from Table 4 that significant differences in the latencies exist between the responses evoked by the click stimulus and the two speech stimuli (bursts and transition) in both ears.

Table 3

Results of ANOVA for latency measure (in msec) for both ears

	Right ear	Left ear
F	75.30	49.61
Sig	.000	.000

Table 4

Results of Tukey's post hoc test for both ears for latency measures across stimuli in normals.

a) Right ear

Stimulus	N	Sub set	
		1	2
Click	20	5.7860	
Burst	20		6.34
Transition	20		6.69
Sig	20	1.000	0.93

b) Left ear

Stimulus	N	Sub set		
		1	2	3
Click	20	5.74		
Burst	20		6.27	
Transition	20			6.80
Sig	20	1.00	1.00	1.000

The results of the present study are in congruence with the results of previously reported studies in literature. ABR evoked by clicks and transitions in normal children have been compared by King, Warrier, Hayes & Kraus (2002). They have reported longer latencies of ABRs evoked using formant transitions. Similar results have been obtained by Reddy, Kumar and Vanaja (2004) where they compared latencies of ABRs evoked by burst of speech syllables and clicks in normal hearing adults. Latencies of ABR evoked by click were shorter than those evoked using speech bursts. However, there is no study comparing response evoked by bursts and transitions.

The difference in the latencies evoked by different stimuli can be attributed to the stimulus duration. The click stimulus has the shortest duration (100µsec) among the three stimuli. The relationship between the stimulus duration and latency is reported previously in literature and there are equivocal results. Some investigators have reported that latency remains unaffected by stimulus duration (Gorga, Reiland, Beauchaine, Worthington & Jesteadt 1987), where as others have reported of increase in the response latency with increase in the duration of the stimulus for click evoked ABR in normal hearing subjects (Funasaka & Ito, 1986; Beattie & Boyd, 1984; Hecox, Squire & Galambos, 1979; Kodera, Yamane, Yamada & Suzuki 1977). This increase in latency with increase in duration of the stimulus was also seen among the two speech stimuli, transition, which had longer duration evoked longer latencies of responses, followed by bursts and then by clicks. Complexity of the stimuli could be another possible explanation for longer latencies of speech stimuli. Transition stimulus is more complex than a burst and there is variation in frequencies over time in transition, which is not present in a burst. Hence, it is possible that processing of transitions takes longer than bursts. Studies need to be carried out to compare the responses for transitions of different durations to check whether it is the duration or complexity that leads to longer latency of response.

Amplitude Measures: Table 5 portrays the mean and standard deviation values for the amplitude measures of responses yielded by the three stimuli-clicks, bursts and transitions. The mean for the response for each of the stimulus is almost congruent except for minor differences which are unlikely to be significant. It was observed that the standard deviation for the click evoked ABR was least, for both the ears. To investigate if these differences in amplitudes were significant, ANOVA was carried out.

Table 5

Mean and SD for amplitude measures in children with learning disability

	Right ear			Left ear		
Stimuli	Click	Burst	Transition	Click	Burst	Transition
Mean	0.40	0.63	0.54	0.30	0.49	0.43
SD	0.20	0.37	0.31	0.13	0.20	0.24

Table 6

Results of ANOVA for both ears for amplitude measure in children with learning disability.

	Right Ear	Left Ear
F	0.112	2.852
Sig	0.89	0.06

It can be thus observed from results of ANOVA that the amplitude is not affected with the variations in the type of stimulus. Reddy, et.al. (2004) also observed similar findings in speech burst evoked auditory brainstem responses in normal hearing adults. There was no difference in amplitudes of responses evoked by the speech bursts and the clicks. They concluded that the spectral envelope of the stimulus does not affect the number of nerve fibers firing, and thus the amplitude. There is no earlier study in literature comparing amplitude of responses evoked by bursts and transitions.

Another finding of the present study was that the standard deviation is observed to be least for the click evoked ABR highlights the fact that the intersubject variability is least for the click stimulus, when compared to the speech stimulus, for both the ears. Figure 2 displays the ABR wave forms obtained for children in the age range of 8 to 12 years for the click, burst and transition stimuli.

Figure2 (a)

ABR waveforms for a subject in age range of 8 to 9 years..

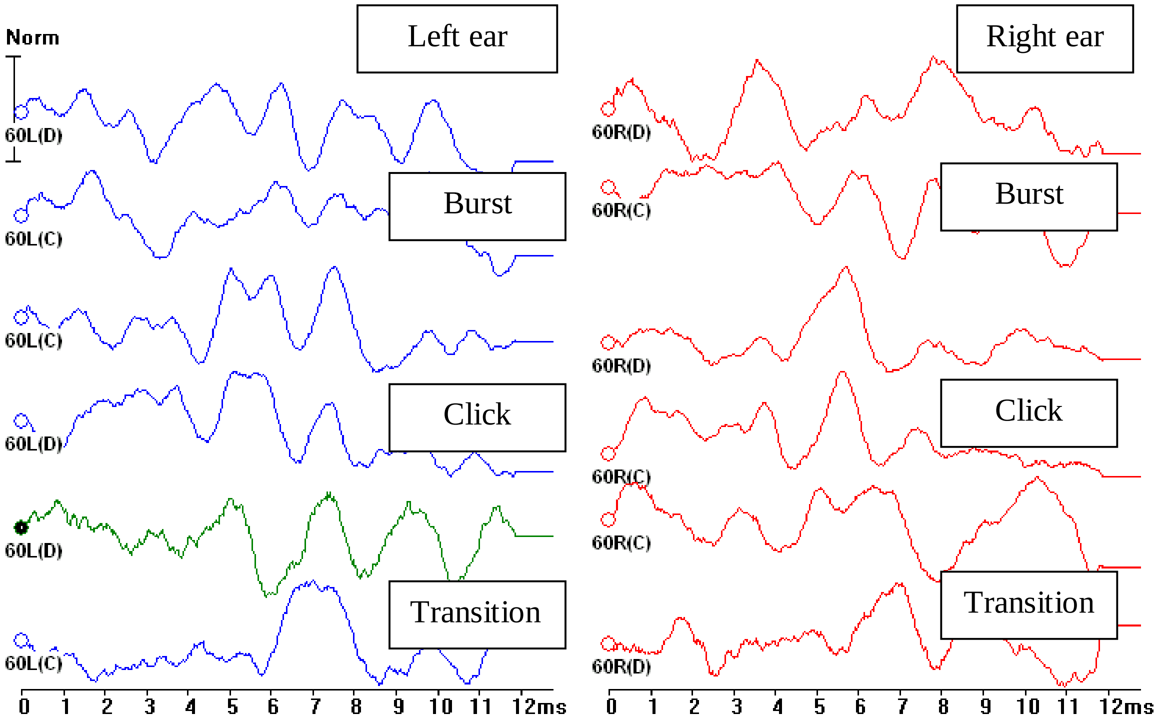


Figure2 (b)

ABR waveforms for a subject in age range of 9 to 10 years.

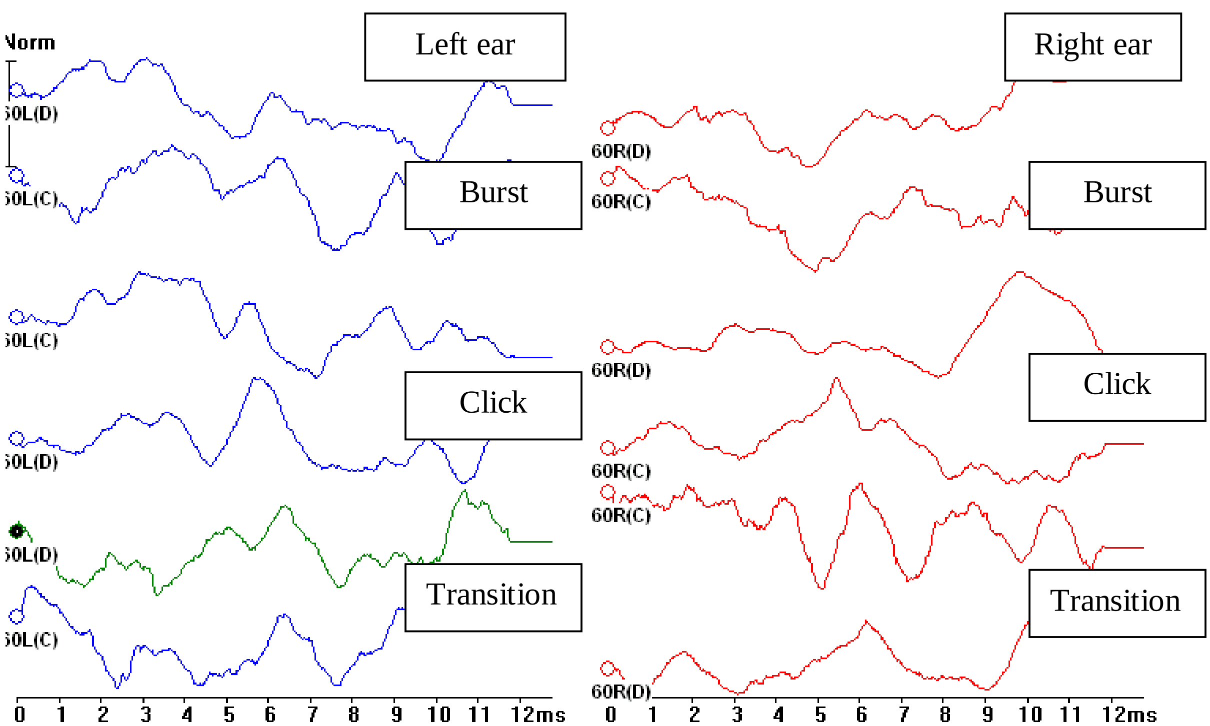


Figure2 (c)

ABR waveforms for a subject in age range of 10 to 11 years.

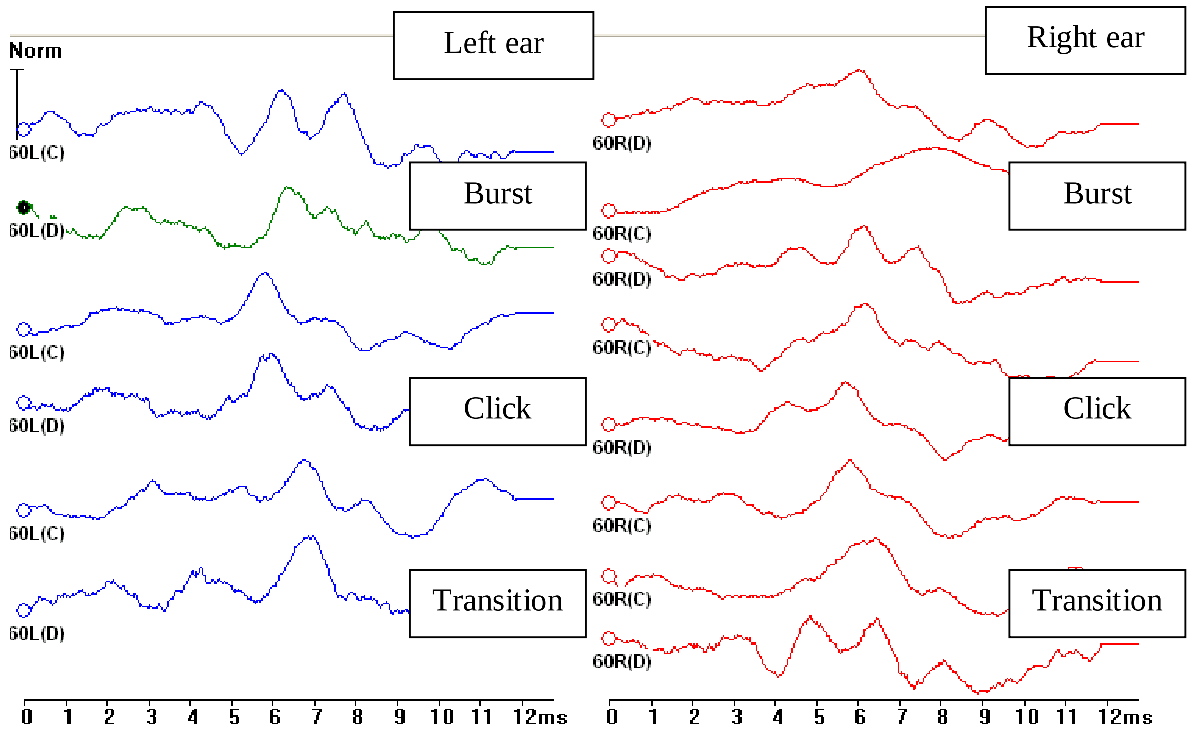
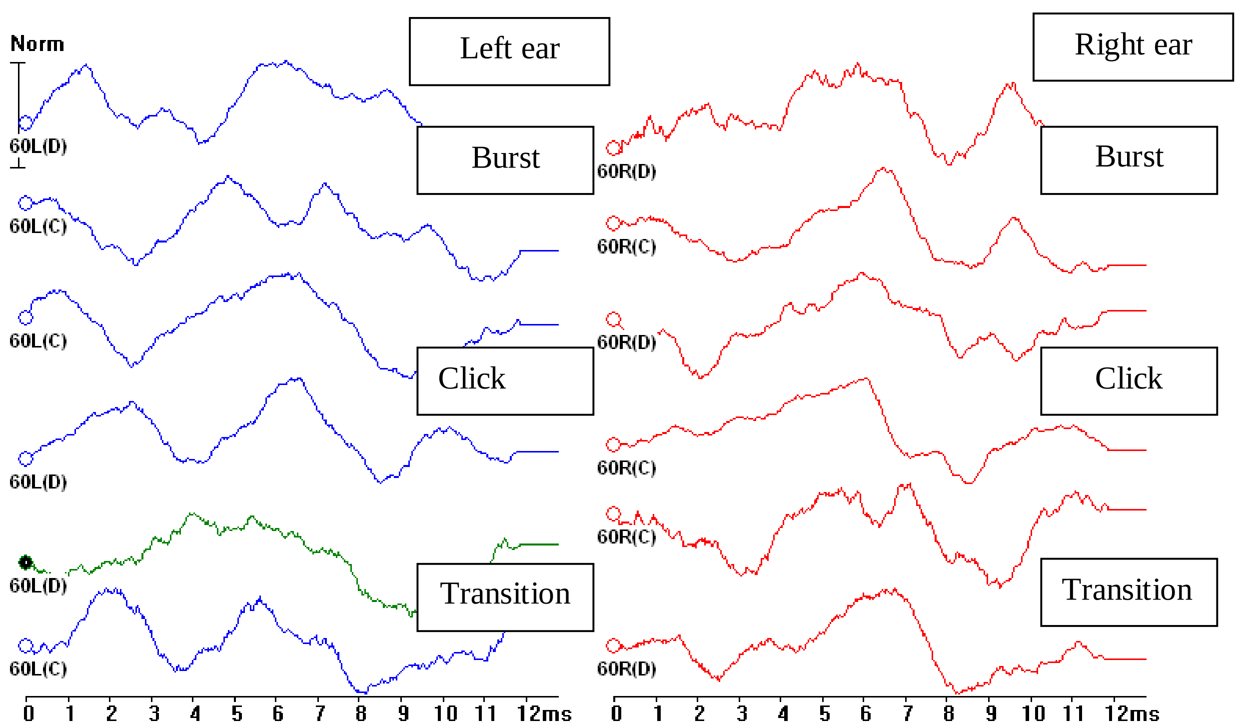


Figure2 (d)

ABR waveforms for a subject in age range of 11 to 12 years.



II. Comparison of ABR across age groups

Table 7 depicts the mean and SD obtained for the four age groups, for the latency and amplitude measures for the burst and transition stimuli. Table 8 shows the results of one way ANOVA performed across the 4 age groups, to see if any statistically significant difference in latency and amplitude of the four groups.

Table 7

The mean and SD values for the four age groups, for the latency (in msec) and amplitude (in microvolts) measures for the burst and transition stimulus.

a) Latency measures

Right ear				
Burst Stimulus				
Age group	8-9y	9-10y	10-11y	11-12y
Mean	6.16	6.29	6.40	6.52
SD	0.30	0.35	0.20	0.33

Right ear				
Transition Stimulus				
Age group	8-9y	9-10y	10-11y	11-12y
Mean	6.40	6.65	6.69	7.01
SD	0.40	0.22	0.36	0.48

Left ear				
Burst Stimulus				
Age Group	8-9y	9-10y	10-11y	11-12y
Mean	6.12	6.47	6.45	6.04
SD	0.22	0.66	0.63	0.72
Left ear				
Transition Stimulus				
Age Group	8-9y	9-10y	10-11y	11-12y
Mean	7.02	6.75	6.93	6.84
SD	0.33	0.12	0.73	0.62

b) Amplitude measures

Right ear amplitude				
Burst Stimulus				
Age Group	8-9y	9-10y	10-11y	11-12y
Mean	0.68	0.46	0.40	0.74
SD	0.29	0.17	0.11	0.26
Right ear amplitude				
Transition Stimulus				
Age Group	8-9y	9-10y	10-11y	11-12y
Mean	0.57	0.51	0.58	0.48
SD	0.14	0.16	0.47	0.33

Left ear				
Burst Stimulus				
Age Group	8-9y	9-10y	10-11y	11-12y
Mean	0.57	0.51	0.52	0.46
SD	0.20	0.24	0.36	0.47
Left ear				
Transition Stimulus				
Age Group	8-9y	9-10y	10-11y	11-12y
Mean	0.99	0.42	0.43	0.46
SD	0.80	0.28	0.16	0.35

Table 8:

ANOVA across four age groups for latency (in msec) and amplitude (in microvolt) measures for the two speech stimuli

a) Latency measures

s	Right Ear		Left Ear	
	Burst	Transition	Burst	Transition
F	1.28	2.19	0.697	0.201
Sig	0.315	0.129	0.571	0.894

b) Amplitude measures

	Right Ear		Left Ear	
	Burst	Transition	Burst	Transition
F	2.70	0.153	0.029	1.72
Sig	0.80	0.926	0.993	0.203

It is evident from the mean and SD values the longest latency of responses was evoked by transition stimulus in all the age groups. However, for the amplitude measures, the burst evoked the highest amplitude in the right ear in the oldest age group, while the transition evoked the largest amplitude in the youngest age group in the left ear. It is evident that there is no main effect of age on the latencies and amplitudes of ABR responses. Earlier studies on click evoked ABR, have reported reliable ABR responses obtained after 18 to 24 months of age (Lauffer & Wenzel, 1990; Eggermont & Salamy, 1988; Gorga et al. 1987; Jacobson, 1985; Fria & Doyle, 1984; Galambos, Hicks & Wilson, 1984). In the present study also, no age effect was seen in children in age-range of 8 to 12 years. Future investigations on younger children, can give definitive results regarding maturation of speech evoked ABR.

III. Comparison of ABR across stimuli in children with learning disability

Latency measures: Table 9 depicts the latency measures (mean and standard deviation) obtained for the responses evoked by the three stimuli- click, burst and transitions, for both ears. It is evident from Table 8 that mean latencies evoked by the different stimuli are variable. As observed in normals, latencies are longest for the transition stimulus, followed by the burst and shortest latency of responses is evoked by click stimulus.

Table 9

Mean and SD values for latency (in msec) measures in children with learning disability

Right Ear				Left Ear		
Stimulus	Click	Burst	Transition	Click	Burst	Transition
Mean	5.9	6.64	7.29	5.90	6.85	7.83
SD	0.29	0.32	0.48	0.39	0.59	0.61

To investigate whether these differences are statistically significant, ANOVA was carried out for the latency measures for all these stimuli. Table 10 displays the results of the ANOVA. It was observed that there is a main effect of stimulus on latency of responses across the stimuli and it is statistically significant ($p<0.05$). Significant differences are present between the latency evoked by the click stimulus and the two speech stimuli. To evaluate if these differences are significant, Tukeys post hoc test was carried out. Results of the post hoc test are displayed in Table 11. The responses evoked by the three stimuli have a very similar to the trend observed in normals. Once again, this difference can be attributed to the stimulus duration

Table 10

Results of ANOVA for latency (in msec) measures across stimuli in both ears in children with learning disability

	Right Ear	Left Ear
F	43.87	29.50
Sig	.000	.000

Table 11

Tukey's post hoc test results for both ears for latency (in msec) measures across stimuli in children with learning disability

a) Right ear

Stimulus	N	Sub set			
		1	2	3	4
Click	10	5.9220			

Burst	10		6.6430		
Transition	10			7.2970	.117
Sig	10	1.000	1.000	.384	1.000

b) Left ear

Stimulus	N	Sub set			
		1	2	3	4
Click	10	5,9070			
Burst	10		6.8520		
Transition	10		7.3350	7.3350	
Sig	10	1.000	.341	.258	.117

<u>Amplitude Measures</u>: Table 12 depicts mean and standard deviation for amplitude measures, obtained using clicks, speech bursts and formant transitions.

Table 12

Mean and SD for amplitude (in msec) measures for different stimuli across ears in children with learning disability

	RIGHT EAR			LEFT EAR		
Stimulus	Clicks	Bursts	Transitions	Clicks	Bursts	Transitions
Mean	0.54	0.57	0.53	0.31	0.50	0.57
SD	0.23	0.25	0.26	0.20	0.30	0.49

It is evident that for both ears, the response evoked by burst stimulus had highest amplitude. In the left ear, also, the same trend was observed. Amplitude was least for responses evoked by click stimulus and, ABRs evoked using click stimulus had the least intersubject variability.

To evaluate whether these differences in the amplitude of responses evoked using different stimuli were statistically significant, ANOVA was performed. It is observed from Table 13, that although differences existed, they were not statistically significant. There are no studies currently available to compare or support the findings of the present study. Figure 3 displays the ABR wave forms obtained for children with learning disability.

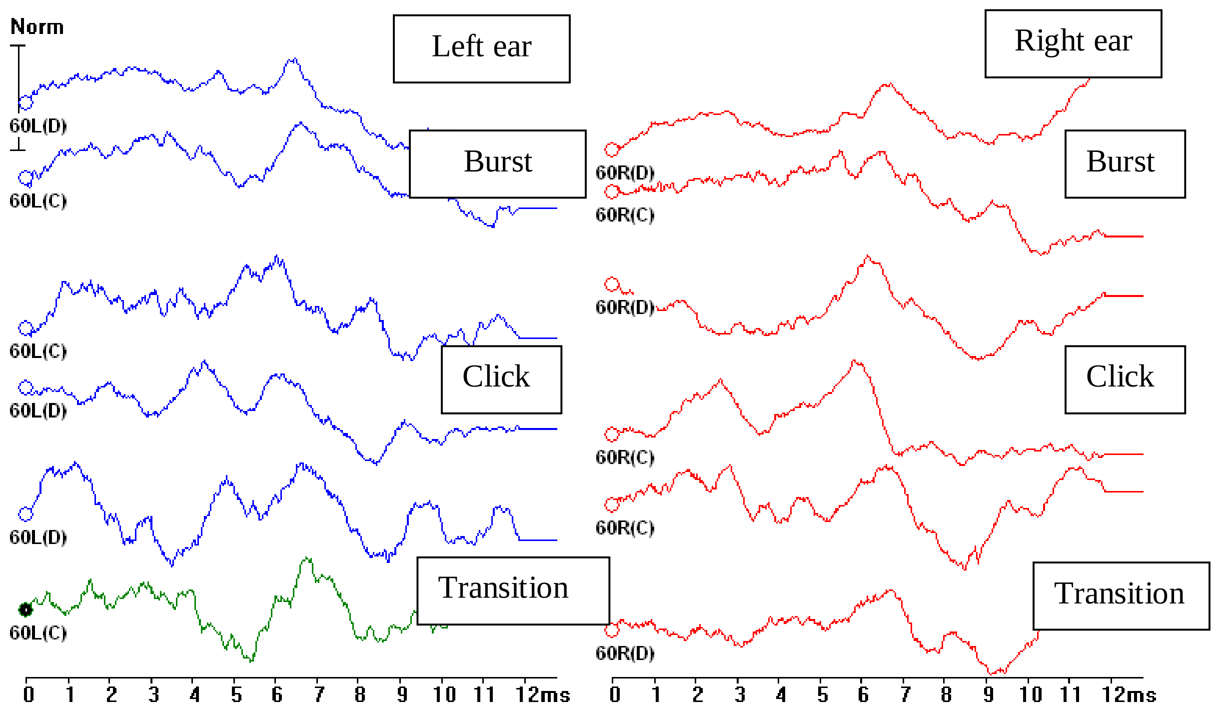
Table 13

ANOVA results for amplitude (in microvolts) measures in children with learning disability

	Right Ear	Left Ear
F	1.488	2.479
Sig	0.244	0.103

Figure 3

ABR waveforms for a subject with learning disability.



IV. Comparisons of ABRs evoked using different stimuli across normals and in children with learning disability:

To investigate if any differences are present in ABRs evoked using different stimuli across groups, and if these differences are statistically significant, independent sample test was carried out. Table 14 depicts the results of the independent sample t-test. It is clear from Table 14 that the two groups had significant differences for latencies for the speech stimuli only. Click stimulus evoked similar latencies of responses in both groups. There were no statistically significant differences in the amplitudes evoked using the different stimuli.

Table 14

Independent sample t test for latency (in msec) and amplitude (in microvolts) measures for comparison across groups.

a) Latency measures

Stimulus	t		Sig.	
	Right	Left	Right	Left
Click	1.18	0.984	0.245	0.334
Burst	2.41	2.54	0.02	0.017
Transition	3.57	2.55	0.001	0.016

b) Amplitude measures

Stimulus	t		Sig.	
	Right	Left	Right	Left
Click	1.672	0.202	0.106	0.841
Burst	0.541	0.047	0.593	0.963
Transition	0.055	0.825	0.957	0.416

The significant differences in the latencies could be attributed to the complexity of the stimuli. The more complex the stimulus, greater will be the time required and higher will be the level of processing required. Based on this postulate it can be understood that click which is a simple non speech tonal stimulus evokes ABR of shortest latency, while complex stimuli like transitions and bursts evoke longer latencies of responses. The individuals having any kind of processing deficits will have greater difficulty in processing stimuli which are complex, like speech, when compared to simple non speech stimuli. These results suggest that recording ABR to complex stimuli can help in early identification of children with learning disability. Figure 4 depicts a comparison of ABR waveforms across normals and children with learning disability.

Figure 4

Analysis of individual data revealed that out of the ten children considered for the study, having learning disability, eight children had prolonged latencies for either of the speech evoked ABRs in the right ear where as only one child showed delayed latencies for click evoked ABR. For the left ear same trend was observed where out of the 5 children with prolonged latencies to speech evoked ABR, only one child (same child who had prolonged latencies to click evoked ABR in the right ear) showed prolonged latency to click evoked ABR. However, the child who showed prolonged latencies for the click evoked ABRs in both ears had prolonged latency to speech evoked ABR as well. Out of the two speech stimuli considered for the study, transition stimulus showed prolonged latencies for 8 children in right ear and 5 children in left ear. Similarly burst evoked prolonged latencies in 5 children in right ear and 3 children in left ear. Only one child had prolonged latency to burst and normal latency to transitions in both the ears. This trend suggests that transitions are more sensitive to identify processing deviancies when compared to bursts. However, conventional click failed to highlight these deficits most of the times.

Wible, Nicol & Kraus (2004) have also reported atypical brainstem representation of onset and formant transitions of speech sounds in children with language based learning problems. They observed that children with learning problems had significantly shallower slopes for wave V-Vn of ABR, when compared to normals. Cunningham et al. (2001) have evoked ABR using speech syllable /da/ (formant transition), with and without presence of noise. They found no difference in quiet between normals and learning impaired children. However, there was significant difference between the groups when constant background noise of 75 dB SPL was introduced.

It is thus evident that speech evoked ABR is more sensitive than conventional click evoked ABR to identify processing deficits in clinical population. The present study is an attempt to highlight the importance of using speech stimuli to evoke ABR, especially in clinical population characterizing processing deviancies of complex stimuli like speech.

CHAPTER V

SUMMARY AND CONCLUSIONS

Learning disability is one of the very common educational handicaps seen in a number of school going children. A large umber of these children have problem in processing of complex stimuli, such as speech. By the time their problem is identified and intervened, they already have lagged behind their peers in a variety of skills. Many behavioral tests and electrophysiological tests have been used in identification of children of children, who are characterized by auditory processing problems. The behavioral tests existing are tedious, time consuming and are confounding by variables like academic prerequisites, subject co-operation, which makes these tests difficult. The available electrophysiological tests are confounded by age effects. Most of these electrophysiological tests tap the processing at the level of auditory cortex. Auditory cortical structures mature by 11 to 15 years of age (Sharma et. al. 1997). With very young children below 5 years of age these electrophysiological responses are affected by subject variables like sleep and attention and are thus difficult to use with the younger age group. Hence, by the time therapeutic intervention begins, the critical age would have already been passed and they lag behind their peers. Thus an immediate need was felt to develop a protocol which would identify children with processing deficits much earlier, so that they can be habilitated early. Recently attempts have been made in literature to elicit ABR using speech stimuli, and it has been found that speech evoked ABR could highlight processing deficits better than the conventional click evoked ABR. However, most of the studies done with speech evoked ABR have either used a transition to evoke

ABR or elicited ABR using speech bursts. There is no study evaluating and comparing brainstem responses evoked using both the speech stimuli, i.e. transitions and burst. No study has evaluated the efficacy of using speech bursts to evoke ABR in children with learning disability.

The present study to investigate whether any maturational changes occur with regard to speech evoked ABR in children in the age range of 8 to 12 years. The present study also aimed at evaluating the brainstem responses evoked using different stimuli in normal children and in children with learning disability. Further the efficacy of the two speech stimuli to evoke ABR and identify the processing deficits in the clinical population was also evaluated.

Twenty normal children and ten children with a formal diagnosis of learning disability were considered for the study ABRs were recorded using IHS smart evoked potential systems version 2.39. Speech stimuli (speech bursts and transitions of syllable /ta/) were used to evoke. ABR. ABR was also evoked using conventional clicks. Stimuli were delivered through Eartone 3A insert earphones at a rate of 30.1/sec. All recordings were done with the conventional four electrode montage.

Latency and amplitudes of the obtained waveforms were analyzed. Analysis of the data revealed the following results:

- Robust ABRs with a good morphology were evoked by all the three stimuli.
- No age effect was seen for both the parameters under study, i.e. the latency and amplitude in the age range of 8 to 12 years.

- There was no statistically significant difference in amplitudes evoked by the three stimuli, within the groups. However, there was a statistically significant effect of stimulus on the latency of responses. In normals, transitions evoked longest latencies, followed by bursts, followed by clicks respectively.
- Similar trend as in normals was seen in children with learning disability with respect to the latency and amplitude parameters, i.e., there was no statistically significant difference in the amplitudes evoked by the three stimuli, however latency evoked by the transition stimulus was the longest, followed by the bursts and clicks respectively.
- In children with learning disability, more number of children showed prolonged latency for transition. However the number of children who showed prolonged latency for bursts was greater than the children who showed deviant responses for click evoked ABR.
- Across the groups, i.e. across normals and children with LDs it was observed that only speech evoked ABR showed significant differences.

Implications of the study

Speech evoked ABR has great potential as a diagnostic tool. The present study was one of the attempts to highlight the significance of using speech stimuli to elicit ABR in clinical population with processing deficits (learning disabled).The extensions of the present study may have important clinical applications.

Prediction of processing deficits: Conventionally the electrophysiological tools used for the evaluation of the processing deficits in the clinical population are time consuming and can be administered for older children due to confounding maturational effects. Speech evoked ABR can be used as an evaluation tool to highlight the processing deficits in very young children or even in infants if appropriate norms are made available for the younger age groups. Children less than two to three years can be tested for speech elicited ABRs and the processing if deviant can be identified at a very young age, to aid early identification and subsequent intervention of auditory processing impairment in future.

Due to early maturation of the brainstem responses, the latency measure of the speech evoked ABR, described in the present study might provide a biological marker for early detection of language impairments characterizing central processing deficits . Further research is needed to determine which specific manifestations of brainstem abnormalities in consideration with behavioral findings may facilitate the early prediction of specific language impairment in young children.

Prediction of success with auditory training: Speech evoked brainstem responses are now known to show deviancies in processing in children with language based learning difficulties. Speech evoked ABRs can be used as a pre treatment baseline and after the termination of the program, it can be used as a post therapy measure. This will yield objective information regarding the usefulness of the training program and will aid as a parameter of outcome measurement also.

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