RELATIONSHIP BETWEEN SPEECH EVOKED ALLR AND DICHOTIC CV SCORES IN CHILDREN WITH DYSLEXIA.

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A Dissertation Submitted in Part Fulfillment of Final Year

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DEDICATED TO

ALMIGHTY GOD

&

MY PARENTS

&

GUIDE

You are the strength for my life……

CERTIFICATE

This is to certify that this dissertation entitled "***Relationship between speech evoked ALLR and dichotic CV scores in children with dyslexia***" is the bonafide work submitted in part fulfillment for the Degree of Master of Science (Audiology) of the student with Registration No. 10AUD026. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled "***Relationship between speech evoked ALLR and dichotic CV scores in children with dyslexia***" has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in other University for the award of any Diploma or Degree.

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DECLARATION

This is to certify that this Masterös dissertation entitled "***Relationship between speech evoked ALLR and dichotic CV scores in children with dyslexia***" is the result of my own study under the guidance of Mr. Prawin Kumar, Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in other University for the award of any Diploma or Degree.

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CHAPTER 1
INTRODUCTION

Dyslexia is a specific learning disability that is neurological in origin. It is characterized by difficulties with accurate or fluent word recognition and by poor spelling and decoding abilities. Learning problem is one of the common educational problems seen in a number of school going children. This learning problem negatively affects a variety of behaviours, so early intervention is one of the most important steps in this regard. In India, the occurrence of dyslexia ranges from 3% to 7.5% of children (Ramma, 2000). The prevalence estimate of this disability has been found to be 3 to 10 % (Snowling, 2000). Children with dyslexia may have auditory processing disorder and have been experimentally investigated by many researchers (Bellis, 1996; Berlin, Lowe-Bell, Cullen, Thompson, & Stafford, 1972; Billiet & Bellis, 2011; Johnson, Nicol & Kraus, 2005; Kraus et al., 1996, Rosen & Manganari, 2001). Studies on incidence of auditory processing deficits in children with dyslexics are estimated to be of 40% (Ramus, 2003).

Studies have shown abnormal processing of speech stimuli and normal processing for tonal stimuli in dyslexic children (Serniclaes, Sprenger-Charolles, Carre, & Demonet, 2001). Tallal (1980) reported that there is deficit in processing of brief, rapidly changing auditory stimulus in dyslexics. Study has suggested that such children have difficulty in processing of complex stimuli especially to process through auditory mode (Estes & Huizinga, 1974; Manson & Mellor, 1984).

The auditory processing of an individual can be assessed through behavioural tests or either by electrophysiological tests. Behavioural test and electrophysiological test has also been useful in uncovering the important aspects of neural basis of central auditory dysfunction. Behavioural tests mainly cut down the external redundancy and assess processing of auditory signal. These behavioural tests includes Dichotic tests, Competing sentence test, Staggered spondaic word test, Pitch pattern test, Duration pattern test, and Gap detection test. These tests are clinically useful to assess one or more auditory processes like auditory integration, sequencing, attention etc.

Dichotic listening test has been frequently used to evaluate the binaural separation and binaural integration abilities. Dichotic CV test has been used to evaluate the normal and impaired auditory process at the cortical level. Dichotic speech test includes variety of stimuli such as nonsense syllables, digits, monosyllabic words, spondaic words or sentences. Studies have shown that children with dyslexia exhibit poorer dichotic listening abilities (Moncrieff & Musiek, 2002; Purdy, Kelly & Davies, 2002).

On the other hand, electrophysiological tests assess the underlying physiology of the auditory system. Auditory evoked potentials (AEPs) provide strong objective methods to assess the neural integrity of the auditory pathway from auditory nerve to cortex (Hood, 1998). Majority of electrophysiological tests has been carried out in individuals with learning disability to assess the auditory processing at the cortical level. The Auditory long latency response (ALLR) is the most frequently used test among the cortical potentials to assess cortical region. Most of the studies have reported a prolonged latency (Arehole, 1995; Guruprasad, 1999; Jirsa & Clontz, 1990; Radhika, 1997) and reduced amplitude in these populations (Dawson, Finely, Philips, & Lewy, 1989; Jirsa & Clontz, 1990; Mason & Mellor, 1984; Radhika, 1997). David and Ghosh (1984) recorded P1, N1, P2 and N2 peaks in individuals with reading problem and results reveal an increased latency of P1 and P2 peaks when compared with normal average readers. Arehole (1995) studied the relationship between long latency responses and learning disorders in individuals with dyslexia. Results revealed an increased P2-P1 inter-peak latency in individuals with dyslexia in comparison to normal children.

Johnson, Nicol and Kraus (2005) described that the synthetic /da/ syllable has been used to study the processing of complex stimuli like speech, at the level of brainstem as well as at the level of cortex and further to study deviancies if any, in clinical population like learning disability. The response manifests as a series of brief neural events that are time-locked to the onset, offset, and the sustained information of the stimulus /da/. This tool has been used to assess binaural listening processing in children with learning disability including dyslexia. Therefore it has been suggested that the use of speech evoked ALLR in assessing such kind of processing deficits is promising to be a valid and reliable tool in such clinical population.

Need for the study

Though behavioural tests have been widely accepted to be the test of choice, however processing deficits may be co-morbid with a number of the pathologies that prevent the administration of behavioural tests. Hence, an attempt is required to check the equivalency of electrophysiological tests in the assessment of (central) auditory processing disorders in children with dyslexia. Cortical potentials have been widely used to understand the neurophysiological basis for speech perception, which would give information of speech processing abilities of the individuals. One such potential may be speech evoked ALLR.

Speech evoked ALLR helps in assessing the capacity of auditory cortex to detect changes within the speech stimuli (Martin & Boothroyd, 1999). There are different types of speech signals which are quite useful in eliciting ALLR includes natural or synthetic vowels, syllables and words (Ceponieni et al., 2001; Sharma, Marsh & Dorman, 2000; Tremblay Friesen, Martin & Wright, 2003). Hence, the recording of ALLR using speech stimuli can probe how the brain processes the signals that underlie auditory detection and discrimination. Majority of the studies have focused on recording of ALLR on click stimulus or more frequency specific tone bursts. But recording of ALLR using tone burst does not give much information about the processing or perception of speech. The P1-N1-P2 evoked neural response is heavily influenced by acoustic content of evoking signal. Hence it is important to know more about how the speech signal is processed in children with dyslexia. Therefore, the speech stimuli /da/ was used in the present study.

Most of the studies have evaluated children with dyslexia, and they observed clinically significant reductions in dichotic listening performance (Maerlender, Wallis & Peter, 2004; Moncrieff & Black, 2008). However, research done in dichotic listening test is very limited in clinical population such as dyslexia, where it can be used as a tool to identify the individuals with dyslexia. Hence further research is needed in this area to probe for difficulties faced by the children with dyslexia. An attempt is also needed to find out how the responses obtained from behavioural test (Dichotic CV tests) and electrophysiological tests (speech evoked ALLR) are related in children with dyslexia.

Aim of the study

The aim of the present study was to investigate the following aspects:

- To evaluate the efficacy of speech evoked ALLR in individuals with dyslexia in comparison to typically developing children.
- To evaluate the performance with dichotic listening test in individuals with dyslexia in comparison to typically developing children.
- To find out the correlation between speech evoked ALLR and behavioural test (Dichotic CV tests) in children with dyslexia.

CHAPTER 2

REVIEW OF LITERATURE

(Central) auditory processing disorder define as a deficits in the processing of information that is specific to auditory modality and the problem may be associated with difficulties in speech understanding, language development and learning (Jerger & Musiek, 2000). Central auditory processing tests involve a various process such as auditory closure, binaural integration, binaural separation, temporal patterning, binaural interaction and neural maturation (Bellis, 1996).

A number of studies have been done in the area of learning disabilities. Reviews of these studies have shown that there is heterogeneity in characteristics, causes and associated deficits. The researchers have reported that there is a subgroup of children with LD which may have auditory or visual processing deficits (Estes & Huizinga, 1974; Manson & Mellor, 1984). Ramus (2003) reported the incidence of auditory processing deficits in children with dyslexics is estimated to be 40%. The prevalence estimates for this disability have been found in between 3 to10% (Snowling, 2000).

Behavioural test and electrophysiological test have been useful in uncovering the important aspects of neural basis of many central auditory dysfunctions. It has been well documented that, at the behavioural level a subgroup of children with dyslexia have primary disturbance in phonological processing (Adlard & Hazan, 1998). In contrast it has also been reported that children with dyslexia have poor speech discrimination ability and that results in phonological processing deficits (Rosen & Manganari, 2001). A difference in phonemic perceptual boundaries has been reported in children who are at risk for dyslexia (Been & Zwartz, 2003). Warrier, Johnson, Hayes, Nicol & Kraus (2004) have investigated the physiological mechanisms that contribute to abnormal coding of speech in children with LD. Therefore it has been suggested that electrophysiological studies are commonly used to understand the neurophysiology of auditory processing and these tests are also useful in early identification of auditory processing deficits. There are various factors which may affect the recording of auditory late latency response (ALLR). They can be broadly classified as subject related factor and stimulus related factors.

Subject related factors

The recording of ALLR waveform depends on the subject status. The age, gender and state of arousal may affect the ALLR recording and the different components of ALLR.

Maturation and aging

The ALLR potentials are generated by multiple brain regions which includes primary auditory cortex, auditory association areas, frontal cortex and subcortical regions (Stapells, 2002). These areas mature at different rates, and hence there are changes in morphology, amplitude and latency of peaks with maturation (Cunningham, Nicol, Zeckar & Kraus, 2000; Ponton, Eggermont, Kwong & Don, 2000). The maturation of ALLR components in infants and children shows systematic changes in latency as well as in amplitude of components of ALLR with age. These potentials are continue to mature until the second decade of life and then again changes during the old age.

Developmental changes have been reported for decrease in ALLR latency and increases in amplitude as a function of age during childhood, till the age of 10 years (Ponton, Don, Eggermont, Waring & Masuda, 1996; Weitzman, Fishbein & Graziani, 1965; Weitzman & Graziani, 1968). In contrast some investigators have shown ALLR latency increases and amplitude decreases with advanced age (Callaway & Halliday, 1973; Goodin, Squires, Henderson & Starr, 1978). However, P1 is reported to be a dominant waveform in school age children and it can be recorded by using variety of stimuli. The literature shows decrease in P1 latency and amplitude during school age (Kraus et al., 1993; Sharma, Kraus, McGee & Nicol, 1997).

Infancy and early childhood

ALLR could be recorded from premature and full term new born infants and older children. However, it is more focused on central nervous system (CNS) maturation (Barnet, Ohlrich, Weiss & Shanks, 1975). The maturation of ALLR depends on the individual and therefore the ALLR waves mature at distinctly different rates (Ceponiene, Rinne & Naatanen, 2002). In general, the ALLR in children is characterised by prominent P1 and P2 waves.

Developmentally, the P1 wave appears first and it followed in the age period of 3 to 6 years by emergence of an almost adult like P2 wave. Interestingly, recognition of memory in newborn infants has been documented by P2 wave of the ALLR and was correlated with cognitive (mental) development at one year of age (deRegnier, Nelson, Thomas, Wewerka & Georgieff, 2001). Prominent changes in ALLR waves due to development have been reported within first year of life, and to a lesser extent within the 2 to 5 years of age as documented by many early investigators (Akiyama, Schutze, Schultz & Parmalee, 1969; Davis & Onishi, 1969; Ohlrich & Barnet, 1972; Weitzman, Fishbein & Graziani, 1965). Studies have shown that the N1 component of ALLR may not present in infants and young children. However, it can be recorded only with extended inter stimulus intervals (ISIs) of 1 second or longer in children age in between 3 to 10 years (Paetau, Ahonen, Salonen & Sams, 1995; Ponton et al., 2000; Sharma et al., 1997).

Studies have also reported that the latency and amplitude values for all the ALLR components do not reach adult like value until 16 to 18 years of age (Courchesne, 1978; Ponton, et al., 2000, Ptok, Blachnik, & Schonweiler, 2004; Sharma et al., 1997). McIsaac and Polich (1992) reported that latency and amplitude values for ALLR components for N1, P2 and N2 were generally longer and smaller for infants as compare to adults.

Gender

Effect of gender are suspected by many investigators but rarely investigated in ALLR measurements. Gender differences in brain volume, structure and function are well documented, especially in the temporal-parietal regions and corpus callosum (Cowell, et al., 1994; Witelson, 1991). Study has shown some evidences that the N1 latencies are shorter and amplitudes are larger in women than in men (Altmann & Vaitulevich, 1990). Onishi and Davis (1968) have reported that ALLR amplitude tended to be larger and have also found that the amplitude versus intensity function was steeper for females than males.

Subject state (state of arousal and sleep)

There is a pronounced effect of sleep on ALLR recording. It has been reported that there are significant but differential changes in major ALLR waves when the person becomes drowsy and falls asleep. Campbell & Colrain (2002) reported that the amplitude of N1 is progressively diminished from wake to sleep state. They have also found that during the transient to deep sleep the P2 amplitude was increased.

deLugt, Loewy and Campbell (1996) have reported that overall amplitude of N1 and P2 may remain reasonably stable across sleep stage and these sleep related changes in morphology can significantly increase the variability of the response. Amplitude of ALLR recording reported to be more variable during sleep (Rapin, Schimmel & Cohen, 1972; Williams, Tepas & Morlock, 1962). It has been also reported that the amplitude of N2 component is markedly increased during sleep (Picton, Hillyard, Krausz, & Galambos, 1974; Williams, Tepas & Morlock, 1962). Picton et al., (1974) have reported that there was increase in amplitude with increased stimulus oriented attention, and progressively diminished amplitude of N1 from the awake state to sleep state.

The P1-N1-P2 complex of ALLR can be affected by subject state. It has been reported that during ALLR recording the P1 does not get affected by either attention or wakefulness and sleep state, while N1 was reported to increase in amplitude by an about of 0.61 µV when signal was attended (Picton & Hillyard, 1974). The study has shown that during ALLR recording the amplitude of N1 to be larger in the attending stimulus compared to that is non attending condition .Similarly the P2 has also shown an increases in amplitude by an about of 0.70 µV when stimulus is attended. Some investigators have shown a slight increase in N2 wave latency, increase in amplitude and a biphasic peak in attentive condition (Ford, Roth & Kopell, 1976).

Stimulus related factor

The waveform of the ALLR also depends on the stimulus used for recording. There are different types of signals which can be used for the recording of ALLR. The auditory system responds in different ways to different signals. The responses evoked by the stimuli depend on the physical characteristics of the signal like intensity, frequency, duration, rate, etc.

Stimulus intensity

Intensity of stimulus is an important parameter in the study of speech processing. Studies have reported that there was an increase in the amplitude of ALLR components with stimulus intensity in a linear fashion though the amplitude-intensity function saturated at intensities exceeding at around 70 dBnHL (Antinoro, Skinner & Jones, 1969; Beagly & Knight, 1967; Picton, Woods, Baribeau-Braun & Healey, 1977). It has also been reported that these findings are true particularly when the short inter stimulus interval is used.

Hall (2007) reported that the maximum response for ALLR was obtained for moderate intensity level at 50-60 dBHL whereas Hyde, (1997) reported at 60-70 dBHL. It was reported that at higher stimulus intensity level, the amplitude of P2 increased and saturated than N1 amplitude. However, the latency of P2 and N2 waves were decreased (Adler & Adler, 1989). Thus there was change in amplitude as a function of stimulus intensity function tended to level off, or saturate, for moderate to high intensities above 70 dB (Picton et al.,1977; Spink, Johannsen, & Pirsing, 1979). Eddins and Peterson (1999) have studied time-intensity relationship for ALLR in normal hearing young adult. The results revealed that N1 was detected for signal intensity levels at an average of 8 dB higher than that of behavioural threshold for 1000 Hz and 7 dB higher for 4000Hz. In general, the latency of ALLR components decreases as the stimulus intensity increases.

Stimulus frequency

As stimulus frequency increases, the amplitude of ALLR components decreases (Antinoro, Skinner, & Jones, 1969). It has been reported that the latency increases as the frequency decreases particularly when high stimulus intensities are used (Jacobson, Lombardi, Gibbens, Ahmed, & Newman, 1992). The low frequency tones elicit significantly larger cortical response amplitude compared to high frequency tones (Jacobson et al., 1992). Sugg and Polish (1995) observed that the amplitude for the N1-P2 component was larger and latency was longer for low frequency tonal signal in comparison to high frequency signal. McCandless and Ross (1970) have found that pure tones were better than the click signal to elicit ALLR because higher cortical areas respond better to the slow variations rather than the transient changes.

Stimulus rate and Inter stimulus Interval (ISI)

There are several studies which have deal with the effect of inter stimulus interval on ALLR recordings. It has been reported that the ALLR is highly depended on ISIs (Budd, Barry, Gordon, Rennie, & Michie, 1998; Hari, Kaila, Katila, Tuomisto, & Varpula, 1982). Studies have shown that longer inter stimulus interval and slower stimulus rate produces substantially larger amplitude for N1 and P2 component but little effect on latency of these components were reported (Davis, Mast, Yoshie, & Zerlin, 1966).

Amplitude of P1-N1-P2 components increases as the rate of stimulus decreases until the inter stimulus interval is approximately 10 second (Davis, Bowers, & Hirsh, 1968; Hari et al., 1982). The most pronounced effect of longer ISI was reported within 1 to 6 second (Davis, Bowers & Hirsh, 1968; Hari et al., 1982). It has been reported that ISI of longer than 1 second is required to consistently record N1 component from children (Bruneau, Roux, Guerin, Barthelemy, & Lelord, 1997).

Some studies have also reported that reduction in the ISI from 4 sec to 1 sec lead to reduction in the amplitude in the order of 50% or more (Picton et al., 1977).

The effect of ISI on the ALLR amplitude was interpreted as linear relation with the refractory period of neurons in the auditory cortex. Hall (2007) reported that the stimulus rate of 1/s or less is appropriate for recording of ALLR. It has been also suggested that during ALLR recording a slow repetition rate of about 1/s is necessary to avoid neural refractory effects and to get better amplitude (Budd et al., 1988).

P2 amplitude is enhanced by using higher intensity sound and longer inter stimulus interval (Ceponiene, Rinne, & Näätänen, 2002; Picton ,Woods, & Proulx, 1978). Study has reported the differential effect of ISI for the amplitude of N1 versus P2. The amplitude of P2 did increase rather systematically in the range of 0.75 to 1.5 seconds (Roth, Ford, Lewis & Kopell, 1976).

Stimulus duration

There was a clear effect of duration on N1 and P2 latency and amplitude. It was observed that with shorter duration stimuli, significantly larger amplitude and shorter latency of ALLR are recorded. Onishi and Davis (1968) have reported that amplitude increases as stimulus duration increases up to approximately 30 to 50 msec, but the amplitude decreases when rise and fall time exceed 50 msec. It has been implemented that ALLR studies on effect of advancing age on sound duration processing. Stimuli of different duration (8 to 18ms) were generated by using 2000 Hz pure tones. Result has shown that the amplitude of N1 wave increased linearly as a function of stimulus duration for all age group (Ostroff, McDonald, Schneider, & Alain, 2003)

Type of stimulus

The components of ALLR can be evoked by a wide variety of stimulus such as click, tone burst, noise burst and different type of speech signal (Naatanen & Picton, 1987). It has been reported that ALLR can be evoked by using both non-speech and speech stimuli.

Click stimuli

Click stimuli, is used for ALLR recording because of its rapid onset and broadband spectrum. It elicits a neural response from large number of auditory neurons almost synchronously and therefore is likely to produce robust response when measured from scalp. It was observed that click evoked threshold correspond best to the region of hearing above 500 Hz (Katz, Burkard, & Medwetsky, 2002).

Tonal stimuli

It gives frequency specific information and hence it can be used in audiogram reconstruction (Stapells, Picton, & Durieux-Smith, 1994). It has been suggested that tone bursts with long rise time/ fall time and plateau time (20 msec each) from 500 Hz to 4000 Hz can be used for threshold estimation (Katz, Burkard, & Medwetsky, 2002). Typically tonal stimuli have been used to elicit ALLR responses (Davis, Bowers & Hirsh, 1968). It has also been suggested that optimal tone bursts that are used to elicit ALLR responses has rise/fall and plateau times of greater that 10 ms (Onishi & Davis, 1968; Rothman, Davis & Hay 1970). Studies have been reported that the low frequency tones elicit significantly larger cortical response amplitude compared to that of high frequency tones (Alain, Woods & Covarrubias, 1997; Jacobson et al., 1992; Sugg & Polich, 1995**).**

Speech stimuli

The tonal stimuli give very limited information about the processing and in turn about perception of speech. Hence speech signals have been used to elicit ALLR. In general, studies have reported that the amplitude of N1 to P2 complex is larger for speech stimuli than for single frequency tonal stimuli but latency values for N1 and P2 are usually earlier for tonal stimuli compared to speech stimuli (Ceponieni et al., 2001; Tiitinen, Sivonen, Alku, Virtanen, & Naatanen, 1999).

Studies have reported different types of speech signals that are used for recording of ALLR which includes natural or synthetic vowels, syllables and words (Ceponieni et al., 2001; Martin & Boothroyd, 1999; Sharma, Marsh & Dorman, 2000; Tremblay et al., 2003). Latency of N1 has been evoked by using speech sounds by varying voice onset time (Sharma, Marsh & Dorman, 2000; Tremblay et al., 2003). It has been reported that natural speech sound also elicited reliable ALLR components and morphology of waveforms varied as a function of speech stimulus (Tremblay et al., 2003). Investigators have found that synthetically generated voiced speech sounds evoked ALLR were recorded with lager amplitude than responses evoked by voiceless speech sounds. Similar type of response pattern was also reported for natural speech sounds (Tremblay, Piskosz & Souza, 2003).

Auditory late latency responses (ALLRs) in Learning Disability

A majority of electrophysiological studies has been done on LD population by using ALLR to understand the auditory processing. It provides a complex but rich source of information about central nervous system pathways and structures coded by auditory stimulation. The elicited responses observed at least after 50 ms following acoustic presentation, occurring later than both the auditory brainstem response (<10 ms) and the middle latency responses (10-50 ms). The ALLR potentials have been characterised by the four components like P1, N1, P2, N2 and it compromise a time domain of 50 to 500 ms (McPherson & Starr, 1993). The ALLR components are labelled according to their latency and polarity at the vertex (Picton, Woods, & Proulx, 1978).

ALLR has been used to study how the processing of phonological and acoustic features of speech sounds occurs (Crotazz- Herbette & Ragot, 2000) and also to identify which of the cortical areas activated and coded by these features (Makela, Alku, May, Makinen, & Tiitinen, 2004). Investigators have used ALLR recording as an objective measure to investigate the neurophysiogical processes that underlie the ability to perceive speech and non speech sounds (Tremblay et al., 2003).

Several studies have been carried out recording ALLR at moderate intensities with low repetition rate below 2/s (Byring & Jaryilehto, 1985; Mason & Mellor, 1984; Radhika, 1997; Satterfield, Schell, Backs, & Hidaka, 1984). Different stimuli have been used for recording ALLR such as speech (Brunswick & Rippon, 1994; Dawson, Finely, Philips, Lewy, 1989), pure tones (Tonnquist-Uhlen, 1996) and click (Satterfield et al., 1984; Dawson et al., 1989; Arehole, 1995). Different components of ALLR waveform discussed under separate heading.

P1 Wave:

P1 is the major component of ALLR and it is characterised by first vertex positive peak. It typically occurs approximately 50 ms after the stimulus onset and lager in amplitude typically more than 2 µV in normal children. The ALLR responses elicited together are referred to as P1-N1-P2 complex and is characterised by a positive peak (P1) followed by a negative peak (N1), followed by positive peak called P2 (Tremblay, Piskoz & Souza, 2003).

Latency of P1 has been reported to be delayed in latency in children with LD (Byring & Jaryilehto, 1985; Leppanen & Lyytinen, 1997; Satterfield et al., 1984). The latency of P1 has been reported to be 88.72 ms (Satterfield et al., 1984). A significant increased in P1 latency in children with LD have also been reported when compared to children without LD (Byring & Jaryilehto, 1985).

Findings of the research carried out by Radhika (1997) have shown mixed results in learning disabled children in the age range of 6-12 years. It has been observed that the P1could be recorded with normal latency and also absent in some of these children. Purdy et al., (2002) reported that P1 component occurs earlier in children with LD. Whereas some studies reported even reduced P1 amplitude ranging from -3.0 to -4.9 µV (Pinkerton, Watson, & McClelland, 1989; Jirsa & Clontz, 1990; Leppanen & Lyytinen, 1997).

In similar line, Rohith (2010) recorded ALLR in children using speech and non-speech stimuli in the age range of 2-15 years. The result revealed that as age increases the P1 latency decreases and the absolute amplitude reduced for stimuli /da/ and 500 Hz tone burst. P1 amplitude obtained in age of 10-15 years was significantly lesser than that of group 2-5 years for both the speech and non-speech stimuli. In addition, P1 amplitude showed larger amplitude for speech evoked stimulus than 500 tone bursts.

N1 Wave:

The N1 is primarily an exogenous potential and occurs about at 100 ms after stimulus onset and with amplitude of comparatively lower than P1. Most of the studies done in children with LD have reported increase in latency of N1 component (Arehole, 1995; Jirsa & Clontz, 1990; Leppanen & Lyytinen, 1997; Radhika, 1997; Tonnquist-Uhlen, 1996). The mean latency value reported in this group were ranges from 113ms-123ms (Arehole, 1995; Jirsa & Clontz, 1990; Tonnquist-Uhlen, 1996) and 125ms-153ms (Radhika, 1997). Longer latencies have been reported for major ALLR waves in children with auditory language impairment and this have been attributed to slower processing speeds (Tonnquist -Uhlen, 1996). However, Arehole (1995) has also observed an increased N1 latency between normal and learning disabled children but it was not statistically significant.

Studies have reported reduced N1 amplitude in learning disabled children (Brunswick & Rippon, 1994; Jirsa & Clontz, 1990; Neville et al., 1993; Radhika, 1997) and was in the range of -0.1to 1.93 µV (Brunswick & Rippon, 1994; Radhika, 1997). Whereas normal amplitude of N1 has been also reported ranging from -3.7 to 3.9 µV (Jirsa, 1992). Moreover, N1 amplitude was not identifiable in some of the learning disabled children as reported by Radhika (1997).

Rohith (2010) observed decreased N1 latency and reduced amplitude for speech syllable /da/ however for tone bursts no such specific pattern was seen. There was a significant difference seen between syllable /da/ and 500 Hz tone bursts for N1 latency in group 1 (2-4.11 years) and group 3 (10-15 years). However, there was no significant difference between latency and amplitude in group 2 (5-9.11 years) for speech stimuli and 500 Hz tone burst.

P2 Wave:

It is an exogenous potential and occurs about 180 ms after the stimulus onset with amplitude of 2-5 µV or more but it may be absent in children (Makela et al., 2004). Most of the studies have reported increased P2 latency in children with learning disability (Arehole, 1995; Leppanen & Lyytinen, 1997; Radhika, 1997; Tonnquist-Uhlen, 1996). From the studies findings for P2 latency has been reported to be in range of 160-188ms in children with LD (Arehole, 1995; Radhika, 1997; Tonnquist-Uhlen, 1996). Jirsa and Clontz (1990) observed P2 at a latency of 220 msec however, few studies refute these findings. Arehole (1995) reported that there was no significant difference for P2 latency between normal and learning disabled children.

Reduced absolute amplitude of P2 has been reported by many investigators in children with learning disability (Brunswick & Rippon, 1994; Leppanen & Lyytinen, 1997; Tonnquist-Uhlen, 1996). Satterfield et al., (1984) have reported a reduction in P2-N2 relative amplitude ranging from 6.3 to 13.4 µV. It has been also reported that P2 amplitude was normal in children with LD and findings of these study contradicts the above findings (Jirsa 1992). However, few studies have shown that P2 was not identifiable in children with LD (Jirsa & Clontz, 1990; Pinkerton et al., 1989; Radhika, 1997).

Rohith (2010) studied that P2 latency decreases as the age increased for both syllable /da/ and 500 Hz tone burst. However, there was no significant group interaction observed for both the stimuli for P2 amplitude. Further, mean latency for speech evoked P2 was longer than 500 Hz tone burst within the same age group, whereas P2 amplitude showed variable responses.

N2 Wave:

It is an endogenous potential and occurs at about 200 ms after stimulus onset. An increased N2 latency has been reported in majority of the studies on children with learning disability (Mason & Mellor, 1984; Satterfield et al, 1984; Tonnquist-Uhlen, 1996). However, Duncan et al., (1994) have reported that the latency of N2 was in normal range from 177 to 230 msec. In contrast, Radhika (1997) recorded N2 peaks both in normal latency range and absence of N2 peaks in children with learning disability in the age range of 6-12 years. Majorities of studies have shown controversial finding about N2 amplitude in learning disabled children with decreased absolute latency. The amplitude of N2 has been ranged from -4.5 to 5.6 µV in children with LD as reported (Satterfield et al., 1984; Tonnquist-Uhlen et al, 1996). However, other studies have also reported absence of N2 in LD children (Duncan et al., 1994; Jirsa & Clontz, 1990; Radhika, 1997).Whereas some of the studies have also showed increased N2 amplitude in LD (Byring & Jaryilehto, 1985; Mason & Mellor, 1984).

There is a dearth for studies investigating speech evoked ALLR in learning disability children or dyslexic. Speech evoked ALLR has been recorded in learning disability children to evaluate the maturational progress of P1, N1 & N2 cortical response over the life span (Cunnigham, Nicol, Zecker, & Kraus, 2000). The results have shown that the maturational pattern in group of children with LD doesnøt differ significantly from typically developing children. However, the ALLR components P1, N1 & N2 were significantly correlated with standardized tests of spelling, auditory processing and listening comprehension in children with learning problem group.

Few studies have suggested that ALLR may be used to access the capacity of auditory cortex to detect changes within the speech stimuli. Wible, Nicol and Kraus (2002) reported that cortical responses for speech stimuli (/da/ of 40 ms) were affected in presence of noise in a sub-group of children with learning problems and this performance was correlated with behavioral measures of auditory processing and spelling. However speech evoked ALLR responses in quiet were normal in these children. Wible, Nicol and Kraus (2002) have reported that P1, N1, P2, and N2 responses were degraded in stressed condition i.e. with repeated presentation in the presence of noise. Findings of this study also suggested that the auditory system in children with LD was more sensitive to the stressed of noisy situation.

Purdy, Kelly and Davies (2002) recorded ALLR components in an investigation of cortical auditory evoked responses in children with learning disabilities, including APD, and a control group of children with no history of learning or auditory problems. Result reveals that the P2 component of the ALLR was not consistently recorded and it was typically smaller in amplitude. ALLR recording has shown there were significant group differences for the P1 component (shorter latency in the APD group) and the N1 component (smaller amplitude in the APD group) characteristics. Liasis et al., (2003) have observed attenuated N1 and P2, increased N1 latency and small N1-P2 peak to peak amplitude in children with APD and ALLR was affected in terms of reduced amplitude, prolonged latency and poor morphology.

Guruprasad (1999) recorded ALLR using tone bursts in children with learning disability in the age range of 8-13 years & age matched control group. The different components of ALLR could be recorded by using tone bursts in all the subjects but none of them had shown ALLR with good morphology of waveforms. The results revealed that P1 latency was delayed but early occurrence of P2 and N1 in children with learning disability. Further, P1-P2 interval was noticed to be shorter in LD group compared to control group. It was also reported that P1-N1 amplitude could not be calculated in any of these subject because of difficulty in detecting N1 peak.

Sandeep and Vanaja (2004) have recorded ALLR for speech and tonal stimuli in children with learning disabilities. There were two groups of subjects included in the age range of 7-12 years with age matched control group. Results revealed that the mean latency of ALLR waveforms were prolonged in experimental group compared to control group for both speech and tone burst stimuli. Further, it was also noticed that processing of speech stimuli were more affected than with tonal stimuli in children with learning disability.

Thus the review of literature suggests that there is abnormal, asynchronous, auditory cortical encoding may underlie some language based learning problems in a subgroup of children with LD. However, the results also suggest that the cortical responses to all stimuli are not equally affected. To conclude, it has been reported in literature that learning disabled children do have central auditory processing disorder which is evident on both electrophysiological and behavioural tests. Therefore, few studies have also compared the sensitivity of these tests.

Behavioural Dichotic listening test in Dyslexia

A number of studies have been identified the presence of binaural integration deficits in children with learning and reading disorders (Obrzut, Conrad, Bryden, & Boliek, 1988; Moncrieff & Musiek, 2002). Dichotic speech tests are used clinically to evaluate the binaural separation with binaural integration ability. It is well documented that those children with dyslexia having auditory processing problem. To assess these problem dichotic tests have been used frequently. It has been observed that when the speech, words or syllables are presented dichotically to normal listeners, highest scores are obtained in the right ear than the left ear. This has been referred to as right ear advantage (REA) and it is believed to reflect from left hemisphere dominance which is responsible for speech and language (Studdert- Kennedy & Shankweiller, 1975). On the other hand, the stimuli from the right ear have direct access of left hemisphere and it is a typical finding for dichotic tests (Katz, 2002). It has been noted that Dichotic tests are sensitive to the lesion affecting either the auditory area of the left temporal lobe or corpus callosum. The results have shown as contra lateral deficits (Pienheiro & Musiek, 1985).

The various dichotic tests have been clinically used in assessment of central auditory processing and these tests are Dichotic digits, Dichotic CV, Staggered Spondiac Word (SSW), Competing Sentence Test (CST), Dichotic Sentence Identification (DSI), and Dichotic Rhyme Test (DRT). Many of the studies have been done for the assessment of C(APD) deficits in learning disabled children using Dichotic Digits (Musiek, 1983), Dichotic CV (Berlin et al., 1972), Staggered Spondaic Word (Katz, 1962) and CST by Willeford (1968). Results of these studies have shown right ear advantage (REA) in learning disabled children. However, in contrast a few studies have also shown left ear advantage (LEA) or no hemispheric dominance. (Bryden, 1970; Guruprasad, 1999; Thomson, 1975). Right ear advantage (REA) has been also reported on dichotic digit test and dichotic CV tests (Bowen & Hynd, 1988; Ganguly, Rajagopal & Yathiraj, 1994; Obrzut, Obrzut, Bryden, & Bartels, 1985).

Dichotic CV test has been used (Berlin, 1972) to measure different perceptual process. The results of Dichotic CVs score have shown mean errors score varying from 48% to 57% (Hynd et al., 1983; Roeser, Millay & Marrow, 1983) in LD children. The obtained mean scores reported were above 38% for right ear and 34% for left ear (Hynd et al., 1983; Obrzut et al., 1985). It has been found that at 90 msec lag, the mean scores obtained were 58% for right ear and 53% for the left ear. However, at 0 msec lag mean scores were 50% right ear and 57 % for left ear for Dichotic CV test (Roeser, Millay & Marrow, 1983).

Ganguly, Rajgopal and Yathiraj (1994) have studied on perception of dichotic CV syllables in normal and learning disabled children in the age range of 8-14 years. The results have shown that the mean scores were of 33.3% in right ear and 53.3 % in left ear on dichotic CV test at 0 msec lag. Reduced double correct score (7.4%) has been reported for learning disabled children by Ganguly, Rajgopal and Yathiraj (1994). Both the groups had showed significant REA however, in contrast LD subjects had shown significantly smaller REA compared to normals. Poorer scores for dichotic word test were obtained in children with learning disability in comparison to normals and Dichotic CV (Swanson & Cochran, 1991). It has been suggested that children with LD have either diminished or nonexistent REA (Bryden, 1970; Thomson, 1975).

Dermody, Noffsinger, Hawkins & Jones (1975) studied performance of LD children on the dichotic CV test and concluded that the LD children perform less efficiently on dichotic tasks as do the normals. They also reported that auditory capacity is significantly reduced in LD children. It was suggested that this poorer score may be due to inherent deficits in central auditory processing which shows auditory perceptual processing deficits seen in learning disability.

Guruprasad (1999) evaluated C(APD) with learning disability in the age range of 8-13 years. Results have shown that at 0 ms lag, LD children showed poorer score on CVs compared to normal for right ear score and double correct scores but were not statistically significant for the left ear performance. They also reported that normal children showed right ear advantage (REA) whereas LD children show a left ear advantage (LEA). However, the differences between two ear scores were not statistically significant for both the groups.

Moncrieff & Musiek (2002) performed dichotic listening tasks on typically developing children and dyslexic children in the age range of 10-11 years. The results revealed that the mean scores of two ears were different on dichotic CV test for both the groups. In addition, scores were lower for children with dyslexia compared to control group. Most of the dyslexic children showed poorer performance on more than one dichotic listening test (DDT, CW & DCV) in comparison to the control group.

Iliadou, Kaprinis, Kandylis, & Kaprinis, (2010) studied about hemispheric laterality assessment with dichotic digits testing in dyslexic and auditory processing disorder in the age range of 17- 46 years. There were three groups of participants (dyslexia, APD and APD with dyslexia) performance compared with control group for dichotic digit test. The results in both ears were shown to be significantly different with less correct results in group with APD and dyslexia, followed by APD group and then by dyslexia group. It was also observed that the dyslexia group showed equal distribution of right and left hemispheric dominance as well no dominance of the two hemispheres. It is probably an indication of presence of heterogeneity in children with dyslexia. Hugdahl et al., (1995) also found similar results for dichotic CV stimuli, and additional auditory event-related potentials (Brunswick & Rippon, 1994).

Moncrieff & Black (2008) studied dichotic listening deficits in 20 children (10 normals & 10 dyslexia) in the mean average age range of 11.6 (dyslexia) and 11.8 (control) years. The results showed that 50% of control children and 67% of dyslexic children show REA on free recall dichotic digit test. With the directed response format of DDT the number of children with REA increased in control group to 80% and in dyslexic to 89%. Result for dichotic CV test shown that control group children produced higher percentage of correct score in both ears than dyslexic children across all of the dichotic listening tests (DDT, CW & DCV). Thus results of dichotic listening tests were poorer and abnormal for dyslexic children.

Helland, Asbjornsen, Hushovd, & Hugdahl, (2008) studied about dichotic listening tests using consonant-vowel task in children with dyslexia. Two group of dyslexic children differed in severity through how they respond to training efforts and the result shown overall significant differences between control and dyslexia groups. One group of dyslexia (respondent group) showed a similar dichotic listening to control group with REA, while other group (non-respondent) group failed to show REA.

Agrawal and Valame (2010) assessed binaural integration deficits in children with LD in the age range of 8-13 using dichotic digit tests. The result revealed that the LD group showed poorer mean score in both ears than the typically developing children. The DDT scores were poorer for LD in the right ear than the left ear in comparison to normal group. The REA for LD group was significantly larger than that of normal group. There was significant difference in the scores between the ears for LD but not for normal groups.

In summary, from the review of literature it can be concluded that there is discrepancy in finding in terms of ear advantage in children with dyslexia. There are studies showed either a typical REA, left ear advantage (LEA) or no advantage in children with dyslexia. Further the scores obtained in dichotic listening tasks showed poorer results in children with dyslexia compared to typically developing children. Thus the behavioural tests like dichotic listening tasks can be helpful in identifying binaural integration deficit in children with dyslexia. It can also be observed that probably combination of speech evoked ALLR and behavioural dichotic CV test may be helpful in assessing children with dyslexia. The combination of two tests (electrophysiological test & behavioural test) can supplement each other in assessing and monitoring in children with dyslexia.

CHAPTER 3
METHOD

The main objective of the study was to see how the speech evoked ALLR is processed in individuals with normal hearing and also in individuals with dyslexia. An attempt was also made to know whether the speech evoked ALLR recorded from individuals with dyslexia is affected when compared with typically developing children. To arrive at the aim the following method was adopted.

Participants

Two groups of participants were included in the study; the groups were named as control group and experimental group. Thirty participants (60 ears) from the both groups in the age range of 10-12 years participated in the study. Control group and experimental group consisted of 30 ears each from 15 typically developing children (13 males & 3 females) and 15 children with dyslexia (11 males & 4 females) respectively. The diagnosis for the experimental group was made by speech language pathologists / Psychologists at All India Institute of Speech and Hearing, Mysore.

Subject selection criteria for control and experimental group

- Participants with hearing sensitivity within normal limits with hearing threshold less than 15 dB HL at octave intervals between 250 Hz to 8000 Hz for air conduction and between 250 Hz to 4000 Hz for bone conduction.
- All the participants had normal middle ear function, as per immittance finding.
- All the participants had average or above average intelligence, based on Ravenös progressive matrices.

Subject exclusion criteria for control and experimental groups

Children diagnosed as dyslexia with any additional associated problems such as attention deficit disorder with/without hyperactivity, chronic psychological disorder, or with any other neurological disorder were excluded from the study.

Test environment

The testing was carried out in an acoustically sound treated room with ambient noise levels within permissible limits as per ANSI S3.1 (1991).

Instrumentation

The following equipments were used for the study:

- A calibrated two channel diagnostic audiometer (Orbiter-922) with TDH-39 headphones and MX-14/AR ear cushion was used for air conduction thresholds. Radio ear B-71 bone vibrator was used for estimating bone conduction thresholds.
- A calibrated middle ear analyzer (GSI-Tympstar, version 2) was used to rule out middle ear pathology.
- ILO version 6 was used to record the Transient evoked otoacoustic emission.
- Bio-logic Navigator pro (version 7.0) evoked potential system was used for recording click evoked auditory brainstem response (ABR) and speech evoked ALLR.
- The recorded version of test materials for dichotic CV test from the personal computer coupled was routed via auxiliary input to the diagnostic double channels audiometer.

Test Materials

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

For dichotic CV test, the material used was dichotic consonant-vowel (CV) word lists (Yathiraj, 1999) consisting of 30 standardized pairs of syllables /pa/, /ta/, /ka/, /ba/, /da/ & /ga/.

Test Procedure

Screening checklist for Auditory Processing (SCAP) was administered on control group developed by Yathiraj and Mascarenhas (2003), was administered on participants in control groups to rule out symptoms of auditory processing disorders. It consists of twelve questions having the symptoms of deficits in auditory processing. The scoring was done on a two point rating scale (Yes/No). Children who scored less than 50% were considered for the study.

Pure tone thresholds were obtained at octave intervals between 250 Hz to 8000 Hz for air conduction and between 250 Hz to 4000Hz for bone conduction (mastoid placement), using modified Hughson and Westlake procedure (Carhart & Jerger, 1959). Tympanometry was carried out using 226 Hz probe tone at 85 dBSPL to rule out any middle ear pathology. For reflexometry, acoustic reflex measurement was performed using reflex eliciting tone of 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz ipsilaterally and contralaterally. Transient evoked otoacoustic emissions (TEOAE) were measured using click stimuli at 85 dBSPL in both ear to assess the outer hair cells functioning.

Click evoked ABR and speech evoked ALLR were recorded in both ears for all the participants using the test protocol mentioned in table 3.1. Participants were made to sit comfortably in order to ensure a relax posture and minimum rejection rate. Gold cup electrodes were placed after cleaning the electrode placement sites with preparing gel. Conduction paste was used to improve the conductivity of the recording signal from the generator sites. The electrodes were secured to the place by using plasters. The electrode placement was kept and followed as per the test protocol.

Test protocol

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

Table 3.1:

Protocol for recording click evoked ABR and speech evoked ALLR.

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

Dichotic CV test

The dichotic consonant-vowel test material was played through personal computer connected to the calibrated double channel diagnostic audiometer. The dichotic CV word lists were presented to both the ears using zero (0) ms lag at 40 dB SL (re: SRT).

The children were instructed as ñ*You will be hearing two words one to each ear at the same time. You should repeat both the words that you hear".* Task understanding was ensured using five practice items before proceeding to the dichotic consonant-vowel test.

Scoring

The responses of all the participants were scored in terms of single correct score and double correct scores. The right ear score (RES), left ear score (LES), and double corrected score (DCS) were scored. A single correct score was calculated when the participants reported the syllable presented to any one ear correctly. A double correct response was calculated when the participants reported the syllable presented to both ear correctly.

Statistical Analysis

Descriptive statistical analysis of the scores in terms of mean, standard deviation and other tests (parametric and non-parametric) such as Multivariate analysis of variance (MANOVA), Paired t-test and Karl Pearson correlation test performed using Statistical package Social Science (SPSS 16.0) software for both speech evoked ALLR and Dichotic CV tests. The results obtained are presented and discussed in the subsequent section.

CHAPTER 4

RESULTS AND DISCUSSION

The aim of the study was to investigate speech evoked ALLR in children with dyslexia and in typical developing children. The other aim of the study was to evaluate both groups on behavioural dichotic CV test. Further, relationship between speech evoked ALLR and behavioural dichotic CV test in children with dyslexia was tried to establish.

To analyze the data, descriptive statistics, Multivariate Analysis of Variance (MANOVA), Paired t-test and Karl Pearson correlation were carried out for speech evoked ALLR and Dichotic CV tests. *Descriptive statistics* was done to find out the mean and standard deviation (SD) for all the parameters for both control and experimental groups. *MANOVA* was administered to compare between experimental as well as control group for latency and amplitude of speech evoked ALLR and behavioural tests (dichotic CV) scores. In order to find out ear advantage *Paired t-test* was used to compare between the two groups. *Karl Pearson's Correlation* was done to check whether any relationship exists between speech evoked ALLR and DCS of dichotic CV scores.

Speech evoked ALLR

In typically developing children, all the peaks of speech evoked ALLR was present in all participants. Whereas in children with dyslexia, all peaks of speech evoked ALLR was present in all subjects expect for two subjects in which N2 was absent in both ears. Hence, the percentage of recorded waveform for P1, N1, and P2 was 100% whereas for N2 it was only 86.6%.

Table 4.1:

Mean and standard deviation (SD) of latency (msec) measure for control and experimental group in speech evoked ALLR

Parameters	Control group (N = 29)		Experimental group (N = 26)	
	Mean (ms)	**SD**	**Mean (ms)**	**SD**
P1	91.26	15.52	113.35	31.57
N1	134.48	23.67	175.14	37.15
P2	192.43	42.57	242.65	43.95
N2	235.68	46.09	303.20	39.19

N = number of ears

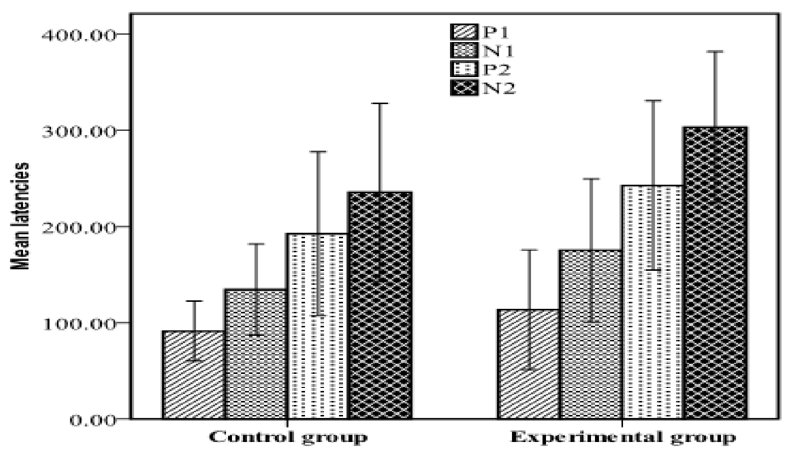

Figure 4.1: Mean and Standard deviation (SD) latency values of speech evoked ALLR for control and experimental group.

P1 wave

From the table 4.1 and 4.3 it can be observed that the mean latency of P1 was significantly prolonged and amplitude was reduced in dyslexic children as compared to typically developing children ($p < 0.05$). This is in agreement with the findings of Satterfield et al (1984) and Byring & Jaryilehto (1985). They found that P1 latency was delayed and amplitude was reduced in children with learning disability as compared to children without learning problem. They attributed it to delayed maturation in children with learning disability.

N1 wave

From the visual inspection it was observed that wave N1 present in all dyslexic children. This finding was consistent with the findings obtained by Radhika (1977). They found that N1 was present in all children with learning disability. Moreover, the results of MANOVA (table 4.1 & 4.3) reveled that latency of N1 was significantly prolonged in children with dyslexia as compared to typically developing children. ($p < 0.05$). The amplitude of N1 was also found to be significantly reduced in dyslexic children as compared to typically developing children. These findings are consistent with the finding of otherôs researchers (David et al, 1985; Kibble et al, 1986; & Pinkerton et al, 1989). They reported that the latency was increased and amplitude was reduced in children with learning disability. This could be related to short attention span in children with dyslexia (Picton et al., 1987). This suggests that children with learning problem take longer time to initiate the negativity.

Table 4.2:

F-value for latency measure between control and experimental groups

Parameters	f-value	p-value
P1	F (1,53) = 11.42	0.001**
N1	F (1,53) = 23.92	0.000***
P2	F (1,53) = 18.50	0.000***
N2	F (1,53) = 33.83	0.000***

*p<0.05; **p<0.01; ***p<0.001

Table 4.3:

Mean and standard deviation values of amplitude (µV) measure of speech evoked ALLR for control and experimental group .

Parameters	Control group (N = 29)		Experimental group (N = 26)	
	Mean (µV)	**SD**	**Mean (µV)**	**SD**
P1	2.88	1.23	1.41	0.82
N1	-2.15	1.51	-3.88	1.96
P2	1.99	0.81	0.71	0.52
N2	-1.48	1.41	-2.81	1.40

N = number of ears

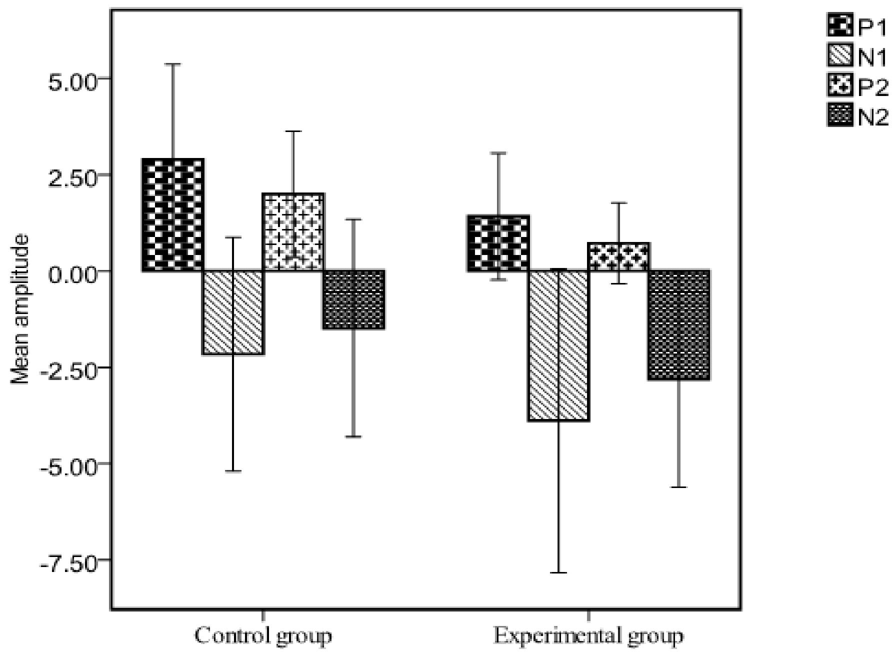

Figure 4.2: Amplitude measure of speech evoked ALLR in control and experimental group.

Wave P2

Table 4.1 & 4.3 depicted that the latency of wave P2 was significantly prolonged and amplitude was reduced in children with dyslexia as compared to typically developing children. ($p < 0.05$). The similar results of increased latency and reduced amplitude of waves P2 was reported by David et al (1984), Byring and Jaryilehto (1985). They found that the latency of wave P2 was prolonged and amplitude was reduced in children with learning disability as compared to children without learning problem.

Wave N2

From the visual inspection it was observed that out of 15 dyslexic children wave N2 was absent in two participants. In rest of the children with dyslexia the wave N2 was quite visible. This finding was consistent with the findings obtained by Radhika (1977). They found that N2 was absent in 8 children out of 12 children with learning disability. Moreover, the results of MANOVA (table 4.1 & 4.3) reveled that latency of N2 was significantly prolonged in children with dyslexia as compared to typically developing children. ($p < 0.05$). There are few studies have been reported in literature on latency of N2 because of wide range of latency variation observed in normal individuals. In the present study these deviancy in N2 latency could be because of the deficits in auditory processing of temporal aspects of the stimuli, which required more controlled attention (David et al, 1984; Byring & Jaryilehto, 1985).

Table 4.4:

F- values for amplitude measure in control and experimental group

Parameters	f-value	p-values
P1	F (1,53) = 13.04	0.001***
N1	F (1,53) = 6.59	0.017*
P2	F ((1,53) = 23.19	0.000***
N2	F ((1,53) = 5.99	0.022*

*p<0.05; **p<0.01; ***p<0.001

To conclude, present study come out with the finding that children with dyslexia performed poorly in comparison to typically developing children. This outcome is based on the differences observed in latency and amplitude measures between two groups in speech evoked ALLR.

Dichotic consonant-vowel (CV) tests

The *descriptive statistics* was done to obtained mean and standard deviation (SD) of dichotic CV score in terms of single correct scores (SCS) of right and left ear and double correct scores (DCS) for children with dyslexia and a typically developing children.

Table 4.5:

Mean and standard deviation values of Dichotic CV scores in control and experimental groups

Scores	**Control group (N = 15)**		**Experimental group (N = 15)**	
	Mean	**SD**	**Mean**	**SD**
LCS	16.93	1.71	14.07	2.31
RCS	22.80	1.56	11.93	2.25
DCS	10.93	2.37	4.93	1.38

LCS=left correct scores; RCS=right correct scores; DCS=double correct scores; N = number of participants

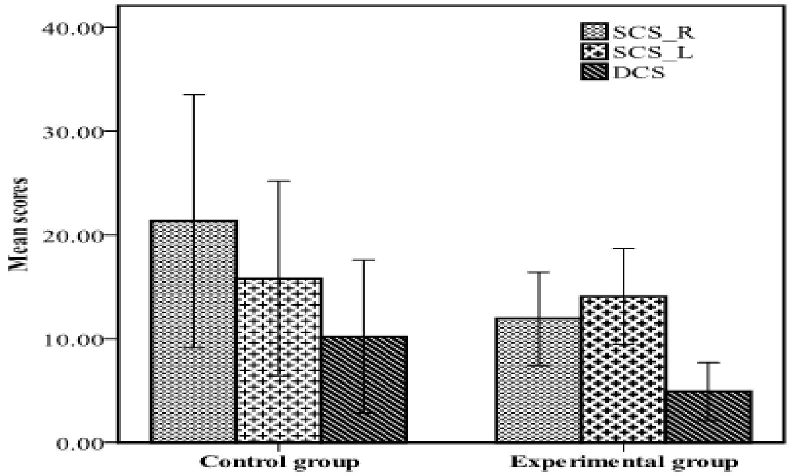

Figure 4.3: Mean Dichotic CV scores for control and experimental group.

SCS_R = single correct scores for right ear; SCS_L = single correct scores for left ear; DCS = double correct scores

MANOVA results showed that there were statistically differences between two groups on behavioural dichotic CV scores (table 4.5 & table 4.6). In typically developing children the mean right corrected and left corrected single scores was 16.93 and 22.80 whereas in dyslexic children it was found to be 14.07 and 11.93. This was much lower in dyslexic children. This difference in left corrected, right corrected single scores between the two groups was statistically significantly ($p < 0.05$). Similarly in typically developing children the mean double corrected scores (DCS) was 10.93 and in dyslexic children it was found to be 4.93. This difference in double corrected scores between the two groups was statistically significant ($p < 0.05$).

These findings suggest that children with dyslexia shows binaural integration deficit in comparison to typically developing children. The present finding is in agreement with other studies on dichotic listening test which assess binaural integration processes (Ayres, 1972; Billiet & Bellis, 2011; Black & Moncrieff, 2008; Cermak & Koomar, 1981; Helland, Asbjornsen, Hushovd & Hugdahl, 2008;

Moncrieff & Black, 2008; Mortan & Siegel, 1991). These studies reported that children with learning disability scored significantly poorer in comparison with typically developing children. In a similar line, Ganguly, Rajagopal and Yathiraj (1994) also found reduced scores in children with learning disability on the dichotic CV test in comparison to typically developing children.

Moreover in order to find out the ear advantage the *paired t-test* was used to compare right and left ear of control as well as experimental group. In control group the mean single correct scores of right ear was 22.80, whereas for left ear it was found to be 16.93. These differences between the scores were statistically higher for right ear ($p < 0.05$). This showed that a typically developing children exhibit a significant right ear advantage.

On the other hand, in experimental group the mean single correct scores in right ear was 11.93, whereas for left ear it was 14.06, which was significantly reduced for right ear ($p < 0.05$). These findings suggested that the children with dyslexia exhibit statistically significant left ear advantage. These finding in children with dyslexia in comparison to typically developing children revealed the differences in performance between two ears (ear advantage) and heterogeneity among dyslexic groups. These discrepancies probably could be because of differences in degree of reading and writing impairment (Helland et al., 2008; Hugdahl et al., 1995; Iliadou, Kaprinis, Kandylis & Kaprinis, 2010; Moncrieff & Black, 2008). The lack of right ear advantage (REA) in children with dyslexia observed in present study may also be explained by a tendency seen in dyslexics to switch attention between the ears rather than splitting their attention (Dickstein & Tallal, 1987).

In the another study Iliadou et al. (2010) found that the purely dyslexic children shows an almost equally distributed right and left hemispheric dominance as well as no dominance of the two hemispheres. This shows heterogeneity of dyslexic group in comparison to typically developing children.

Table 4.6:

F values for Dichotic CV scores between control and experimental group

Scores	f-value	p- value
LCS	F (1,28) = 14.89	0.001***
RCS	F (1,28) = 235.42	0.000***
DCS	F (1,28) = 71.41	0.000***

*p<0.05; **p<0.01;***p<0.001

To conclude, behavioural dichotic CV tests results in present study revealed poorer performance for children with dyslexia in comparison to typically developing children. The poorer performance was observed for single correct scores as well as for double correct scores between two groups. It was also observed that typically developed children show REA whereas children with dyslexia exhibit left ear advantage (LEA). Hence, the outcome of present study indicates there is binaural integration deficit in children with dyslexia in comparison to typically developing children.

Relationship between speech-evoked ALLR and Dichotic CV test

Karl Pearson's correlation was used to check whether there were any relationship between different components of speech evoked ALLR (latency & amplitude) and double corrected scores (DCS) of dichotic CV tests in typically developing children as well as dyslexic children.

Table 4.7:

Correlation between speech evoked ALLR and dichotic CV test

	Parameters	Double correct scores (DCS)	
		Correlation coefficient	
		(r)	p value
Latency	**P1**	0.23	0.39
	N1	0.06	0.80
	P2	0.00	0.99
	N2	0.32	0.28
Amplitude	**P1**	0.41	0.60
	N1	0.10	0.71
	P2	0.02	0.92
	N2	0.47	0.10

From the table 4.7 it can be inferred that there is a positive correlation between dichotic listening (DCS) and speech evoked ALLR. This suggest that dichotic listening tends to be poorer when there is an increase (prolong) in latency and reduction in amplitude of ALLR and vice versa. Though, there was the relationship between speech evoked ALLR and dichotic listening, but it was not statistically significant. This suggest that the speech evoked ALLR could be taken as alternative tool to assess dichotic listening. Moreover, we did not find any study in this regard to support the findings of present study. Probably larger sample size may require to validate the present findings.

However, there are some studies which indirectly support the present findings. Banai et al. (2009) studied the relationship between sub-cortical auditory encoding and literacy-related skills in children with learning problems. They observed statistically significant correlation between the measures of timing components (transition) of sub-cortical auditory encoding and reading skills. Moreover, the relationship was less significant between the harmonic components (formants) of sub-cortical auditory encoding and reading skills. Based on these finding they concluded that good readers show more temporally precise encoding and more robust representation of speech harmonics in comparison to poor readers who represents poor timing of sub-cortical auditory encoding and impoverished representation of signal harmonics. To conclude, there is a relationship between dichotic listening and speech evoked ALLR. However it was not statistically significant in children with dyslexia.

CHAPTER 5

SUMMARY AND CONCLUSION

The present study was taken up with objective to see the relationship between speech evoked ALLR and behavioural test scores in dyslexic children. Since both the tests assess the processing of speech at the cortical level so it could be expected to investigate the correlation between both the groups. To accomplish the aim 15 children with dyslexia and 15 typically developing children in the age range of 10-12 years was studied for speech evoked ALLR and dichotic CV tests.

A. Speech evoked ALLR

- Speech evoked ALLR could be recorded from all children with dyslexia and typically developing children.
- Out of 15 individuals wave N2 was absent in two children with dyslexia, whereas in typically developing children all the peaks were present.
- Latencies were significantly prolonged and amplitude was reduced in dyslexic children as compared to typically developing children.

The results of speech-evoked ALLR revealed that children with dyslexia showed abnormal encoding of speech signal at the cortical level.

B. Behavioural tests of auditory processing (Dichotic CV scores)

- Dichotic CV scores were significantly reduced in dyslexic children as compared to typically developing children.
- Significant right ear advantage was found in typically developing children whereas dyslexic children showed significant left ear advantage.

Results of behavioural tests depicted that children with dyslexic have poor performance on dichotic listening tests.

C. Relationship between speech-evoked ALLR and Dichotic CV scores

- Positive but non-significant correlation was found between double corrected score (DCS) and speech evoked ALLR.

Results of these findings revealed that, there is relationship between dichotic listening and the speech evoked ALLR. This suggest that dichotic listening tends to be poorer when there is increase in latencies or reduction in amplitude of speech evoked ALLR in dyslexic children. Hence, speech evoked ALLR could be taken as tool to assess dichotic listening.

Limitation/future directions

- The study may be carried out on a larger group of subjects.
- Different lag time and different speech stimulus may be used.
- Multiple electrode placements may be used for better peak morphology.

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