DICHOTIC WORD (CVC) TEST FOR NATIVE HINDI SPEAKING CHILDREN

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Dedication

To my parents

Thanks is too small for all the faith you have in me... I am honored to have you as my parents. Thank you for giving me chance to prove and improve myself through all walks of my life.

Thank you for your unconditional support in my studies.

I would also like to thank my Bhaiya and Bhabhi who is always the source of my inspiration, my sweet little sis Kajal, my dude brother Birendra and my nephew Abhinav.. hoping that with this research I have proven that there is no mountain higher as far as the god is on our side!!!

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How can I forget my Didi Dr. Archana and her family to help me in this Dissertation!!!

CERTIFICATE

This is to certify that this dissertation entitled ***“Dichotic word (CVC) test for native Hindi speaking children”*** is a bonafide work submitted in part of fulfilment for the degree of Master of Science (Audiology) of the student Registration No.: 09AUD016. 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 diploma or degree.

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CERTIFICATE

This is to certify that this dissertation entitled ***"Dichotic word (CVC) test for native Hindi speaking children"*** has been carried out under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

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DECLARATION

This is to certify that this master's dissertation entitled ***"Dichotic word (CVC) test for native Hindi speaking children"*** is the result of my own study under the guidance of **Ms. Chandni Jain,** Lecturer of Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other university for the award of any diploma or degree.

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Chapter- 1

INTRODUCTION

Auditory processing is the term used to describe what happens when brain recognizes and interprets the sound heard. Humans hear, when sound travels through the ear and is changed into electrical information that can be interpreted by the brain. When the processing or interpretation of information is affected it is termed as (Central) Auditory Processing Disorder (CAPD). Central Auditory Processing Disorder is an umbrella term for a variety of disorders that affect the way the brain processes auditory information. It is not a sensory hearing impairment and individual with auditory processing disorder usually have normal peripheral hearing ability. (C)APD demonstrate difficulty in one or more of the following abilities or skills: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition, including temporal integration, temporal discrimination (e.g., temporal gap detection), temporal ordering, and temporal masking; auditory performance in competing acoustic signals (including dichotic listening); and auditory performance with degraded acoustic signals (ASHA, 1996; Bellis, 2003; Chermak & Musiek, 1997).

Central auditory processing involves various processes such as auditory closure (decoding), binaural integration, binaural separation, temporal pattering, binaural interaction, neuromaturation and interhemispheric transfer (Bellis, 1996). Central auditory system mechanism and processes affect non-verbal as well as verbal signals and influence various higher functions including language and learning (Phillips, 1995; ASHA, 1996). Katz, Stecker and Henderson (1992) described central auditory processing as "what we do with what we hear". In children with CAPD may have negative impact on language acquisition, social skill development and school performance (Musiek & Lamb, 1994).

APD goes by many other names. Sometimes it is referred to as Central Auditory Processing Disorder (CAPD). Other common names are auditory perception problem, auditory comprehension deficit, central auditory dysfunction, central deafness, and so-called "word deafness". Chermak and Musiek (1997) estimated that APD occurs in 2 to 3% of children, with a 2-to-1 ratio between boys and girls. While Cooper and Gates (1991) estimated the prevalence of adult APD to be 10 to 20%.

Definitive diagnosis of Central Auditory Processing Disorder cannot be made until specialized auditory testing is completed and other etiologies have been ruled out. The auditory tests that is used to assess central auditory function falls in two major categories, that is, Electrophysiological measurement (Larsby, Hallgreen & Arlinger 2000) and Behavioral measurement (Musiek, 1999)

- Electrophysiological and Electro acoustical measures: This includes auditory brainstem response, middle latency response, cortical event-related potentials (P1, N1, P2, P300), otoacoustic emission, acoustic reflex thresholds, acoustic reflex decay.
- Behavioral tests: This includes binaural integration tests (Dichotic speech tests), auditory temporal processing and patterning tests, monaural low-redundancy speech tests and binaural interaction tests.

Among the test battery, dichotic listening tests have been an essential test and is used across all age groups (Jerger & Musiek 2000). It was originally introduced by Broadbent (1954) and is used to study the relationship between cerebral dominance and learning disabilities (Ayres, 1977), cognitive development (Obrzut & Hynd, 1981), auditory processing disorder (Tobey, Cullen, Rampp & Fleischer-Gallagher, 1979) and language disorder (Pettit & Helms, 1979). Depending upon the instruction given to the listener, dichotic task may assess the process of binaural integration, binaural separation or combination of both (Bellis, 2003). In dichotic listening skill the right ear advantage is observed through age 9 to 10 years, although performance varies based on the linguistic complexity of the signal, with development noted for specific type of dichotic skill through adolescence (Fischer & Hartnegg, 2004). The more difficult the task is, the greater would be the right ear advantage (Moller, 2007).

Stimuli options available for dichotic listening tasks include consonant-vowel syllables, digits, words and sentences. The different types of stimuli offer various levels of difficulty when used in dichotic listening tasks. In a study by Noffsinger, Martinez and Wilson (1994) digits were found to be the easiest stimulus in a dichotic listening task, followed closely by sentences. Both of these types of stimuli were correctly recalled over 90% of the time for both ears in a group of normal hearing young adults. Nonsense consonant-vowel syllables proved to be significantly more difficult with accuracy levels of just over 70% for both ears.

Dichotic digit test unlike sentences limit contextual cues. However it is a close set task so it may tend to overestimate speech recognition ability. Dichotic word test limit the use of syntactical cues and is a open set stimulus that may result in recognition performance in the middle of the difficulty continuation (Roup, Wiley & Wilson, 2006).Furthermore among other dichotic listening test, the dichotic CV test does not show expected neuromaturational effect in normally hearing children (Roeser, Millay& Morrow, 1983). Therefore, its utility in diagnosing auditory processing disorder in children is questionable.

However, words may have several advantages over digits because they are a much less restricted set than digits which allows for word sets of varying difficulties. There are also currently many standardized, recorded lists of words available which allows for performance comparisons across patients or subjects. The greatest benefit, however, may lie in using a combination of all stimulus options in dichotic listening tasks to obtain an even wider range of difficulties than just words alone allow for (Noffsinger, Martinez & Wilson, 1994; Roup, Wiley & Wilson, 2006).

Need for the study

- The need is to incorporate the Dichotic word test as a part of the central auditory nervous system evaluation battery as it has a good sensitivity in identifying and differentiating the cerebral level lesion (Berlin, 1976).
- The auditory system is undergoing maturation and thus age specific data is required which will help in making decision about child's auditory system whether it is developing normally or not. It also enables clinician to monitor a child's performance over time. It helps in determining whether poor performance is related to a delay of maturity or a disorder of the auditory processing system. A

child with a maturational delay is expected to show improvement over time whereas a child with a disorder of the auditory system will show no improvement over time (Keith, 2000).

- According to Musiek, Gollegly and Ross (1985) normative data from a representative population is required to ensure if it is a valid and reliable measure of auditory processing ability. It is ideal to have speech tests in all languages because the perception of speech is influenced by their first language (Singh & Black, 1966).There is no specific data for Dichotic word test in Hindi language to assess the auditory processing. So, there is need to develop a Dichotic word test in Hindi language.

Objective

1) To develop the Dichotic word test in Hindi language for children (7 years to 11.11 years).
2) To establish preliminary data for the dichotic word test in normal hearing children between the age range of (7 year to 11.11 years).
3) To investigate the test scores across age and gender.
4) To investigate the ear difference in dichotic word test (Ear effect).

Chapter- 2

REVIEW OF LITERATURE

Auditory processing stated simply is “what we do with what we hear” (Katz Stecker and Handerson, 1992). Butler (1983) defined auditory processing as the abstraction of meaning from an acoustic signal and the retrieval of that meaning. ASHA (2005) defines auditory processing, as involving the following skills: Sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition including temporal integration, temporal ordering and temporal masking, auditory performance in competing acoustic signals, auditory performance with degraded acoustic signals. Auditory processing disorder is defined as involving a deficit in one or more of the above. The British Society of Audiology (2005) defined APD as something that affects non-speech sounds. A central auditory processing disorder is a hearing disorder resulting from impaired brain function; characterized by poor recognition, discrimination, separation, grouping, localization, or ordering of non-speech sounds.

The prevalence of auditory processing disorders is unclear, because there is no 'gold standard'. Based on clinical reports and prevalence data for co morbid conditions, Chermak & Musiek (1997) estimated that the prevalence of APDs was 2-3% in children with a 2-to-1 ratio between boys and girls. Bamiou, Musiek and luxon (2001) reported a frequency of 7% and seen twice as often in boys than in girls. Cooper and Gates (1991) found the prevalence of (C)APD in older adults from 23% to 76%.

The causes of auditory processing disorder are unknown. There is anecdotal evidence to suggest links to: Maturational delay of the Central Auditory Nervous System, Developmental abnormalities (inappropriate development of the auditory/language areas of the brain),Prolonged otitis media with static or fluctuating hearing loss can lead to central auditory processing deficits that can cause language and learning delays long after the middle ear problem is treated (Keith, cited in Matson, 2005), Genetic links (Katz & Wilde, 1994). Baran (1996) described eight possible etiological bases for auditory processing problems: (1) subtle, subclinical compromise of the peripheral hearing mechanism not detected by routine peripheral hearing assessment; (2) auditory deficits related to neurological compromise; (3) auditory deficits related to more subtle cerebral morphological abnormalities; (4) auditory deficits related to normal degenerative processes (ageing); (5) cognitive deficits: (6) psychological/emotional deficits: (7) language differences; and (8) changes in acoustical environment.

Auditory processing disorders often coexist with learning disabilities, language disorders, attention deficit disorders, and dyslexia (Chermak & Musiek, 1997; Caccace & MacFarland, 1998).

Sub-groups of APD

In the past, many APD tests have been developed. Subjects with APDs form a heterogeneous group. Therefore they need to be tested with a battery of tests and search for subgroups. One way to approach scoring pattern is to develop auditory sub-profiles.

The Buffalo model (Katz, Smith & Kurpita, 1992) categorized APD into four sub type: Decoding, Tolerance-Fading Memory, Integration, and Organization based on the relationship between patterns of performance on one particular test of auditory processing, and learning difficulties in children. They tested 94 children of 6-12 year who referred for auditory testing with the battery of three tests and classify 91% of children with these categories as follows: Decoding 50%, Tolerance-fading memory 20%, Integration memory 17%, and Organization 4%.

Bellis and Ferre (1999) categorized APD into three main categories: auditory decoding deficit, integration deficit, prosodic deficit and other two sub categories are association deficit and output organization deficit based on patterns of findings on a battery of different combinations of auditory processing tests including Dichotic Listening(the Dichotic Digits test, Dichotic Rhyme, Competing sentences or the Staggered Spondaic Word test), Monaural low-redundancy speech (Low-pass filtered speech),Temporal Patterning (Frequency Patterns test) and Binaural interaction(Consonant – vowel – consonant binaural fusion).

Integration deficit in CAPD

Binaural integration performance is the ability of the listener to process different information being presented to each ear at the same time. (Musiek, 2006).This task is assessed through a variety of dichotic listening tests with digits, word sand consonant-vowels. Performance in each ear is measured as stimuli is simultaneously presented in competition to the two ears (Moncrieff & Musiek, 2002).A number of studies have identified the presence of binaural integration deficits in children with learning and reading disorders (Hynd, Obrzut, Weed & Hynd, 1979; Obrzut, Conard, Bryden & Boliek 1988; Moncrieff & Musiek,2002).

Dichotic listening tests are among the most powerful of the behavioral test battery for assessment of hemispheric function, interhemispheric transfer of information, and development and maturation of auditory nervous system in children and adolescents, as well as for the identification of lesions in the central auditory nervous system (Keith & Anderson, 2007).Depending on the instructions given to the listener, dichotic tasks may assess the processes of binaural integration, binaural separation or a combination of both (directed attention) (Bellis, 1997).The dichotic digits test and dichotic rhyme test are powerful tests for diagnosing binaural integration problems and are especially good tests for use in children as young as the age of seven (Muller & Bright, 1994; Moncrieff & Musiek, 2002).

Dichotic Speech Tests

Dichotic speech testing, introduced by Broadbent (1954), requires the simultaneous presentation of different speech signals in to both ears. The competing signals can range from the less-difficult pairing of broadband noise with speech to the more-difficult pairing of two lexically similar speech signals (Carter & Wilson, 2001; Roup, Wiley& Wilson, 2006). The speech stimuli used in dichotic listening includes digits, words, sentences, or nonsense syllables (Noffsinger, Martinez & Wilson, 1994; Roup, Wiley& Wilson, 2006). These tests, as a group, are reported to be sensitive to cerebral and interhemispheric compromise (Musiek, Kibbe & Baran, 1984) and brainstem involvement (Katz, 1962; Jerger & Jerger, 1974). It is a non-invasive technique used to assess brain lateralization and asymmetry when processing speech or non-speech auditory signals (Foundas, Corey, Hurley, & Heilman, 2006; Hugdahl, Westerhausen, Alho, Medvedev & Hamalainen, 2008). Depending on the type of acoustic signals presented to the listener, an "ear advantage" has been found, with the signal presented to one of the ears perceived as more dominant (Rimol, Eichele & Hugdahl, 2006). Research has shown that when linguistic stimuli in the form of a consonant-vowel (CV) are simultaneously presented into both ears, there is a right ear advantage (REA). That is, when participants are asked to report back on what they have heard, the signal presented to the right ear is more readily perceived (Asbjornsen & Helland, 2006; Hugdahl, Westerhausen, Alho, Medvedev & Hamalainen, 2008; Tallus, Hugdahl, Alho, Medvedev, & Hamalainen, 2007). On the other hand, when non-speech stimuli, such as melodies are presented simultaneously to both ears, a left ear advantage (LEA) is found (Kimura, 1961).

Dichotic listening has also been used to investigate the functional properties of the left and right hemispheres. Kimura (1967) investigated ear superiority for melodies, where two different melodies were presented simultaneously to each ear and participants picked which two they heard from a group of four. Results indicated that there were significantly more identifications made for melodies presented to the left ear than for the right ear. The results were taken to indicate a dissociation of auditory asymmetries depending on the type of stimulus presented and these asymmetries, in turn, reflect the functional differences between the left and right hemispheres. The predominance of the right temporal lobe in the integration of melodic patterns is reflected as a LEA.

Musiek, (1983) developed a dichotic test in which digits are presented simultaneously to both ears and named it as dichotic digit test. Results of investigations using the dichotic digits indicate contralateral deficits in subjects with right temporal lobe lesions and bilateral or contralateral deficits in subjects with left hemisphere lesions (Baran & Musiek, 1991; Musiek, 1983). This test is not highly linguistically loaded and is easy and quick to administer. One criticism of this test is that it offers no normative data, only cut-off ranges for normal and abnormal scores is available (Katz, Johnson, Brandner, Teryl & Ferre, 2002). It is a central auditory test that assesses binaural integration skills. It is sensitive to auditory processing abnormalities, easy and fast to administer, and is not influenced by mild to moderate hearing loss (Musiek, 1983).

Berlin and Lowe-bell (1972) introduced dichotic consonant vowel test for central auditory nervous system assessment. Although this test is lightly linguistically loaded, it's difficult because of the similarity in the CVs (pa, ba, ta, da, ka, and ga). In addition, one version of the Dichotic CV test had a 15, 30, 60 or 90 msec delay in the presentation of the second stimulus. Normal individuals improve with a delay of 30 msec. or more. However, no improvement with delays was reported in subjects with temporal lobe lesions (Berlin & Lowe-bell, 1972). Investigators have reported either contralateral ear deficits or bilateral deficits with left hemisphere compromise (Berlin & Lowe-bell, 1972; Mueller, Beck & Sedge, 1987).

Factor affecting dichotic listening

There are multiple factors that may affect dichotic test results beyond the status of the central auditory nervous system, including acoustic features of the signal, linguistic content of the signal, listener instructions, symmetry of a subject's peripheral hearing and a subject's age, memory span, motivation and cognitive abilities (Denckla, 1989; Silman, Silverman & Emmer, 2000)

- Stimulus related factors
- Subject related factors

Stimulus related factor

1) *Intensity*

For Dichotic listening test in normal hearing subjects, 50 dB HL or the subject's most comfortable listening level (MCL) is commonly used (Silman, Silverman & Emmer, 2000). Level at which the stimulus should be presented also depends upon the stimulus type. Berlin & Cullen (1977) found that digits and words for the W-22 list can be presented at lower level than CVs.

Speaks and Bissonette (1975) presented6 CV syllables in pairs dichotically using four intensities levels 80, 70, 60, 50 dB SPL. The experiment was done in two phases. In the first phase speech level in the right ear was attenuated in 8 dB steps from each of four reference intensities. In the second phase speech level in the left ear was amplified in 8dB steps. Results showed that the REA (Right ear advantage) was cancelled by attenuation of signal level in the right ear, but the amount of attenuation to cancel the REA varied with reference intensity (i.e. 22dB for 80 dB SPL to 5dB for 50 dB SPL ref intensity) Tallus, Hugdahl, Alho, Medvedev and Hamalainen (2007) manipulated the strength of intensity difference between the right-ear and left-ear speech inputs in order to make the REA either weaker (left-ear input>right-ear input) or stronger (left-ear input<right-ear input). The results showed that the interaural intensity difference significantly affected the ear advantage.

Hugdahl (2008) investigated the effect of differences in the right or left ear stimulus intensity on the ear advantage. For this, interaural intensity differences were gradually varied in steps of 3 dB from -21 dB in favor of the left ear to +21 dB in favor of the right ear. Thirty-three right-handed adult participants with normal hearing acuity were tested. The results showed: (a) a significant right ear advantage (REA) for interaural intensity differences from 21 to -3 dB, (b) no ear advantage (NEA) for the -6 dB difference, and (c) a significant left ear advantage (LEA) for differences from -9 to -21 dB. It was concluded that the right ear advantage in dichotic listening withstands an interaural intensity difference of -9 dB before yielding to a significant left ear advantage.

Roeser, John and Prince (1972) tested 32 dichotic digits at intensity level of 10, 30, 50, 70 dB SL w.r.t SRT and found fewer correct responses at lower intensity levels i.e. at 10 dB SL. Also right-left difference did not vary as a function of Intensity.

2) *frequency*

When two different auditory signals are presented simultaneously, one to each ear one of them is usually perceived as having a greater perceptual salience than the other. There are two main type of such asymmetry. The first asymmetry is because of left hemisphere dominance for the processing of speech sounds and is called the right ear advantage (REA) for speech (Kimura, 1961). The second type of auditory perceptual asymmetry arises when two dichotic signals are relative close in frequency (Efron & Yund, 1976). Ear dominance for pitch is independent of handedness as well as of the ear advantage observed with dichotic speech sounds (Yund & Efron, 1977). On the other hand, ear dominance is correlated with a difference in the frequency resolving power of two ears (Divenyl, Efron &Yund, 1977). The dichotomy between the two ears in perception to verbal and non-verbal inputs is not unequivocal. It has been shown that subjects attending to non-verbal properties (pitch or loudness variation) of dichotic verbal input reported better from the left ear than from the right ear (Nachshon, 1970; Spellacy & Blumstein, 1970). Since one of the important features of verbal material is its sequential character, it can be assumed that sequential patter non-verbal information will be mediated by left hemisphere (Helprin, Nachshon & Carmon, 1973). Kimura (1967) reported a significantly greater number of accurate identification from the left ear than right ear in an identification task of dichotically presented melodies in twenty normal hearing subjects.

3) *Temporal effect/ lag effect*

When normal hearing listeners are stimulated dichotically with speech material, there is a right ear advantage observed. However, when the stimuli are presented to the ear at onset time asynchronies of approximately 30 to 90 msec the lagging member of pair is perceived more accurately than the stimuli presented first. Gelfand, Hoffman, Waltzman and Piper (1980) studied the lag effect on dichotic listening task in 24 young adults (17-28 years) and in 24 elderly subjects (28-60 years). Result indicated that both of the groups were not similar. The left ear scores of the young group increased for the 30 ms left-lagging condition, and right ear performance improved for the 30 ms right-lagging condition. Beyond 30 ms, the score for both ear improved with offset in either direction. In elderly population both right and left ear scores improved with lag in either direction. The left ear scores increased at a faster rate than right ear scores, regardless of the direction of lag. Mirabile, Porter, Hughes and Berlin (1979) did a study on 7-15 year age children to identify simultaneous and time-staggered dichotic CV stimuli at 5 onset asynchronies: 0, 15, 30, 60 and 90 msec. For simultaneous presentation there was right ear advantage and improvement in performance with age. For lag time, performance increases as asynchrony were increased and this was more for younger males than females. Prachi and Yathiraj (2000) showed higher right ear scores than left ear at 0 msec or delayed at 30 msec or 90 msec lag for young adult within the age range of 18-30 years using dichotic CV test. Krishna and Yathiraj (2001a) also found right ear advantage for 0, 30 and 90 msec lag time for children between 7-11 years of age in dichotic CV task.

4) Phonetic effect

The better perception of one consonant compared with the other consonant is called the “phonetic effect or stimulus dominance”. Some consonants seem to elicit a better REA compared to other components.

a. Voiced Vs. voiceless consonant

There are several studies in the literature comparing the differential effect of voiced and voiceless consonant on dichotic perception. Berlin, Hughes and Berlin (1973) reported that higher scores for voiceless stops |pa|, |ta|, |ka| than for voiced stops |ba|, |da|, |ga| in pairs of natural syllables contrasting in voicing. The findings were supported by Roser, John and Prince (1972); Niccum, Rubens and Speaks (1981). Rajagopal, Ganguly and Yathiraj (1996) reported that regardless of ear of presentation, the voiceless syllables are reported correctly when compared to the voiced syllables.

Repp (1976) studied the effect of variation in voice onset time (VOT) on the perception of dichotic CV syllables contrasting in voicing features. Variation in VOT had a systematic effect on the probability of hearing the fused stimuli as voiced or voiceless sounds, changing the VOT of the voiceless stimuli had a larger effect than changing the VOT of a voiced stimulus. Rimol, Eichele and Hugdahl (2006) investigated 89 subjects with normal hearing and found the effect of voice-onset-time (VOT) in dichotic listening with consonant-vowel (CV) syllables. The results showed that syllable pairs with long VOT presented in the right ear and short VOT simultaneously presented in the left ear, produced the largest REA followed by the long-long (LL) and short-short (SS) conditions. The long-short (LS) condition produced a significant left-ear-advantage (LEA). These results demonstrate that VOT significantly affects ear-advantage.

b. Place of articulation

Studies have revealed that velars consonant were more often perceived better than alveolars, which in turn are reported more correctly than labials. (i.e. velar > alveolar > labials (Porter, Trondle & Berlin, 1976; Speaks, Niccum & Tasell, 1985). Rajgopal, Ganguly and Yathiraj (1996) found similar results in study where velars best perceived followed by labials and alveolar. Voyer and Techentin (2009) investigated the place of articulation in stop CV syllable pairs in dichotic listening task and the results indicated that the presence of right ear advantage, which varied in such a way that location of the velar syllable typically produced better performance compare to non-velar sounds.

c. Vowels and consonants

Most of the studies show little or no REA for vowels(Darwin, 1969; Studdert-Kennedy & Shank-Weiler, 1970). Weiss and House (1973) dichotically presented 10 vowels (American) in CVC syllable where the consonant was kept constant and vowels were varied. The vowels were classified into long vowel and short vowel. Results showed that REA was better for long vowels compared to short vowels. Studies have been done on different positions of the consonants. Troast, Shewan, Nathanson and Samt (1968) reported equal REA for initial and final consonant in natural CVC syllables. In contrast to this study, Darwin (1969) reported stronger REA for final consonants position when presented dichotically. Studdert-Kennedy and Shankweiler (1970) also reported strong REA to initial and final consonant of CVC syllables but no REA for vowels.

5) *Effect of masking/signal to noise ratio*

Weiss and House (1973) performed a Dichotic competing vowels task at two Signal to noise ratio (SNR) 0 dB and -10 dB in thirteen subjects. The presentation level was kept at 70 dB SPL. Results revealed that as the SNR becomes poorer, the overall scores reduced and the REA became more pronounced. At favorable SNR ear preference were not apparent. Cullen, Thompson, Hughes, Berlin and Samson (1974) investigated effect of SNR when signal was presented at 60 dB SPL and band limiting noise was introduced with SNR varied from 0 to 30 dB in both channels simultaneously. They found performance decreased with low SNR, but right ear advantage was maintained as long as SNR was varied between two channels with 12 dB SNR difference between channels. This implies the need to balance SNR between 2 channels and a good absolute SNR so as not to obscure REA due to floor or ceiling effect

` Sequeira, Specht, Hamalainen and Hugdahl (2008) addressed background noise effects on the REA, CV-syllables were presented either in silence or with traffic background noise vs. 'babble'. Both 'babble' and traffic noise resulted in a smaller REA compared to the silent condition. The traffic noise, moreover, had a significantly greater negative effect on the REA than the 'babble', caused both by a decreased right ear response as well as an increased left ear response.

6) *Stimulus matreial*

The type of stimuli used in dichotic listening can also have an effect on word recognition performance (Carter & Wilson, 2001; Studdert-Kennedy & Shankweiler, 1970; Takayanagi, Dirks & Moshfegh, 2002; Wilson& Jaffe, 1996). For example, as the number of pairs of digits presented dichotically increases from one to four, recognition performance is largely decreased (Wilson & Jaffe, 1996). Noffsinger, Martinez & Wilson (1994) tested word recognition performance with digits, sentences, and nonsense syllables and found high performance levels for digits and sentences, but more difficulty recognizing nonsense syllables. Furthermore, testing of nonsense syllables in dichotic pairs that differed by only one phoneme showed that a significant REA existed for differences in initial and final stop consonants, but not for vowels (Studdert-Kennedy & Shankweiler, 1970).Obrzut, Bolick and Obrzut (1986) administered four types of dichotic stimuli(words, digits, CV syllables, and melodies) in 12 children(5 male, 7 female; mean age 10.5 years) in three experimental conditions (free recall, directed left, and directed right) to examine perceptual asymmetry as reflected by the right-ear advantage (REA). While REA for words and CV syllables and the LEA for melodies were found under free recall. Directed condition had no REA effect on recall of CV syllables but had a dramatic effect on recall of digits. Word stimuli and directed condition interacted to produce inconsistent perceptual asymmetry while directed condition reduced overall recall for melodies. The findings lend support to the hypothesis that perceptual asymmetries can be strongly influenced by the type of stimulus material used and the effect of attentional strategy employed. Rajgopal, Ganguly and Yathiraj (1996) stated that Dichotic CV test is more difficult task when coupled to dichotic digit test. The performances of subjects were poor on dichotic CV because in dichotic CV the presentation of stimulus is more simultaneous and also CVs are less meaningful than digits and rarely occur in isolation.

Digits are a closed stimulus set, meaning there are a limited number of choices from which the participants can guess. The digits are highly recognizable, as subjects are extremely familiar with these words. In many cases, monosyllabic words are favored over digits, sentences, and consonant-vowel syllables for four important reasons. First, the use of syntactical cues is minimized when using words. Second, monosyllabic words are standardized and commercially available for widespread use. Third, there exists a large database for listeners with normal and impaired hearing. Lastly, monosyllabic words comprise an open stimulus set, unlike digits. This means there are almost endless amount of monosyllabic words that may be used, which limits the participant's ability to guess the correct answer. It is for the previous reasons that Roup, Wiley and Wilson(2006) used monosyllabic words in their dichotic research. The remaining stimulus options are less desirable when performing dichotic listening tests. Too many contextual clues are available when listening to sentences, giving the participant an advantage in performance. In regard to consonant vowel testing, many researchers believe this task is too difficult.

7) *Stimulus familiarity*

Nachshon and Carmon (1975) studied the effect of speech lateralization, stimulus familiarity and their interaction on ear superiority in CV syllables with six consonant (3 familiar) and 4 vowels (2 familiar). Test was done in four contexts, that is, FF, FN, NF, and NN (F– Familiar; N– Not familiar). In FN condition familiar stimulus (vowel or consonant) was given to left ear & the non familiar stimulus was given to right ear. Results revealed that in FF or NN condition consonant showed REA and the recall of vowel are same for both the ears.NF consonant and NF vowels showed stronger right ear superiority due to interaction of familiarity and language effect. This shows strong effect of stimulus familiarity.

Mohr and Costa (1985) examined laterality of ear preference in repeating 2, 3 and 4 word pairs (WP) of dichotic stimuli in English and French in 80 right-handed subjects, and tested in both their native language (L1) and nonnative language (L2). Result indicated that relative performance accuracy decreased as a function of word pairs per trial (from 2 to 4) as well as language (from L1 to L2). Right-lateral preference in turn increased as a function of WP (from 2 to 4) as well as language (L1 to L2). Right-ear advantage (REA) in L2 decreased as a function of language proficiency (low to high). REA was observed in over 90% of subjects. A rationale for greater lateralization of L2 performance is offered. Concerning actual words as opposed to nonsense syllables, divisions between lexically “easy” words and lexically “hard” words demonstrate that “easy” words are identified correctly more often than “hard” words in dichotic word recognition testing (Carter & Wilson, 2001). Making changes in the lexical difficulty of stimuli for speech recognition testing appears to affect every subject, regardless of handedness, age, or level of hearing (Takayanagi, et al., 2002).

Subject related factors

1) *Age*

The effect of age on dichotic listening may be different depending on the type of stimuli used. Dichotic listening test on children suggest that the more linguistic loaded stimuli shows more pronounced maturational effect (Bellis, 1997). Berlin, Lowe-Bell, Cullen, Thompson and Loovis (1973) tested dichotic CVs on 5 to 13 year old normal hearing children. They noted that developmental effects were seen only when subjects were required to repeat both stimulus pairs, and this was attributed to increased channel capacity with increasing age. Jerger, Chmiel, Allen and Wilson (1994) investigated the effect of age and gender on Dichotic Sentence Identification (DSI). They analyzed DSI scores on 356 subjects (203 males and 157 females) from age 9 to 91 years. Results revealed larger REA or left ear deficit, with increasing age.

Gelfand, Hoffman and Waltzman (1980) studied the effect of age on dichotic CV recognition at 0, 30, 60, and 90 msec. onset asynchronies in 24 subject (17 to 28 yrs) and 24 subjects(60-78 yrs). Results showed significant reduction in the total dichotic scores for elderly group. Ear advantage depends on age and linguistic complexity. Studies on elderly subjects reveal a decreased REA with increasing age. Bellis and Wilber (2001) researched the right ear advantage (REA) found in dichotic listening tasks in several age groups. Participants were placed in four groups based on age: 20-25 years, 35-40 years, 55-60 years, and 70-75 years. They found that although an REA was found in all groups, the oldest age group (ages 70-75) exhibited a larger REA than the youngest age group (ages 20-25) - 6% as compared to 2%. Because many older adults possess age-related peripheral hearing loss, it is no surprise that the overall performance of older adults is worse than younger adults. Because the hearing loss is symmetrical bilaterally, only a small REA would be expected due to the use contralateral pathways during dichotic listening tasks. However, the REA in the older adults was significant in size which suggests that it is not the peripheral hearing loss causing a large REA, but rather, a central auditory processing disorder related to age. Interhemispheric transfer is affected by aging in that as adults get older, the corpus callosum suffers many changes. The corpus callosum is responsible for connecting the two hemispheres and acting as a communication line for the brain.

Regishia and Yathiraj (2003) studied the effect of maturation on dichotic test. Subjects taken were 37 males and 37 females within the age range of 7 to 11.11 years and 24 adults from 18 to 25 years. Materials used were dichotic digit test (DDT) and Dichotic CV test (DCVT). Results showed that Developmental trend seen in right ear score (RES), left ear score (LES) and double correct score (DCS). Developmental trend more was evident for DCVT than for DDT as higher DDT scores was seen even in the younger age group. RES matures even after 11 years and no significant difference in the LES across age groups was observed. Krishna and Yathiraj (2001a) studied the normative data for children for DCVT. Subjects were 25 male 25 female in the age range of7-11 years and results showed that scores improve from 7-11 years old.

2) *Gender effects*

According to (Jerger, Chmiel, Allen & Wilson, 1994) as age increases, females show a decrease in performance in the right ear compared to males. On the other hand, females show greater performance than males in the left ear. As a result, older males exhibit a larger right ear advantage than older females due to their better right ear performance and worse left ear performance. Piazza (1980) studied the influence of gender on hemispheric processing in two groups of young adults. Within the study were 8 males and 8 females who participated in dichotic listening tasks, using both verbal and nonverbal stimuli. Research supported that gender of the subject played a role in the lateralization of information to the hemispheres. More specifically, females excelled when processing nonverbal speech stimuli, while males excelled with speech-stimuli. The difference in performance between male and female subjects, however, was small (5.7% vs. 3.1%, respectively).The gender of the subject is an important variable throughout dichotic research. Bellis and Wilber (2001) suggest that there are gender interactions with aging that affect interhemispheric transfer during auditory stimulation for subjects who are middle-aged. For early and late adulthood effects on the auditory evaluation of interhemispheric transfer are small and clinically insignificant.

3) *Attention*

Keith, Tawfik and Katbamna (1985) administered dichotic CV on twenty-five subjects (20 to 36 years of age) by utilizing the directed listening paradigm and free recall instructions. Results indicated that subjects showed right ear advantage in the directed right listening condition, and left ear advantage in directed left listening condition. Free recall listening conditions showed a right ear advantage.

Hiscock, Inch and Kinsbourne (1999) studied dichotic listening in 96 right-handed normal hearing adults who attended selectively to the left and right ear and divided their attention equally between both ears. Participants listened for specified targets and reported the ear of entry. Experiments yielded a right-ear advantage for detection and for localization. Attention instructions had no effect on detection. However, focusing attention on one ear increased the number of targets attributed to that ear while decreasing the number of targets attributed to the opposite ear. Free recall and directed-attention right generally result in an REA in most young and older adult listeners, while directed-attention left generally results in a left-ear advantage or a small REA in most young and older adult listeners (Roup, Willey & Wilson, 2006).

4) *Practice effects*

Porter, Troendle and Berlin (1976) studied practice effects on dichotic listening task using dichotic CV material. They investigated long-term effects of practice on performance by testing once a week over period of eight weeks. Results revealed that a slight increase in double correct scores (28% - 38%), a slight drop in both single correct responses (65% - 58%) and decreased either correct responses (7% - 4%). However, overall dichotic performance does not become a stable measure until subjects have experienced at least 300 dichotic trials.

5) *Response mode*

Jancke (1993) administered dichotic test of monosyllabic CV in 56 right handed males and 50 left handed males. Different response modes speak, write and lastly visual (which were presented onto a monitor screen CV verbal) was utilized. Result suggests that ear advantage scores were not influenced by response mode. Krishna and Yathiraj (2001b) took 10-11 years age children and they performed a dichotic CV test using two response modes (oral and written) and results revealed that REA was not influenced by response mode.

6) Handedness and Dichotic Listening

Dichotic performance of right- and left-handed listeners by Wilson and Leigh (1996) indicated a difference in performance levels on the task. They collected data from 24 right-handed listeners and 24 left-handed listeners using the dichotic consonant-vowel materials. According to the results, both right- and left-handed individuals exhibited a right ear advantage. However, left-handed subjects were more variable in their performance when compared to the right-handed subjects. Right handed subjects identified 72.8% of the stimuli presented to the right ear and 56.5% of the stimuli presented to the left ear, resulting in a 16.3% right-ear advantage. On the other hand, left-handed subjects identified 62.9% of the stimuli presented the right ear and 61.1% of stimuli presented to the left ear, resulting in only a 1.8% right-ear advantage.

Dichotic listening test in clinical population

Peripheral hearing loss

Fifer, Jerger, Berlin, Tobey and Campbell (1983) administered dichotic sentence test to fourteen normal hearing listeners and fourty eight hearing-impaired subjects to determine the influence of peripheral hearing loss on test performance and found that Dichotic Sentence Identification test is resistant to the influence of peripheral hearing loss until the pure tone average of 500, 1000, and 2000 Hz exceeds approximately 50 dB. Speaks, Niccum, and Tasell (1985) administered four Dichotic listening test: digits, vowel words, consonant words, and CV nonsense syllables on twenty seven patients with sensorineural hearing loss. Reliable differences among left-ear scores, right-ear scores, performance level, and the ear advantage were observed among the four tests. The digit test appeared to be most promising for assessing central auditory function when the patient had a sensorineural hearing loss because performance for the digits was only slightly affected by the peripheral hearing loss. Niccum, Speaks, Katsuki-Nakamura and Tasell (1987) found conditions under which simulated conductive hearing loss (insertion of EAR plugs) would affect performance on a digit dichotic test. Performance for left ear plugged and right ear plugged conditions was compared with performance in a normal hearing condition. Conductive hearing losses did not affect dichotic performance at test intensities 12 dB above the "knees" of monotic performance-intensity functions for the plugged ears (95% correct points) but did affect dichotic performance for some listeners at intensities that were within 8 dB of the monotic knees.

Temporal lobectomy

Berlin, Lowe-Bell, Jannetta and Kline (1972) examined dichotic listening task (nonsense syllables) from four patients with temporal lobectomies and compared it to hundred normal individuals. First, presented simultaneously then with time separations from 15 to 500 msec. Results showed that with simultaneous onset, normal individuals showed right ear superiority and with time separations of 30 to 90 msec normal’s showed a lag effect. But temporal lobectomy patients showed poorer contralateral ear function than ipsilateral ear function, and no lag effect. Olsen (1983) examined Dichotic Consonant-Vowel (CV) test to 50 normal hearing subjects and patients who underwent removal of the anterior portion of the right or left temporal lobe for control of seizures.

Results analyzed that not all patients with temporal lobe seizures with subsequent temporal lobectomy demonstrated performance below the lower limits of normal established by the sample of normal subjects. Collard et al. (1986) used four dichotic speech tests on 30 patients who were tested before and after temporal lobectomy for control of intractable seizures. Ipsilateral ear scores improved on all tests postoperatively; these improved scores reached statistical significance for the Staggered Spondaic Word test and dichotic consonant-vowel test.

Intracranial lesion

Musiek (1983) assessed Competing Sentences, Staggered Spondaic Words, and Dichotic Digits on 30 adult subjects with intracranial lesions (12 brain stem and 18 hemispheric). Digit test appeared most sensitive, followed by the Staggered Spondaic Word test and Competing Sentence test. All tests demonstrated greater ipsilateral ear deficits for subjects with brain stem lesions. However, for subjects with hemispheric lesions all tests showed generally poorer scores for the ear contralateral to the lesion.

Single functional hemisphere

Stefano, Marano and Viti (2004) evaluated stimulus-dominance and ear asymmetry in 48 normal hearing subjects and 2 patients with a single functional hemisphere. Results showed that in normal the number of stimulus-dominated responses is five times higher than in patients with single function hemisphere, and is negatively correlated to the index of laterality. It is suggested that dichotic stimuli may interfere one with another during the subcortical acoustic processing and at cortical level, when competing for verbal output. Subcortical interference accounts for stimulus-dominance in the single-hemisphere patients.

Cerebral hemispherecotomy

Bode, Sininger, Healy, Mathern and Zaidel (2007) examined two commonly used dichotic listening tests, the consonant–vowel (CV) nonsense syllables and the fused words (FW) tests for who had undergone cerebral hemispherectomy. The results are consistent with the anatomical model of the ear advantage (Kimura, 1961). Most syllables or words are reported for the ear contralateral to the remaining hemisphere, while few or none are reported for the ear ipsilateral to the remaining hemisphere. In competing inputs to the two ears, the stronger contralateral ear-hemisphere connection dominates/suppresses the weaker ipsilateral ear-hemisphere connection. It is seen that the CV test were sensitive to side of resection, higher in the right hemispherectomy than in the left hemispherectomy groups.

Cortical injured

Hughes, Tobey and Miller (1983) tested dichotic temporal order judgment task using speech and non-speech stimuli on thirteen cortically injured young men. Subjects with injuries outside the temporal and frontal lobes performed the dichotic tasks at levels comparable to that of neurologically normal subjects. In contrast, subjects with temporal lobe lesions performed at near chance levels on all of the conditions and frontal lobe damage showed moderate impairment on the dichotic tasks.

Dyslexia

Roeser, Millay and Morrow (1983) assessed dichotic consonant-vowel (CV) syllables /pa/, /ba/, /ta/, /da/, /ka/, and /ga/ with no temporal offsets between channels (+/- 2 msec) and with temporal offsets of 30, 60, and 90 msec between channels in learning disabled children. Data were analyzed for ear asymmetry (right ear advantage), double correct responses (auditory capacity), and the effects of temporal offsets (the lag effect). Thirty two normal children (mean age- 6 year 6 months) were evaluated once each year over a four year period and results showed no significant change in ear laterality over the four year. However, there was a significant, age-related increase in auditory capacity. None of the subject showed a significant lag effect. Seventeen learning disabled children (mean age- 9.3 year) were compared to age and sex matched normal controls group and results failed to show a significant group difference for ear asymmetry, auditory capacity, or the lag effect. Overall, findings indicate that the dichotic CV syllables test has limited prognostic value in identifying auditory processing dysfunction in children classified as having "learning disability". Hugdahl, Helland, Faerevaag, Lyssand and Asbjornsen (1995) studied dichotic CV task on right and left handed dyslexic subjects and compared with an age, sex, and handedness matched control group. Finding was the absence of an expected right-ear advantage (REA) in the right-handed dyslexic group as compared to the right-handed normal readers. Both the dyslexic and normal left-handed groups did not show a REA. Moncrieff and Black (2008) administered dichotic listening tests with digits, words and consonant-vowel (CV) pairs to two groups of right-handed 11-year-old children, one group diagnosed with developmental dyslexia and an age-matched control group. Dyslexic children performed more poorly than controls from their left ears when listening to digits and words and from their right ears when listening to CVs.

Moncrieff and Musiek (2002) assessed the Dichotic Digits test, the Competing Words subtest of the SCAN, and the Dichotic Consonant-Vowel test on normal and dyslexic right-handed children. Only one dichotic listening test, Competing Words from the SCAN, produced a consistent right-ear advantage across all of the children tested. Obrzut, Conard, and Boliek (1989) examined cerebral lateralization of left- and right-handed good readers and left- and right-handed reading disabled sixty children (age from 7-13 years) via a dichotic selective attention task (free recall, directed left, directed right) using consonant-vowel (CV) and tonal stimuli. The expected REA (left hemisphere processing) was found for CV stimuli only by right-handed good readers across all three dichotic conditions. The left-handed good readers and left-handed reading-disabled children were left ear (LE) dominant in free recall and in the directed left condition, but were right ear (RE) dominant in the directed right condition. Conversely, right-handed reading-disabled children produced a REA during free recall and directed right conditions, but were LE dominant in the directed left condition. In contrast, a significant LEA (right hemisphere processing) was found for tonal stimuli across all dichotic conditions for all four groups.

Poor verbal reader

Phillip, Richard and Kerrie (1983) compared a group of good and poor readers on the dichotic CV task. These data was analyzed in terms of a normative model which attempts to show the effects of overall performance and guessing on double correct responses. It was concluded, that the poor double correct performance of the poor readers is the direct result of poor auditory processing capacity.

Psychotic

Malaspina et al., (2000) examined nine healthy control subjects and sixteen schizophrenia patients (8 with normal and 8 with diminished REA). REA-diminished patients had greater positive symptoms and lower mental status scores (all $P<0.05$) and had right middle temporal gyrus hyper metabolism. Both schizophrenia groups had decreased right frontal and increased medial temporal lobe metabolism vs. control subjects. REA-diminished patients had right temporal lobe hyper metabolism under a resting condition (eyes open, visual fixation). Results suggest reduced right ear (left hemisphere) advantage for dichotic word perception in schizophrenia is related to a predisposition to over activate right temporal lobe region. Lishman, Toone, Colbourn, McMeekan and Mance (1978) found that on a dichotic listening test patients who recently recovered from schizophrenic or manic-depressive psychoses showed larger ear difference scores than normal. i.e. when asked to identify dissimilar words fed synchronously to the two ears.

Green, Hugdahl and Mitchell (1994) assessed the functional integration of the left hemisphere in hallucinating and non hallucinating psychotic patients through dichotic consonant-vowel test under three conditions: a non forced attention, forced left ear attention and forced right ear attention. The non hallucinating patients showed the normal right ear advantage. In contrast, the hallucinating patients showed no ear advantage.

Neither group was able to modify its performance when instructed to attend to either the left or the right ear.

Stuttering

Foundas, Corey, Hurley and Heilman (2004) studied dichotic consonant-vowel on individual with persistent developmental stuttering (n = 18) and matched controls (n = 28) in three attention conditions: non-directed attention, attention directed right, and attention directed left. Matched controls and right-handed men who stutter had the expected right-ear advantage (REA) in the non-directed attention condition. In contrast, left-handed men who stutter had a left-ear advantage (LEA), and right-handed women who stutter did not have a lateral ear bias in the non-directed attention condition. Right-handed women who stutter had the greatest tendency to hear a sound that was not presented to either ear, and were relatively unable to selectively direct attention left or right. In contrast, left-handed men who stutter were able to shift attention to the left and right ear better than any other group.

Multiple sclerosis

Jacobson, Deppe and Murray (1983) administered dichotic CV test, Synthetic Sentence Identification (SSI) test, and the Staggered Spondaic Word (SSW) test on twenty "definite" multiple sclerosis patients. Test results were variable, with the higher percentage of abnormalities obtained with the CV test, followed by the SSI, and finally the SSW.

Clinical Implications

Research involving dichotic word recognition performance has clinical implications. Dichotic listening tests can be used in the assessment of auditory processing disorder in children and in other clinical population like aphasia (Bouma & Ansink, 1988), demyelinating disorders (Rao et al., 1989), primary degenerative dementia (Mohr, Cox, Williams, Chase & Fedio, 1990) and closed head injury (Levin et al., 1989). It is also helpful in deciding about the hearing aids in elderly individuals with hearing loss. It can be demonstrated that some older adults have an auditory processing disorder resulting in a larger than expected right ear advantage, monaural amplification rather than binaural amplification might be more appropriate (Carter, Noe & Wilson, 2001). Monaural amplification could be advantageous for these individuals because it would allow them to process information through their "stronger" right ear without potentially distracting information from their left ear. They tested word-recognition performance using both monaural and binaural amplification in older adults with bilateral hearing loss. Results revealed better performance with monaural right-ear amplification due to left-ear processing deficits. In patients experiencing an auditory processing disorder, monaural amplification may be the best option, despite a binaural peripheral hearing loss.

Chapter- 3

METHOD

The aim of the study was to develop and establish preliminary data for dichotic word test in Hindi speaking children. This study was carried out in two phases:

I- Development of test stimuli for Dichotic word test in Hindi language.

II- Establishing the preliminary data for Dichotic word test in Hindi language across different age groups.

I- Development of test stimuli

Selection of words

Around 800 monosyllabic words were collected from children's text book, magazine, day to day conversation and dictionary. The familiarity of these words were checked by administering it on Hindi speakers (Twelve adults and six children) who were asked to rate these words on five point rating scale.

I- I do not know the word

II- I know the word but not the meaning of the word

III- I know both word and meaning, but do not use the word

IV- I know both word and meaning and use the word occasionally

V- I know both word and meaning and use the word frequently

The words which were rated as "V" were selected for the recording.

Recording of words

Words were recorded on data acquisition system with a 16 bit analogue to digital convertor at a sampling frequency of 44.1 KHz by 5 native Hindi female speakers in an acoustically treated room. All five recordings were given to five experienced audiologists (native Hindi speakers) to choose the best recoding in terms of intelligibility, rate of speech and clear articulation. The elicitation and scaling of selected recording test material was done using Adobe audition (version 3.0) software to ensure that the intensity for all the words was same.

Preparation of dichotic word pairs

Duration of all recorded words was calculated and paired in such a way that onset and offset of stimulus coincides. Maximum difference in duration of each word in pair was not kept greater than 10 ms as guidance by (Lamm, Share, Shatil & Epstein, 1999).Two different lists of dichotic word pairs consisting of 3 practice word pairs and followed by 20 test word pairs were formed. In 20 test word pair the 20 word goes to the right ear and the same 20 word goes to the left ear but in each pair the two words which goes to the right and left ear were not the same. As per the guidelines given by Roup, Wiley & Wilson (2006) care was also taken that the two words in a pair never had same starting phoneme and same vowel. Inter stimulus interval of 10 second was given in between word pairs for response time. Specific instruction was recorded in both channels 5 second before the beginning of each list. A 60 Second 1000 Hz calibration tone was recorded at the beginning of the compact disc at a level equal to the average intensity of the words.

Recording of dichotic word test on a compact disc

Two lists of 23 pair of words were recorded in a compact disc in two different channels in such a way that one word goes to the right ear and the other to left ear simultaneously.

II- Establishing the preliminary data for Dichotic word test in Hindi language

Subject

Data was collected from 90native Hindi speaking children (45 boys and 45 girls) in the age range 7-12 years. These subjects were divided into five groups with each group having 9 boys and 9 girls.

I. 7 years - 7 year 11 months

II. 8 years - 8 year 11 months

III. 9 years - 9 year 11 months

IV. 10 years - 10 year 11 months

V. 11 years - 11 year 11 months

Class teacher assisted in identifying children having language and behavior problems and based on their observation these children were excluded from the study.

Subject selection criteria

Subjects required to fulfill the following criteria:

- All subjects should be right handed. To confirm right handedness, the laterality preference schedule which is a part of *Functional Neuropsychological Assessment*

Battery (Venkatesan, 2011) was used. If the child response like he/she able to do more than 50% work (out of 30 questions) through right hand, foot, eye and ear then he/she was taken as a subject.

- Should pass the Screening Checklist for Auditory Processing (SCAP) developed by Yathiraj and Mascarenhas (2003).This checklist has 12 questions. It was administered to rule out any kind of auditory processing deficit. Children who scored less than 50% (6 out of 12) were considered for this study.
- No history of hearing loss, ear disease, trauma, ototoxic drug intake and/or ear operation.
- Bilateral normal hearing sensitivity in the frequency from 250 Hz to 8000 Hz for air conduction and 250 Hz to 4000 Hz for bone conduction. Pure tone threshold were obtained by using modified version of Hughson and Westlake procedure (Carhart & Jerger, 1959).
- Speech recognition threshold should be ±12 dB (re: PTA 0.5, 1 & 2 kHz) in both ears. It was obtained by using the Hindi spondee word list at 20 dB SL (re: PTA) spondee were presented and the children were asked to repeat the spondees. The minimum intensity at which the children were able to correctly repeat two out of three spondees was considered as speech recognition thresholds.
- Speech identification scores should be more than or equal to 90% at 40 dB SL (re: SRT) in both ears. It was carried out at 40 dB SL (re: SRT) using the monosyllabic words in Hindi (developed by De, 1973). Children were asked to repeat the words presented through headphones. Each correct response was given

a score of 5%. The total correct response was calculated and termed as speech identification score.

- Bilateral ‘A’- type tympanogram and acoustic reflex (ipsilateral and contralateral) present in both ears to ensure normal middle ear functioning. During this testing children were made to sit comfortably and asked not to swallow. Tympanometry was carried out with 226 Hz probe tone and ipsilateral and contralateral acoustic reflex were obtained at 500, 1000, 2000 and 4000 Hz.
- No illness on the day of testing that might affect the hearing and overall performance.
- No neurological problems
- Subjects should not have previous experience of dichotic listening task.

Testing environment

All the evaluations were carried out in an acoustically treated two-room situation as per ANSI S 3.1 (1991).

Instrumentation

- A calibrated dual channel MA-53 audiometer coupled with acoustically matched MAICO headphone and radio ear B-71 bone vibrator was used to estimate pure tone threshold, speech recognition threshold and speech identification scores.
- A calibrated Intra acoustic AT-235 immittance meter coupled with Telephonic TDH-39P headphone was used for obtaining tympanogram and acoustic reflex threshold.

- A laptop with adobe audition (version 3.0) software was used to record and present the developed test material.

Administration of developed Dichotic word test

Dichotic word test stimuli were presented through laptop connected to the calibrated MA-53 dual channel audiometer. Daily listening check of the equipment was done at the beginning of each test session to ensure appropriate routing of signals, and appropriate channel. Intensity was set at most comfortable level (40 dB SL re: SRT). Each subject was asked to listen to the instructions for dichotic word task recorded before each set of dichotic word list on compact disc. Instruction given was: "You will hear two words simultaneously on to both ears. You should repeat both the words that you hear. You may repeat word from any ear first". For task understanding the trial words were presented before the test words. In this study verbal response were taken from all children and tester marked "√"for the correct response on the dichotic word test data sheet.

Score calculation of dichotic word test

Each subject's response was recorded in the scoring form. The right ear score, left ear score and double correct score were calculated for both the list. A correct response was considered for each word that was repeated correctly. A score of one was given to each correct pair and also each correct word. Three practice item word pairs were not considered in the testing score. The right ear scores were calculated by total number of correctly repeated words in the right ear and same way left ear scores were calculated. Double correct scores were calculated through total number of word pair correctly repeated by the subject in any order.

Analysis

Mean and standard deviation for Right ear score (RES), Left ear score (LES), and Ear advantage (EA) for each test condition was calculated. All the statistical analysis was performed using Statistical Package for the Social Science (SPSS) version 17.0 software.

Chapter- 4

RESULTS AND DISCUSSION

The current study was carried out to develop dichotic word test in Hindi and to have a preliminary data for the developed test. This test has two different lists of single word pairs consisting of 3 practice word pairs and 20 test word pairs which were administered on five groups of children from 7 to 11.11 years. Each group had 18 participants with equal number of males and females. The data collected was subjected to statistical analysis using Statistical Package for the Social Science (SPSS) version 17.0 software. The following statistical analyses were carried out to analyze the data:

1) Descriptive statistics was done to find out the mean and standard deviation for lists, ear and gender across all age groups.
2) Mixed analysis of variance (ANOVA) was done to investigate overall list, gender and age effect for right correct scores, left correct scores and double correct scores and ear effect for single correct scores.
3) Multivariate analysis of variance (MANOVA) was done to evaluate the age effect within each list.
4) Paired t- test was done to investigate the ear effect and the list effect within subjects.
5) Duncan's Post hoc analysis was done to find out significant differences in scores across the age groups.

List effect

The mean and standard deviation (SD) for single correct scores (right and left) and double correct scores were obtained for the two lists across five age groups (7-11.11 year) as represented in Table 1.

Table 1. *Descriptive statistics for single and double correct scores for both lists*

Age group (Years)		**Right correct score**		**Left correct score**		**Double correct score**	
		List I	List II	List I	List II	List I	List II
7-7.11	Mean	10.44	10.78	6.55	6.50	2.28	2.39
	SD	1.82	1.93	1.46	2.09	1.71	1.38
8-8.11	Mean	11.44	11.33	8.39	8.28	3.83	3.50
	SD	1.24	1.85	1.29	2.70	2.25	1.95
9-9.11	Mean	12.94	13.11	9.33	9.28	6.00	6.06
	SD	1.55	1.53	1.71	1.99	1.19	1.00
10-10.11	Mean	15.44	15.67	12.44	12.39	9.50	9.50
	SD	1.38	1.24	1.92	1.29	1.62	1.15
11-11.11	Mean	17.05	16.94	15.06	15.28	13.33	13.61
	SD	1.26	1.10	1.11	1.81	1.18	1.79

From Table 1, it can be seen that there is minimal difference in the mean values for the right ear correct scores, left ear correct scores and double correct scores for the two lists. Mixed ANOVA was carried out to see the overall list effect. Mixed ANOVA results showed no significant effect on lists for single correct scores [F (1, 80) = 0.05, p>0.05] and double correct scores [F (1, 80) = 0.01, p>0.05]. Paired 't' test was done to evaluate the difference in scores between two lists across five age groups. Results of the paired 't' test are shown in Table 2.

Table 2. *'t' value, and its significance between the two lists across age groups.*

Age (years)	Dependent variables	t- value '17'	Sig. (2tailed)
7-7.11	RCS I – RCS II	0.64	P>0.05
	LCS I – LCS II	0.10	P>0.05
	DCS I – DCS II	0.24	P>0.05
8-8.11	RCS I – RCS II	0.22	P>0.05
	LCS I – LCS II	0.14	P>0.05
	DCS I – DCS II	0.61	P>0.05
9-9.11	RCS I – RCS II	0.48	P>0.05
	LCS I – LCS II	0.11	P>0.05
	DCS I – DCS II	0.25	P>0.05
10-10.11	RCS I – RCS II	0.54	P>0.05
	LCS I – LCS II	0.09	P>0.05
	DCS I – DCS II	0.00	P>0.05
11-11.11	RCS I – RCS II	0.29	P>0.05
	LCS I – LCS II	0.38	P>0.05
	DCS I – DCS II	0.47	P>0.05

Note: RCS I- Right correct score for list I; RCS II- Right correct score for list II

LCS I- Left correct score for list I; LCS II- Left correct score for list II

DCS I- Double correct score for list I; DCS II- Double correct score for list II

From Table 2, it is evident that the paired ‘t’ test did not show significant difference between two lists for right, left and double correct scores. This was same for all five age groups which indicates that when the two words are presented in two different channels at 0 ms lag time it does not alter the performance of the subjects between the lists. Hence it can be concluded that both lists are equal in difficulty level and so either of the list can be used for clinical purpose.

Gender effect

Mean and standard deviation for males and females across the two lists for all the five age groups were calculated and are tabulated in Table 3 and 4.

Table 3. *Mean and standard deviation (SD) of right, left and double correct scores for males and females across age groups for list I*

Age group (year)	Gender	List I					
		RCS		**LCS**		**DCS**	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
7-7.11	**M**	10.33	1.66	6.33	1.58	2.44	1.33
	F	10.55	2.07	6.78	1.39	2.11	2.09
8-8.11	**M**	11.78	1.30	8.33	1.58	3.78	2.33
	F	11.11	1.17	8.44	1.01	3.89	2.31
9-9.11	**M**	13.00	1.41	9.22	2.11	5.89	1.16
	F	12.89	1.76	9.44	1.33	6.11	1.27
10-10.11	**M**	15.55	1.67	12.33	2.34	9.44	2.13
	F	15.33	1.12	12.56	1.51	9.56	1.01
11-11.11	**M**	17.00	1.00	15.00	0.71	13.22	0.83
	F	17.11	1.54	15.11	1.45	13.44	1.51

Table 4. *Mean and standard deviation (SD) of right, left and double correct score for males and females across age groups for list II*

Age group (year)	Gender	List II					
		RCS		LCS		DCS	
		Mean	SD	Mean	SD	Mean	SD
7-7.11	M	10.67	1.41	6.11	2.84	2.56	1.74
	F	10.89	2.42	6.89	0.93	2.22	0.97
8-8.11	M	11.11	2.08	8.44	3.09	3.56	2.60
	F	11.56	1.67	8.11	2.42	3.44	1.13
9-9.11	M	13.11	1.27	9.22	2.11	6.11	1.05
	F	13.11	1.83	9.33	2.00	6.00	1.00
10-10.11	M	15.66	1.22	12.11	1.54	9.33	1.32
	F	15.67	1.32	12.67	1.00	9.67	1.00
11-11.11	M	16.67	1.00	15.00	1.22	13.44	1.13
	F	17.22	1.20	15.56	2.29	13.78	2.33

Note: RCS- Right correct score; LCS- Left correct score; DCS- Double correct score, M-Male; F- Female.

From Table 3 and 4, it can be seen that mean scores for males and females are almost similar for right, left and double correct scores across all the five age groups for both the lists. The mixed ANOVA was done to find out the overall effect of gender. Results revealed no significant differences in gender for single correct scores [F (1, 80) = 0.68, p>0.05]   as well as double correct scores[F (1, 80) = 0.18, p>0.05]

The present study reveals that there is no significant difference between the performance of male and female across age groups and for each list of the dichotic word test. This is in congruence with the previous studies done by Roberts et al., (1994) and Meyers, Roberts, Bayless, Volkert and Evitts (2002) on dichotic word test. Bellis and Wilber (2001) administered dichotic listening test of consonant-vowel in adult and reported that no gender effect was seen.

However there are studies in literature showing that language performance is better in females than males, even in children as young as 2 to 3 years (Dionne, Dale, Boivin & Plomin, 2003). Girl aged 1 to 5 years are more proficient in language skills, produce larger utterences, and have more vocabularies than boys (Ruble& Martin, 1998; cited in Plotnik, 1999) and these advantages persist even through the school years for verbal and written language (Lynn, 1992). Though, gender difference favors female but the difference is relatively small so it has little practical significance (Hyde, 1994; cited in Plotnik, 1999). Gender effects on the auditory evaluation of inter-hemispheric transfer are small and clinically insignificant (Bellis & Wilber, 2001).Hence, it can be concluded that boys and girls in the range of 7 to 12 years develop in similar manner for binaural integration task.

Age effect

There was no significant difference in the mean scores of males and females so the data of both the gender were combined to see the overall age effect for both the lists. The mean and standard deviation across the age groups for both the list is tabulated.

Table 5.*Mean, standard deviation (SD) and range across the age groups for both lists*

Age group (Years)		**List I**			**List II**		
		RCS	**LCS**	**DCS**	**RCS**	**LCS**	**DCS**
7-7.11	**Mean**	10.44	6.55	2.28	10.78	6.50	2.39
	SD	1.82	1.46	1.71	1.93	2.09	1.38
	Range	7 - 14	4 – 9	0 – 6	8 - 14	2 – 11	0 - 5
8-8.11	**Mean**	11.44	8.39	3.83	11.33	8.28	3.50
	SD	1.24	1.29	2.25	1.85	2.70	1.95
	Range	11 - 14	6 – 11	0 – 7	8 - 15	4 – 13	0 - 5
9-9.11	**Mean**	12.94	9.33	6.00	13.11	9.28	6.06
	SD	1.55	1.71	1.19	1.53	1.99	1.00
	Range	10 - 15	7 – 13	4 – 8	9 - 15	6 – 13	4 - 7
10-10.11	**Mean**	15.44	12.44	9.50	15.67	12.39	9.50
	SD	1.38	1.92	1.62	1.24	1.29	1.15
	Range	13 - 18	7 – 15	6 – 12	13 - 18	10 – 14	7 - 11
11-11.11	**Mean**	17.05	15.06	13.33	16.94	15.28	13.61
	SD	1.26	1.11	1.18	1.10	1.81	1.79
	Range	15 - 19	12 – 17	11 – 16	15 - 19	12 – 19	10 - 18

Note: RCS- Right correct score; LCS- Left correct score; DCS- Double correct score

From Table 5, it is evident that mean scores for right correct scores, left correct scores and double correct scores increased as the age increases. The right ear scores are greater compared to left ear scores and double correct scores indicating right ear advantage in both the list. It can also be seen that mean double correct scores are lesser for all the age groups compared to single correct scores.

Figure 1 indicates that the mean right ear correct score, mean left ear score and mean double correct score increased as the age increases from 7 to 11.11 years for list I and the mean value for double correct scores is much lesser compared to right ear correct score and left ear correct score.

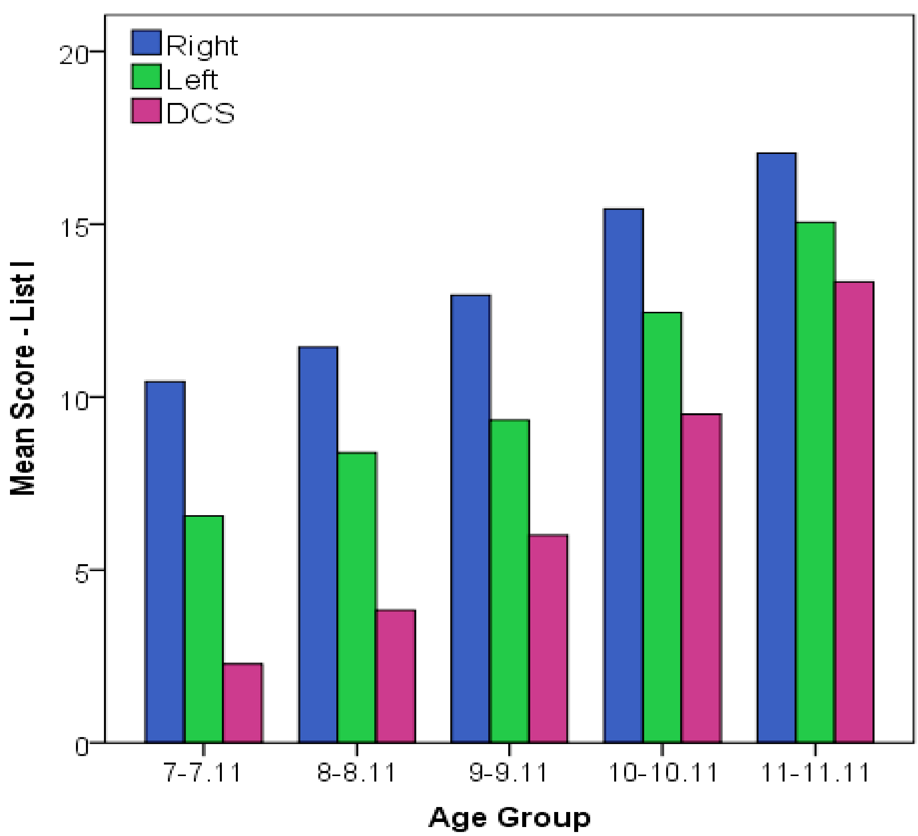

Figure 1: Mean of right ear correct score, left ear correct score and double correct score across the five age groups for list I.

For list II similar trend was seen as shown in figure 2. The mean of right, left and double correct scores increased as age increases.

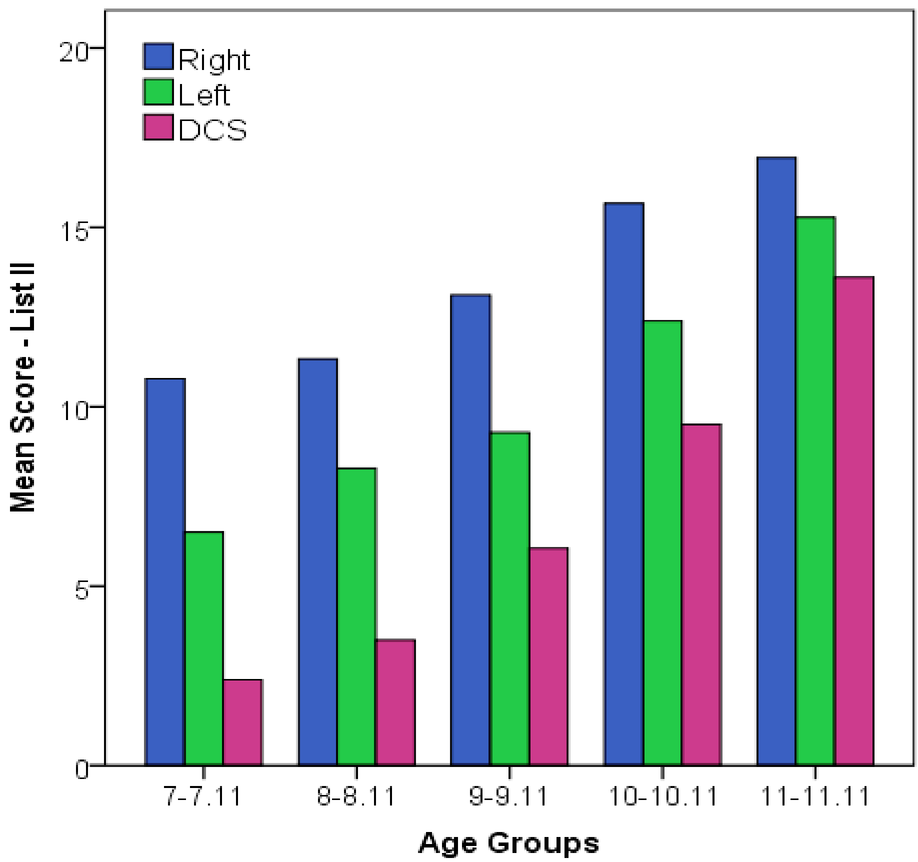

Figure 2: Mean of right ear correct score, left ear correct score and double correct score across the five age groups for list II.

Mixed ANOVA was done to evaluate overall significant difference between the groups. Mixed ANOVA results revealed significant effect of age group [F (4, 80) = 185.27, p<0.01] for single correct scores. There was also significant interaction between ear and age groups [F (4, 80) = 5.63, p>0.05]. However, there was no statistically significant interaction seen between age group and gender [F (4, 80) = 0.22, p>0.05], age group and list [F (4, 80) = 0.04, p>0.05], age group, list and gender [F (4, 80) = 0.03, p>0.05], ear, age group and gender [F (4, 80) = 0.10, p>0.05], list, ear and age group [F (4, 80) = 0.21, p>0.05] and list, ear, gender and age group [F (4, 80) = 0.36, p>0.05]. Similarly for double correct scores, there was a significant difference seen for the age group [F (4, 80) = 251.39, p<0.01]. However, there was no statistically significant interaction seen between age group and gender [F (4, 80) = 0.18, p>0.05], age group and list [F (4, 80) = 0.20, p>0.05] and age group, list and gender [F (4, 80) = 0.05, p>0.05] for the double correct score.

Further investigation was done though MANOVA to see the significant difference in the different age groups within these two lists. Results revealed significant difference across the age groups for right ear correct scores [F (4, 85) = 63.23, p<0.01], left ear correct scores [F (4, 85) = 88.44, p<0.01] and double correct score [F (4, 85) = 133.32, p<0.01] for list I and right correct scores [F (4, 85) = 52.99, p<0.01], left correct score [F (4, 85) = 53.29, p<0.01] and double correct scores [F (4, 85) = 169.39, p<0.01] for list II. Duncan’s Post-hoc analysis was done within the age groups, to find out which of the groups are significantly different. Except for the left ear scores of second (8 – 8.11 year) and third (9 – 9.11 year) groups it showed significant differences across all the age groups at 95% of the confidence level for right correct scores, left correct scores and double correct scores for list I. Duncan’s post hoc analysis of list II showed significant differences across all the age groups at 95% of the confidence level for right correct scores, left correct scores and double correct scores except right correct scores of first (7 – 7.11 year) and second (8 – 8.11 year) group and left correct score of second (8 – 8.11 year) and third (9 – 9.11 year) group.

Present study indicates that as age increases the scores improved and this could be due to the differential myelination of the sub-cortical structure from the cortical structures. Yakovelev and Lecousis (1967) reported that dichotic listening performance do not reach adult values till around 10 to 11 years of age. The functional development time is consistent with the myelination time course. However, corpus callosum and certain auditory association areas may not have completed myelinogenesis until 10 to 12 years or older (Salamy, Mendelson, Tooley& Chapline, 1980). Hayakawa et al., (1989) reported that corpus callosum becomes adult like by the age of 11-12 years, whereas Johnson, Farnsworth, Pinkston, Bigler and Blatter (1994) reported that growth and efficiency of corpus callosum increases till early adult years. Pujal, Vendrell, Junque, Marti-Vilalta and Capdevila (1993) reported that corpus callosum is the last structure to be fully developed and to show the age related changes. Due to incomplete maturation of corpus callosum and delay in myelination of higher cortical structures, there is not much information passed to the higher level and hence score may be reduced in the lower age group for dichotic listening task. As age increases, the myelination of the cortical structure especially corpus callosum gets completed and the scores of the dichotic listening increases.

Poor left ear performance in dichotic listening task in children may reflect a decrease ability of the corpus callosum to transfer complex stimuli from the right hemisphere to the left hemisphere. As age increases myelination of the corpus callosum is completed, the inter-hemispheric transfer of information improves and left ear scores approach to those found in adults (Musiek, Gollegly, & Baran, 1984).

Berlin, Hughes, Lowe-Bell and Berlin (1973) reported that when CV stimuli presented to both the right and left ear the single and double correct scores increased significantly with age, which suggests an increase in the brain's ability to process two channel stimuli as function of age. Similar finding were seen by Willeford and Burleigh (1994) who used sentence material which were presented dichotically. However, ear advantage varies with the type of stimuli used in the above two studies.

Possible explanation for these findings is that CV nonsense syllable are less linguistically loaded than sentences. So, processing demand on two hemispheric and inter-hemispheric connections would be less complex. In contrast dichotic sentences are more linguistic loaded so require more inter-hemispheric communication via corpus callosum as well as integrity of both temporal lobes (Bellis, 1996). But dichotic words are an open stimulus set that may result in recognition performance in the middle of the difficulty continuum that is neither too easy (like the CV) nor too difficult (like sentences), yet sensitive to performance difference between ear and groups (Roup, Wiley & Wilson, 2006).

Ear effect

The mean and standard deviation (SD) for right and left ear scores across the five age groups for both the list are tabulated in Table 1. From Table 1, it can be inferred that mean scores of right ear was greater than that of left ear in both the list across all five age groups. Mixed ANOVA was done to find out the difference in score across two ears for both lists. Results showed significant difference in scores between right and left ears [$F(1, 80) = 383.93$, $p<0.01$] for both the list. Paired t test was done to find out difference in the scores between the two ears across five age groups for both the lists. Paired t test results revealed a significant difference between the right ear scores and left ear scores for all the five age group in both list as evident in Table 6.

Table 6. *Paired 't' test showing 't' value, and its significant differences across two ears*

Age (years)	**Dependent variables**	**Mean differences**	**t- value '17'**	**Sig.(2 tailed)**
7 – 7.11	RCS I – LCS I	3.89	7.34	P < 0.01
	RCS II – LCS II	4.28	7.50	P < 0.01
8 – 8.11	RCS I – LCS I	3.05	7.08	P < 0.01
	RCS II– LCS II	3.06	4.98	P < 0.01
9 – 9.11	RCS I – LCS I	3.61	8.42	P < 0.01
	RCS II – LCS II	3.83	8.35	P < 0.01
10 – 10.11	RCS I – LCS I	3.00	4.64	P < 0.01
	RCS II – LCS II	3.28	11.33	P < 0.01
11 – 11.11	RCS I – LCS I	1.99	9.35	P < 0.01
	RCS II – LCS II	1.66	6.52	P < 0.01

Note: RCS I- Right correct score for list I; RCS II- Right correct score for list II

LCS I- Left correct score for list I; LCS II- Left correct score for list II

The presence of right ear advantage as seen in the present study is supported by the earlier reported literature (Musiek et al., 1989). Berlin, Lowe-bell, Cullen, Thompson and Loovis (1973) reported that dichotic CV had higher right ear advantage where as

Willeford and Burleigh (1994) reported that dichotic sentence gave greater right ear advantage which reduces as the age increases. Right ear advantage in dichotic listening task was postulated by Kimura's structural model (Kimura, 1967). This model postulated that, it is the bilaterally asymmetry in brain function as a stimulus type which give rise to the right ear advantage. Hugdhal (2005) said that the contralateral ascending auditory system consist more fibers and is consequently stronger leading to more cortical activity than the ipsilateral projection. Also, left hemisphere is dominant for speech in most cases which explains the right ear advantage (Rasmussen &Milner, 1977). Right ear advantage occurs in dichotic listening task because of stronger activity in the contralateral system which inhibits the ipsilateral side processing (Yasin, 2007).

Chapter- 5

SUMMARY AND CONCLUSIONS

Dichotic listening tests are among the most powerful of the behavioral auditory processing test battery for the assessment of hemispheric function, interhemispheric transfer of information, development and maturation of the auditory nervous system, and the identification of lesion of the central auditory nervous system (Keith & Anderson, 2007). In this, the two ears are stimulated simultaneously with different speech sounds (Hugdahl, 1995) and the subject is asked to report what is being heard, either in both ears (free recall) or in one of the ears, either left or right (directed attention) (Bellis, 1996). Commonly used speech stimuli for dichotic testing are consonant-vowel (CV) nonsense syllables, digits, words, spondees, and sentences (Keith & Anderson, 2007). Among these sentences have many contextual cues which will be useful for the participant in dichotic listening tasks, compare to consonant-vowel stimuli. Hence, dichotic CV's are considered to be more difficult than sentences (Niccum, Rubens& Speaks, 1981). However, for monosyllabic words syntactical cues are limited, standardized words lists are easily available and frequently used, and an open-set stimulus makes them neither too easy nor too difficult which results in recognition performance in the middle of the difficulty continuum (Roup, Wiley & Wilson, 2006).

Present study was taken up with the aim of developing preliminary data for dichotic word (CVC) test in Hindi language. The test consists of monosyllabic words which were familiar for children within the age range of 7 years to 12 years. These monosyllabic words were paired in such a way that they differed in initial syllable and two words in a pair never had same starting phoneme and same vowel (Roup, Wiley & Wilson, 2006).These paired words were then aligned and imposed on a stereo track in such a way that they were played simultaneously in to both ears with duration difference between the pair of words was not kept greater than 10 ms (Lamm, Share, Shatil & Epstein, 1999). The test stimuli consisted of two lists of 23 monosyllabic word pairs, with three being trial pair words.

Data was collected from 90 native Hindi speaking children (45 boys and 45 girls) in the age range of 7 - 11.11 years. These subjects were divided into five groups with each group having 9 boys and 9 girls. Prior to administration of dichotic word test children were tested with routine audiometric testing (Pure tone audiometry, Speech recognition threshold, Speech identification scores & Immittance evaluation), and Screening Checklist for Auditory Processing (SCAP) (Yathiraj & Mascarenhas, 2003) to ensure normal auditory functioning. Laterality Preference Schedule (Venkatesan, 2011) was also administered to ensure right handedness in subjects.

Responses were recorded as single correct scores (right & left ear) and double correct scores. Raw data was subjected to statistical analysis using Statistical Package for the Social Science (SPSS) version 17.0 software. Descriptive statistics, ANOVA, MANOVA, paired t test and Duncan's Post hoc analysis was done to investigate list effect, gender effect and age effect for single correct scores and double correct scores and ear effect for single correct scores. The summary of the results of current study are as follows-

- There was no significant difference between two lists for right, left and double correct scores. So, either of the list can be used clinically.
- There was no significant difference between the performance of males and females across age groups and for each list of the developed dichotic word test.
- The mean of right correct scores, left correct scores and double correct scores increased as the age increases. The right ear scores are greater compared to left ear scores and double correct scores indicating right ear advantage in both the dichotic word list.
- Significant difference was found for both single correct scores and double correct scores across all the age group, except for the left ear scores of second (8 – 8.11 years) and third (9 – 9.11 years) group for list I. Similarly significant difference was also found for list II except for right correct scores of first (7 – 7.11 years) and second (8 – 8.11 years) group and left correct score of second (8 – 8.11 years) and third (9 – 9.11 years) group.
- Significant difference was seen for right ear scores and left ear scores for all the five age groups for both the lists indicating right ear advantage.

Future research

1) The present study was done in a limited population (18 subjects with equal number of males and females in all five age groups). In future, this test can be administered on larger population for standardizing the developed test and to be used as a clinical tool for the assessment of auditory processing disorder.

2) The developed dichotic word test can be used in other clinical population such as learning disability, stutterer, ADHD. Hence further research can be done in these clinical populations.
3) Preliminary data for the dichotic word test in adult population would help in understanding the age of maturation for dichotic words.

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APPENDIX I

Dichotic word pairs in Hindi

List I

Right (Trial words)		Left (Trial words)	
नाच	/natʃ/	बेच	/betʃ/
देख	/d̪ek^h/	धूप	/d̪^{h}up/
जीभ	/dʒib^h/	देर	/d̪er/

Right (Test words)		Left (Test words)	
१. मौत	/mɔt̪/	काट	/kat/
२. तीर	/t̪ir/	खोल	/k^{h}ol/
३. लाख	/lak^h /	बीच	/bitʃ/
४. लौट	/lɔt/	रोज	/rodʒ/
५. बैल	/bæl/	ताक	/t̪ak/
६. याद	/jad̪/	चोट	/tʃot/
७. काट	/kat/	खोद	/k^{h}od̪/
८. खोल	/k^{h}ol/	दिल	/d̪ɪl/
९. सच	/sətʃ/	मौत	/mɔt̪/
१०. तेज	/t̪edʒ/	बैल	/bæl/
११. जोर	/dʒor/	लौट	/lɔt/
१२. कौन	/kɔn/	तीर	/t̪ir/
१३. जीत	/dʒit̪/	लाख	/lak^h /
१४. रोज	/rodʒ/	याद	/jad̪/
१५. ताक	/t̪ak/	सच	/sətʃ/
१६. चोट	/tʃot/	बाल	/bal/
१७. खोद	/k^{h}od̪/	तेज	/t̪edʒ/
१८. बीच	/bitʃ/	जोर	/dʒor/
१९. दिल	/d̪ɪl/	कौन	/kɔn/
२०. बाल	/bal/	जीत	/dʒit̪/

APPENDIX II

Dichotic word pairs in Hindi			
List II			
Right (Trial words)		**Left (Trial words)**	
नोट	/not/	हार	/har/
खेत	/kʰet̪/	भैंस	/bʰæs/
तेल	/t̪el/	कान	/kan/
Right (Test words)		**Left (Test words)**	
१. भाग	/bʰag/	गोल	/gol/
२. रोक	/rok/	धूल	/d̪ʰul/
३. दिन	/d̪ɪn/	नाक	/nak/
४. घूस	/gʰus/	रोक	/rok/
५. नाम	/nam/	खेल	/kʰel/
६. बोल	/bol/	भाग	/bʰag/
७. धूल	/d̪ʰul/	चाय	/tʃaj/
८. गोल	/gol/	घर	/gʰər/
९. नाक	/nak/	मोर	/mor/
१०. जाल	/dʒal/	रोग	/rog/
११. चोर	/tʃor/	दाग	/d̪ag/
१२. घर	/gʰər/	बोल	/bol/
१३. चाय	/tʃaj/	घूस	/gʰus/
१४. खेल	/kʰel/	चैन	/tʃɛn/
१५. नीम	/nim/	जाल	/dʒal/
१६. लिख	/lɪkʰ/	चोर	/tʃor/
१७. मोर	/mor/	दिन	/d̪ɪn/
१८. रोग	/rog/	नीम	/nim/
१९. चैन	/tʃɛn/	नाम	/nam/
२०. दाग	/d̪ag/	लिख	/lɪkʰ/

APPENDIX III

Screening checklist for central auditory processing (SCAP)

Yathiraj and Mascarenhas (2002)

Please place a tick (√) mark against the choice of answer that is most appropriate.

Sl. No.	Questions	Yes	No
1	Does not listen carefully and does not pay attention (requires repetition of instruction).		
2	Has a short attention span of listening (approx 5-15mins).		
3	Easily distracted by background sound.		
4	Has trouble in recalling what has been heard in the correct order.		
5	Forgets what is said in few minutes.		
6	Has difficulty in differentiating one speech sound from other similar sound.		
7	Has difficulty in understanding verbal instruction and tends to misunderstand what is said which other children of the same age would understand.		
8	Show delayed response to verbal instruction or questions.		
9	Has difficulty in relating what is heard with what is seen.		
10	Poor performance in listening task, but performance improves with visual cues.		
11	Has a pronunciation problem (mispronunciation of words).		
12	Performance is below average in one or more subjects, such as social subjects, I/II language.		

APPENDIX IV

Laterality Preference Schedule, Modified

I. With which hand would you:

S. No.	Activity	RIGHT	LEFT	No Preference
1.	Wipe a table with a cloth			
2.	Hold a glass when drinking			
3.	Put a coin in a box			
4.	Raise when called out			
5.	Write			
6.	Brush teeth			
7.	Eat			
8.	Comb/brush your hair			
9.	Open a drawer or dresser			
10.	Point to objects			
11.	Pick an object kept on the table			
12.	Switch on the light			
13.	Have the greatest strength			
14.	Hold a pair of scissors for cutting			
15.	Use first while putting on shirt			
16.	Erase a pencil mark with eraser			
17.	Hurl a ball			
18.	Hold on umbrella while walking			

II. With which foot would you:

19.	Kick a ball			
20.	Hop			
21.	Put on your footwear first			
22.	Stand the longest			
23.	Extend first when asked to stand and walk			
24.	Have the greatest strength			

III. With which eye would you:

25.	Look through a small hole			
26.	Aim while hitting a ball			
27.	See through a hole			
28.	Spontaneously see when asked to close one eye			

IV. With which ear would you:

29.	Listen to telephone			
30.	Listen to faint sound from distance			