DICHOTIC WORD (CVC) TEST IN INDIAN ENGLISH SPEAKING CHILDREN

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Dedicating to a heart that deeply cares and have faith in me,

amma, appa and anand!!

You add a lot of love
To everything you share,
And even though
You mean a lot,
You'll never know how much,
For you helped
To change the world
Through every life you touched.
You sparked the creativity
And helped me strive for goals
That could not be bought,
You are such a special to me
That no words can truly tell
However much you're valued
For the work you do so well!!

Thank You

CERTIFICATE

This is to certify that this dissertation entitled ***"Dichotic Word (CVC) Test in Indian English Speaking Children"*** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student (Registration No.07AUD001). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that the dissertation entitled ***"Dichotic Word (CVC) Test in Indian English Speaking Children"*** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other university for the award of any Diploma or Degree.

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DECLARATION

This dissertation entitled ***"Dichotic Word (CVC) Test in Indian English Speaking Children"*** **is** the result of my own study under the guidance of Devi N, Lecturer, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any other University for the award of any Diploma or Degree.

Mysore,

May, 2009

Register No. 07AUD001

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1. Introduction

Auditory processing disorders (APDs) refer to problems in the perceptual processing of auditory information by the central nervous system as demonstrated by difficulties in one or more of the following skills: Sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition, auditory performance in competing acoustic signal, and auditory performance in degraded acoustic signals (ASHA, 2005). "An auditory processing disorder (APD) may be broadly defined as a deficit in the processing of information that is specific to the auditory modality. It may be associated with difficulties in listening, speech understanding, language development, and learning" (Jerger & Musiek, 2000).

Normal auditory processing involves a number of distinct processes or skills. A breakdown or deficit in any one of the skills leads to central auditory processing disorder (CAPD). Due to the complexity of central auditory functions, there is no single measurement available which completely describes these functions. Nevertheless, different kinds of tests, ranging from electrophysiological measurements (Larsby, Hallgren, & Arlinger, 2000) to behavioural measurement of cognitive abilities, can give different aspects and angles of approach and together contribute to the understanding of these functions (Musiek, 1999). As the CAPD represents a heterogeneous group of auditory deficits, it is important to have a test battery approach to assess different level of processing as well as functioning within the central auditory nervous system. There are numerous tests that have been developed over the period of time to assess central auditory function which reflect the variety of auditory processes and functioning of various regions or levels within the central auditory nervous system that underlie auditory behavior and listening, and which rely on neural processing of auditory stimuli.

Among the test battery for testing the auditory processing, dichotic listening tests have been an essential part of the test battery for assessing individuals of all ages (Jerger & Musiek, 2000). Dichotic listening tests are among the most powerful of the behavioral test battery for assessment of hemispheric function, inter-hemispheric transfer of information, and development and maturation of auditory nervous system in children and adolescents, as well as identification of lesions of the central auditory nervous system (Keith & Anderson, 2007).

Dichotic listening tasks utilize syllables, digits, words, spondees and sentences which have been useful in predicting cerebral dominance for speech. These tests have also been used to study the relationship between cerebral dominance and learning disabilities (Ayres, 1977) cognitive development (Obrzut & Hynd, 1981), auditory processing disorders (Tobey, Cullen, & Rampp, 1979) and language disorders (Pettit & Helms, 1979). 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, 2003).

It has been reported that a majority of the individuals with Auditory processing deficit fit an Integration Deficit profile, characterized primarily by a large inter-aural asymmetry during dichotic speech tests mostly of contra-lateral ear effects (Moncrieff & Musiek, 2002). A number of studies have identified the presence of binaural integration deficits in children with learning and reading disorders (Moncrieff & Musiek, 2002).

Of the variety of speech stimuli available to measure dichotic listening (e.g., digits, words, consonant-vowels and sentences), digits are the most utilized. An advantage of digit stimuli is that, unlike sentences, they limit contextual cues. Digits, however, are a closed-set task that may tend to overestimate dichotic speech recognition ability. Digits are highly familiar, quite limited in the available number of possible responses, and have been shown to be relatively easy to recognize for both normal hearing and hearing-impaired listeners (Musiek, 1983a; Speaks, Niccum, & Van Tasell, 1985; Strouse & Wilson, 1999a, 1999b). As an alternative, monosyllabic words (other than digits) may offer several advantages as a dichotic stimulus including:

(1) Monosyllabic words are meaningful components of speech that limit the use of syntactical cues (Committee for Hearing, Bioacoustics and Biomechanics [CHABA], Working Group on Speech Understanding and Aging, 1988).

(2) Recorded monosyllabic word lists offer a standardized test of word recognition that are commercially available and in widespread use (Roup, Wiley, & Wilson, 2006).

(3) There is a large normative database for these monaural word-recognition materials from listeners with normal hearing and listeners with hearing loss across age groups in both quiet and competing message listening environments (Stockley & Green, 2000).

(4) Unlike digits, words are an open set stimulus that may result in recognition performance in the middle of the difficulty continuum i.e. neither too easy nor too difficult, yet sensitive to performance differences between ears and groups (Roup, Wiley, & Wilson, 2006).

Damasio, Damasio, Castro-Caldus, and Ferro (1976) compared a digit test with multisyllabic word test and concluded that the "coding and decoding of words that stands for digits is, in many instances, not as lateralized a process as coding and decoding of words not representing digits".

In regards to the other forms of stimuli, many researchers believe that sentences provide too many contextual clues making the testing easy in dichotic testing and that CV stimuli are too difficult. Another factor to consider when choosing stimuli is that the type of stimuli used does have an effect on the magnitude of the ear advantage, as the advantage is dependent upon the difficulty of the task (Wilson & Jaffe, 1996). The more difficult the task, the greater the right ear advantage (Moller, 2007). The right ear advantage is typically smallest when digits are used and largest when CVs are used. Dichotic words or sentences typically result in a right ear advantage that falls in between that of digits and CVs (Moller, 2007). Currently, available data documenting dichotic monosyllabic-word recognition performance, other than dichotic digits, is limited for both young and older adults (Prior, Cumming, & Hendy, 1984).

Need for the Study

1) The need for developing Dichotic Word Test (DWT) is crucial because the auditory system is undergoing maturation, thus age-specific data are required to help in making decisions about whether a child's auditory system is developing normally or otherwise. The availability of age-specific normative data also enables clinicians to monitor a child's performance over time (Keith, 2000).

2) To incorporate the Dichotic word test as part of the central auditory nervous system evaluation battery, since dichotic measures have demonstrated good sensitivity in identifying and differentiating cerebral level lesion (Berlin, 1976; Roup, Wiley, & Wilson, 2006).

3) 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 would be a prerequisite. It is ideal to have speech tests in all languages as the individual perception of speech is influenced by their first language or mother tongue (Singh & Black, 1966). There is no specific data for dichotic word test on Indian population for assessing the auditory processing. Hence there is a need to develop a test and to detect their problems which is appropriate for Indian children.

Objective of the Study

1. To develop the dichotic word test on Indian English speaking children of Kannada origin.
2. To standardize the developed test.
3. Investigate the effect on different stimulus list.
4. Investigate if the scores are different across gender and age (Gender & Age effect).
5. Investigate if there is any ear difference on the scores of dichotic word test (Ear effect).

2. Review of Literature

Katz, Stecker, and Henderson (1992) describe central auditory processing as "What we do with what we hear." In other words, it is the ability of the brain to process incoming auditory signals. The brain identifies sounds by analyzing their physical characteristics frequency, intensity, and temporal features. Once the brain has completed its analysis of the physical characteristics, it then constructs an image of the signal from these component parts for comparison with stored images (Schminky & Baran, 1999).

ASHA (1996) created Task Force on Central Auditory Processing Consensus Development which identified certain behaviors involved in central auditory processing namely

- *Sound localization and lateralization*, or ability to know where sound has occurred in space.
- *Auditory discrimination*, or ability to distinguish one sound from another.
- *Auditory pattern recognition*, or ability to determine similarities and differences in patterns of sounds.
- *Temporal aspects*, or abilities to sequence sounds, integrate a sequence of sounds into meaningful combinations, and perceive sounds as separate when they quickly follow one another.
- *Auditory performance decrements*, or ability to perceive speech or other sounds when another signal is present.
- *Auditory performance with degraded acoustic signals*, or ability to perceive a signal in which some of the information is missing.

The Task Force considered auditory processing disorder to be a deficiency in one or more of these abilities (ASHA, 1996). This definition acknowledges that many neurocognitive functions are involved in the processing of auditory information. Some are specific to the processing of acoustic signals, while others are more global in nature and not necessarily unique to processing of auditory information (e.g. attention, memory, & language representation). However, these latter functions are considered components of auditory processing when they are involved in the processing of auditory information (Schminky & Baran, 1999).

Auditory processing disorder is thought to occur primarily in young children and older adults. In children, the majority of individuals with auditory processing disorder are not the result from documented, discrete neuropathologic impairments (Stach, 1998). Rather, the pathogenesis of the resulting hearing disorder is largely an idiopathic dysfunction of the central auditory nervous system. Although some children may be genetically predisposed to auditory processing disorder, it is more likely a developmental result of inconsistent auditory input during auditory perceptual development (Stach, 1998).

The exact prevalence of auditory processing disorder in the pediatric population has not been firmly established due to lack of standard definition of auditory processing disorder, which caused difficulty in establishing an accurate number, leading to a variance in prevalence estimates (Keith, 1995). Mild cases of auditory processing disorders may be inconspicuous, as the affected children may learn to compensate in various academic and social situations. According to Chermak and Musiek (1998), the incidence of auditory processing disorder has been estimated to be as high as 3 to 5% and is more common than the incidence of hearing loss. Bamiou, Musiek, and Luxon (2001) report a frequency of 7%

and seen twice as often in boys than in girls (Schminky & Baran, 2000). Santucci (2003) estimated the current prevalence of auditory processing disorder in the pediatric population to be around 3 to 5%. In India, it has been found that percentage of children to have dyslexic ranges from 3% (Ramaa, 1985) to 7.5% (Ramaa, 2000).

Many auditory processes are involved in the appropriate perception of an acoustic event (Handel, 1989). Most of these processes are inter-dependent. No single test of auditory processing disorder can be expected to challenge the variety of functions in different listening situations. Therefore, it is necessary to use a test battery approach (Dempsey, 1983).

The value of assessing auditory processing with a test battery approach has repeatedly been acknowledged because of the inherent heterogeneity of the population presenting with auditory processing problems (Jerger & Musiek, 2000). Test batteries for auditory processing disorder should include behavioral and electrophysiological tests to ensure the assessment of peripheral, the central auditory process, and the pathways (Chermak & Musiek, 1997). However, with all these test batteries, it appears to be impossible to map the auditory abilities of young children in a reliable way, because of the demands made by the tests with respect to attention span, auditory processing, articulation, and possibly language level, are too high (Stollman et al., 2004).

Recognizing the insensitivity of the traditional auditory tests in assessing the central auditory nervous system, researchers developed variety of behavioral tests (Noffsinger, Olsen, Carhart, Hart & Sahgal, 1972). Baran and Musiek (1991) categorized behavioral test into dichotic speech tests, temporal ordering tests, monaural low redundancy speech tests and binaural interaction tests. It is not necessary to use the entire test battery or a test from each category for the assessment of auditory processing disorder for children. Rather, the selection of test battery depends on the age of the child, specific auditory difficulties the child displays, the child's native language and the cognitive status, and so forth (Willeford & Burleigh, 1985).

For many years, dichotic listening tests have been an essential part of the test battery for assessing individuals of all ages (Jerger & Musiek, 2000). Various dichotic listening tests include Dichotic CV, Dichotic Digit, Staggered Spondiac Word test (SSW), Competing Sentence Test (CST), Synthetic Sentence Identification test with Contra-lateral Competing Message (SSI-CCM), Dichotic sentence identification test, and Dichotic rhyme test (Bellis, 1996) which assess integration, interaction as well as separation. Among those tests, binaural integration has been the focus of a significant amount of attention over the past several decades. This task is assessed through a variety of dichotic listening tests with digits, words and consonant-vowels (Moncrieff, 2002). Performance in each ear is measured as the stimulus is simultaneously presented in competition to the two ears (Moncrieff & Musiek, 2002). The presence of a large interaural asymmetry has been a hallmark of a processing disorder, usually described as a left-ear deficit (Moncrieff, 2002).

Dichotic listening

Although Dichotic Listening was developed in the 1960s, it is still widely used and can be regarded as a non-invasive and practical technique in terms of determining the cerebral dominance of auditory language abilities. This technique was brought up by

Broadbent in 1954 and later developed by Kimura in the early 1960s (Kolb & Whishaw, 1990).

Dichotic speech tests are psychoacoustic tests sensitive for central auditory functions (Bellis, 1996) which are commonly employed in the evaluation of children and adults suspected of auditory processing deficits, especially in the evaluation of interaural asymmetry (Jerger, 2006). In dichotic speech test, both the ears are stimulated simultaneously with different speech sounds (Hugdahl, 1995). These tests assess the ability to separate or integrate different stimuli that are presented to the ears simultaneously (ASHA, 2006). The simultaneous presentation of stimuli to both ears makes the signals from the ears depend on contralateral pathways to a greater extent while the ipsilateral pathways are suppressed by the competing stimulus situation. This means that the stimuli from the left ear have longer way to the speech dominant left hemisphere, since these signals are conveyed via the right hemisphere and the corpus callosum. On the other hand, the stimuli from the right ear have direct access to the left hemisphere. This leads to a right ear advantage (REA), a typical finding in dichotic speech tests (Katz, 2002; Hallgren, 2005). This right ear advantage will be seen until the child is approximately 11 years old since corpus callosum is the last structures to mature (Katz, 2002).

There are certain variables which can influence the performance or affect the interpretation of the dichotic listening test. This includes the following:

Stimulus Related Factors	*Subjects Related Factors*
Intensity	Age
Frequency	Gender
Temporal effects	Response mode
Bandwidth	Response condition
Phonetic	Practice effect
Effect of masking/ SNR	Handedness
Material used	
Stimulus familiarity	

Stimulus Related Factors

1) *Intensity of the Stimulus*

The effect of dichotic listening on intensity has not been studied extensively. However, there are few studies which suggest that right ear laterality does not vary as a function of sensation level. Roeser, John, and Prince (1972) reported fewer correct responses at lower intensity levels of around 10 dBSL. Also right-left difference did not vary as a function of intensity. But the right ear advantage may reduce by the attenuation of signal level in the right ear. Similar results were obtained by Speaks and Bissonette, (1975); Bloch and Hellige (1989).

Tallus, Hugdahl, Alho, Medvedev, and Hamalainen (2007) manipulated the strength of intensity difference between the right ear and left ear speech inputs to make the right ear advantage either weaker or stronger. The results showed that the interaural intensity difference affected the ear advantage significantly. Similarly, Hugdahl (2008) gradually varied the intensity in steps of 3 dB from -21 dB in favor of the left ear to +21 dB in favor of the right ear to see the effect of interaural intensity difference on the ear advantage. The results showed a significant right ear advantage for interaural intensity differences from +21 to -3 dB, no ear advantage for the -6 dB difference, and a significant left ear advantage 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.

Thus, intensity plays a major role in dichotic listening test where lower scores were obtained for lowest sensation level and as the sensation level increases, the scores also improved. In addition, the difference in intensity between the two ears will affect the dichotic listening test.

2) *Frequency of the Stimulus*

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 20 normal subjects. It has been reported that subject attending to non-verbal properties (e.g. Pitch) of dichotic verbal input reported better from the left ear than from the right ear (Blumstein & Spellicy, 1970). Hence, the nonverbal aspects of verbal input are mediated by right hemisphere. Since one of the important features of verbal materials is its sequential character, it can be assumed that sequentially patterned non-verbal information will be mediated by left hemisphere (Halperin, Nachshon, & Carmon, 1973).

Halperin, Nachshon and Carmon (1973) indicated that the direction of the ear superiority varied as a function of complexity of the temporal patterns. Increase in complexity by increasing the number of transitions accompanied by a gradual shift from left ear to right ear superiority. Thus, most of the studies report perceptual asymmetries when two different auditory signals are presented simultaneously. A right ear advantage for verbal stimuli (speech) and a left ear advantage for tones and other nonverbal stimuli was reported. Similarly, nonverbal aspects of verbal material were mediated by right hemisphere and the non-verbal attributes of sequentially patterned sounds were mediated by left hemisphere (Halperin, Nachshon, & Carmon, 1973). Thus, the ear asymmetry is a consequence of spectral information processing.

3) Temporal Effects/ Lag Effect of the Stimulus

In dichotic testing, various lags between the stimuli have been used. It has been observed that as the lag time increases, the lagging stimulus becomes more intelligible. Lowe, Cullen, Berlin, Thompson, and Willett, (1970) varied the onset time between natural speech CV’s up to 90 or 500 ms starting from 30 ms. Result showed a lag effect in 30 to 90 ms ranges and less lag effect after 90 ms. Similar investigation on lag effect was done by Berlin, Lowe-Bell, Jannetta, and Kline (1972) and the results revealed that the lagging the

CV stimuli by 30 to 60 ms became more intelligible than when it was given simultaneously. This time advantage occurred to the lagging syllable and not to the leading syllable.

The intelligibility of the lagging stimuli increases upto 30 ms lag and increasing the duration beyond 30 ms increases the intelligibility of both leading and lagging stimuli (Berlin, Lowe-Bell, Cullen, Thompson, & Loovis, 1973). However, there are reports of right ear advantage remaining the same with different lag times. Prachi and Yathiraj (2000) showed higher right ear scores than left ear at 0 ms and also for both 30 and 90 ms lag times when testing for young adults (18 to 30 years) using dichotic CV test. Similar results were obtained for children (7 to 11years) by Krishna and Yathiraj (2001) which showed right ear advantage for 0, 30, and 90 ms lag time.

Thus, varying the lag time of the stimulus will leads to different degree of right ear advantage and also the intelligibility of the either leading or the lagging stimulus or both differs. Hence, lag time is an important factor to be considered in dichotic listening test.

4) *Phonetic Effect/ Stimulus Dominance*

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 right ear advantage compared to other consonants. It occurs with greater frequency than ear advantage and is of greater magnitude.

di Stefano, Maramno, and Viti (2004) reported that the number of stimulus dominated responses were higher in individuals with normal hearing than in single functional hemisphere patients and were negatively correlated to the index of laterality. It was suggested that one dichotic stimulus may interfere with another during the sub cortical acoustic processing and at the cortical level, when competing for verbal output. Also, the presence of higher stimulus dominance in dichotic listening masks the right ear advantage. Hence, eliminating the stimulus dominance factor is the preliminary step to construct useful dichotic listening test.

a) Voiced Vs. Voiceless Consonant

There are several studies in the literature comparing the differential effect of voiced and voiceless consonant on dichotic perception. Most of the studies indicate that voiceless stops were more dominant than voiced stops and scores were higher for voiceless stops than for voiced stops regardless of ear of presentation (Roeser, Johns, & Price, 1972; Berlin, Lowe-Bell, Cullen, Thompson, & Loovis, 1973; Porter, Trondle, & Berlin, 1976; Rajagopal, Ganguly, & Yathiraj, 1996).

Repp (1976) studied the effect of variation in voice onset time (VOT) on the perception of dichotic CV syllables contrasting in voicing features. Results revealed that changing the VOT of the voiceless stimuli had a larger effect than changing the VOT of a voiced stimulus. Rimol, Eichele and Hugdahl (2006) also showed that syllable pairs with long VOT presented in the right ear and short VOT simultaneously presented in the left ear, produced the largest right ear advantage followed by the long-long and short-short conditions. The long-short condition produced a significant left-ear-advantage. Several other studies reported the different degrees of laterality effects and this difference is attributed to the differences in VOT between the syllables (Sandmann et al., 2007; Zaehle, Jancke, & Meyer, 2007; Bayazıt, Oniz, Ozgoren, & Gunturkun, 2008).

These results demonstrate that VOT significantly affects ear-advantage as observed in the dichotic listening test and suggest that VOT may be a more powerful determinant of dichotic listening performance than the classic right ear advantage effect.

b) Place of Articulation

Dichotic tests have been developed with the consonants with different place of articulation. Most of the literature suggests that velar consonants were better perceived followed by alveolars, which in turn were reported more correctly than labials (Porter, Trondle, & Berlin, 1976; Speaks, Niccum, & Tasell, 1985; Rajagopal, Ganguly, & Yathiraj, 1996).

Voyer and Techentin (2009) investigated the place of articulation in stop CV syllable pairs in a dichotic listening task and the results indicated the presence of right ear advantage, which varied in such a way that location of the velar syllable typically produced better performance compared to non-velar sounds. These studies were in support with earlier studies saying velars were more correctly identified than others. Hence the magnitude and direction of perceptual asymmetries may differ depending on the place of articulation of the stimulus in the dichotic listening paradigm.

c) Vowels and Consonants

Most of the studies show little or no right ear advantage for vowel (Darwin, 1969; Studdert-Kennedy, & Shankweiler, 1970; Cutting, 1974; Hugdahl, & Andersson, 1984). Weiss and House (1973) revealed right ear advantage for vowels in a consonantal context due to transition of the vocal tract but the degree of right ear advantage varied among the vowels. Long vowels had greater right ear advantage compared to short vowels. Among consonants, liquids, semivowels and fricatives have been found to produce reduced and less reliable right ear advantage than stop consonants (Darwin, 1971; Haggard, 1971).

Studies have also been carried out on different positions of the consonants. Troast, Shewan, Nathanson, and Samt (1968) reported equal right ear advantage for initial and final consonant in natural CVC syllables. In contrast, Darwin (1969) reported stronger right ear advantage for consonants in the final position when presented dichotically. Studdert-Kennedy and Shankweiler (1970) also reported strong right ear advantage to initial and final consonant of CVC syllables but no right ear advantage for vowels.

Thus, the presence of vowel in the consonantal context may affect the laterality effect to a various degree and it also depends on the type of vowels and the consonants that were combined. Also the position of the consonants, affects the ear advantage to a certain extent.

5) Effect of Masking/ Signal to Noise Ratio (SNR)

Different types of masking have different type of effects on the performance of dichotic listening tasks (Cullen, Thompson, Hughes, Berlin, & Samson, 1974). Weiss and House (1973) performed a dichotic competing vowels task at two different SNR and the findings showed reduced overall scores and more pronounced right ear advantage as the SNR becomes poorer.

The effect of background noise on the right ear advantage to CV syllables was investigated by Sequeira, Specht, Hamalainen, and Hugdahl (2008). Both babble and traffic noise resulted in a smaller right ear advantage compared to the silent condition. Moreover, the traffic noise had a significantly greater negative effect on the right ear advantage than the babble, caused both by a decreased right ear response as well as an increased left ear response. Thus, the amount of background noise that is present while the dichotic listening tests were performed will significantly affect the test results.

6) *Stimulus Material*

Several test procedures such as Dichotic Digit Test (Kimura, 1961a,b; Musiek, 1983a), Staggered Spondaic Word (Katz, 1962), Synthetic Sentence Identification (Speaks, & Jerger, 1965), Dichotic CV Test (Berlin, & Lowe, 1972), and Dichotic Rhyme Test (Wexler, & Halwace, 1983) have been developed to measure the dichotic listening. All these dichotic speech tests were aimed at reducing both external and internal redundancy so that it becomes difficult for the subject to respond.

Obrzut, Bolick, and Obrzut (1986) used four types of dichotic stimuli for children in three condition of free recall, directed right, and directed left. Results revealed right ear advantage for words and CV syllables and left ear advantage for melodies under free recall condition. In directed conditioned, CV syllables had no effect on right ear advantage but had a dramatic effect on recall of digits. Word stimuli and directed condition interacted to produce inconsistent perceptual asymmetry. In addition, the directed condition reduced over all recall for melodies. This supports the hypothesis that perceptual asymmetric can be strongly influenced by the type of stimulus material used.

Noffsinger, Martinez, and Wilson (1994) also revealed that the listeners had difficulty in identifying digits or synthetic sentence but accurate responses were less frequent when the stimuli were dichotic CV. Similar investigation by Rajgopal, Ganguly, and Yathiraj (1996), stated that Dichotic CV test was more difficult task when coupled to dichotic direct test. The poorer performance on dichotic CV is due to the simultaneous presentation of stimulus which is less meaningful than digits and rarely occurs in isolation. Hence the response obtained from subjects in dichotic listening varied depending on the stimuli used.

7) *Stimulus Familiarity*

Nachshon, and Carmon, (1975) used CV syllables with six consonant (3 familiar) and four vowels (2 familiar) to study the effect of stimulus familiarity. Results revealed right ear advantage in Familiar-Familiar and Non Familiar-Non Familiar condition for both consonant and vowel. In Non Familiar (Left ear) - Familiar (right ear) condition, both consonant as well as vowels showed stronger right ear superiority due to interaction of familiarity and language effect. This shows strong effect of stimulus familiarity.

Subject Related Factors

1) *Age*

Literature suggests that with advancing age, changes occur within the central auditory system. Aging is accompanied by a decline in cognitive as well as auditory function (Martin & Jerger, 2005). The effect that aging has on recognition performance on dichotic materials is unclear. Some studies show that recognition performance on materials presented to the left ear declined as a function of age (Borod & Goodglass, 1980), whereas performance on materials presented to the right ear was constant as a function of age (Clark & Knowles, 1973).

The effect of age on dichotic listening may be different depending on the type of stimuli used. Dichotic listening on children suggest that more the linguistically loaded stimuli presented, the more pronounced the maturational effects are likely to be (Bellis, 2003). There is converging evidence that aging causes a progressive decline in the central processing of speech and this decline is greater for left ear than for right ear input (Bellis, 2003).

Jerger, Chmiel, Allen, and Wilson (1994) reported larger right-ear advantage with increasing age using dichotic sentence paradigm. Similar study by Hugdahl, Carlsson, and Eichele (2001) revealed right ear advantage in all age groups from 7 to 70 years in non-forced and forced right condition. However, the youngest age groups did not show an increase right ear advantage to the same degree as the older age groups. In the forced-left condition, all age groups, with the exception of the youngest groups, showed a left-ear advantage. Hence the right ear advantage in dichotic listening was subject to developmental effects and attentional effects and it develop with increasing age. In the Indian context, Regishia and Yathiraj (2003) studied the effect of maturation on dichotic test which showed a developmental trend in right ear score, left ear score, and double correct score and it was more seen in dichotic CV test than dichotic digit test.

Even though age have shown greater effect on dichotic listening performance, an investigation employing dichotic listening in clinical work should match clinical and control subjects. This will reduce the likelihood of age being confounded with variable interest as well as make the experiment more sensitive to differences in those variables.

2) Gender

There are equivocal findings in the literature on gender and dichotic perception. Lake and Bryden (1976) combined data from several studies and reported right ear advantage on 73.6% of males and 62.2% of females. Several other studies stated the similar results and this was attributed to more bilateral organization of cognitive abilities for females than in males (Bryden, 1988; Hines, 1990; Voyer, 1996; Cited in Halpern, 2000). Others have not showed any significant difference in performance (Carr, 1969; Briggs & Nebes, 1976).

Kalil (1994) did an exhaustive survey from six neuropsychological journals to see if there is a gender difference in human laterality. Of the 352 dichotic and monaural listening experiments identified, 40 % provided information about the gender differences. Of those positive outcomes, nine supported the hypothesis of greater hemispheric specialization in males than in females.

In contrast, study by Robert et al. (1994) and Meyers, Roberts, Bayless, Volkert and Evitts (2002) on dichotic word test showed no significant difference between genders. Sommers, Alemanc, Sommers, Boks, and Kahn (2008) showed that the males were more frequently left handed than females, but there was no gender difference in asymmetries of the planum temporale, dichotic listening or the functional imaging findings during language tasks measured by the asymmetric performance on dichotic listening tests and functional imaging techniques.

Although gender have not been shown greater effect on dichotic listening performance, clinical and control subjects should match while employing dichotic listening in clinical work to reduce the effect on those variables.

3) *Practice Effect*

Practice effect is one of the most common variable which affects testing. In dichotic listening condition, it has been reported that right ear advantage does not change to a greater extent with practice effect. Porter, Troendle, and Berlin (1976) investigated long term effects of practice on dichotic CV performance and found a slight increase in double correct responses (28% to 38%) and a slight drop in both single correct scores (85% - 65%) and neither correct scores (7% to 4%) over days. They also found absolute advantage of right ear over left ear but the absolute magnitude of voiceless advantage did not change significantly over days. They also reported velar were most often reported correctly than alveolar which in turn were reported more correctly than labials even after practice. Similar results were reported earlier by Ryan and McNeil (1974); Johnson and Ryan (1975). Thus, effect of practice did not change the magnitude and direction of the ear advantage.

4) Response Mode

There are evidences which suggest that in humans, the two cerebral hemispheres alter in degree to which they are involved in processing different kind of information. The mode is an important factor in establishing preferential processes by one hemisphere over the other. Response of the listener on dichotic listening can be of written down response or orally repeating the heard stimulus or by visual recognition. Merrell and Atkinson (1965) showed that the oral discrimination score were always higher than written down scores. Similar results were found by Nelson and Chaiklin (1970).

Ear advantage was also studied by using different modes of responses. Jancke (1993) evaluated the difference in results on three response conditions (speak, write & visual condition) using dichotic CV test. Results revealed that there was no significant influence of response mode on right ear advantage. Similar results were found by Krishna and Yathiraj

(2001) using two response mode (oral & written). Hence response mode is not a major factor that affects the dichotic listening.

5) Response Condition

Throughout the history of dichotic testing, varieties of response conditions have been used. The two most prominent response conditions are free recall and directed attention recall. According to Strouse, Wilson, and Brush (2000), the directed right recall typically produce large right ear advantage than the free recall, as a result of the listener being able to ignore the stimuli presented to the non-cued ear and give full focus to the right ear stimuli. If the subject is asked to attend to the left-ear, a left-ear advantage was generally exhibited. However its magnitude was less than the right ear advantage of directed right ear recall (Strouse, Wilson, & Brush, 2000).

Another response option within directed recall is post-cued directed recall which is much more difficult, and is more influenced by memory and cognitive abilities. The right ear advantages exhibited in post-cued directed recall are typically inflated, with the suggested cause being the increased difficulty of the task (Strouse, Wilson, & Brush 2000). The inflated right ear advantages and poor overall performances exhibited in post-cued recall conditions have caused many researches to choose other response conditions, such as free recall or pre-cued directed recall.

Musiek et al. (2005) examined the effect on the fused dichotic word test and the dichotic CV test in free recall, direct attention to left ear or to the right ear condition. Results revealed high significant differences in response on the dichotic CV test, but only marginal shift in performance on the fused dichotic word test. Hence, fused dichotic word test are resistant to alterations in the laterality of attention compared to dichotic CV test. Similar findings were reported by Asbjornsen and Bryden (1996). Thus the magnitude and direction of ear advantage in dichotic listening also varies depending on the type of response conditions.

6) Handedness

As a huge majority, people process language in their left hemisphere. In a study using the sodium amytal technique, Branch, Milner, and Rasmussen (1964) found that 90% of right handed people had language lateralized in the left hemisphere and 60% of left-handed subjects exhibited left hemisphere language processing. These results indicate left handed people being more ambidextrous than right-handed people. This means that left handed people may have more connections between their hemispheres, resulting in less lateralization. Due to this left hemisphere lateralization, researchers restrict testing to right-handed subjects when measuring dichotic speech recognition.

Wilson and Leigh (1996) performed dichotic listening task on left and right handed listeners. Results revealed right ear advantages for both right and left handed subjects. However, the magnitude of the right ear advantage of right handed listeners were much larger than the advantage of the left handed listeners, which shows that left handed listeners generally exhibit more variability in dichotic situations. For this reason, dichotic research is often conducted only with right handed listeners in order to ensure more reliability and less variability of results.

Dichotic Listening in Clinical Population

1) *Peripheral Hearing Loss*

Peripheral hearing loss affect central auditory processing test results. Studies suggested that dichotic digit test was not significantly affected by mild to moderate cochlear hearing loss. (Musiek, 1983a). Most of the studies concluded poorer scores in the presence of sensorineural hearing loss but the amount of performance depends on the type of material used, being least affected in dichotic digit compared to other dichotic test (Musiek, 1983a; Speaks, Niccum, & van Tasell, 1985).

Roeser, Johns, and Prince (1976) studied the effect of dichotic listening on bilaterally symmetrical sensorineural hearing loss using dichotic digit and dichotic CV test. Large ear advantages were discovered suggesting that sensorineural loss may significantly affect the size and direction of the ear advantage. Speaks, Niccum, and Tasell, (1985) studied the effect of different stimulus material on dichotic performance in individuals with sensorineural hearing loss. Results showed that dichotic digit material was least affected by hearing loss compared to vowel words, consonant words, and CV nonsense syllables. Neijenhuis, Tschur, and Snik (2004) also got poorer scores in individuals with hearing loss compared to normal hearing individuals even with adjusted presentation level using Dutch auditory processing test.

Also the otitis media in the early stages does affect the various auditory processes at the later age. However, there are equivocal findings regarding the effect of otitis media on dichotic tests. Schilder, Snik, Straatman, and van den Broek (1994) studied the effect of auditory perception on school going children who had history of otitis media with effusion at 2 to 4 years of age. The auditory tests used at 7.5 to 8 year of age which showed significant effect of otitis media with effusion on Speech in noise test but not on other tests (Filtered speech, Binaural fusion, Dichotic speech and Auditory memory). In contrast, Amala and Yathiraj (2003) found poorer scores on dichotic CV test for children who had otitis media with effusion in their early childhood.

Hence, the selection of test battery majorly depends upon the presence of peripheral hearing loss and its effect on different test materials should be considered before administering the dichotic test.

2) *Temporal Lobe Lesion*

Studies have shown that the central auditory deficits existed in patients with temporal-lobe lesions. When such patients were presented with dichotic simultaneous and time staggered speech material, poorer scores were obtained for the contralateral ear than ipsilateral ear, leading to absence of lag effect (Berlin, Lowe-Bell, Jannetta, & Kline, 1972). Similar findings were reported on dichotic CV tests by Speaks, Gray and Miller (1975). Thus, the dichotic listening is more sensitive to cortical lesion.

Gramsted, Engelsen, and Hugdahl (2006) evaluated dichotic listening performance in subgroups with and without left hemisphere cognitive dysfunction, and in subgroups with left and right temporal epileptic focus. Left hemisphere cognitive dysfunction led to more correct responses to left ear stimuli in forced and non forced attention conditions, and fewer correct responses to right ear stimuli in the non-forced attention condition which was probably caused by basic left hemisphere perceptual dysfunction. However, dichotic listening was less affected by a left sided epileptic focus than by left hemisphere cognitive dysfunction. Hence the influence of cognitive functioning on dichotic listening performance was stronger in forced than in non-forced attention conditions.

3) *Spilt-brain Patients*

Milner, Taylor, and Sperry (1968) compared split-brain patient's results with normal listeners and cases of temporal lobectomy using dichotic digit test. Results showed slight right ear advantage to normal listeners and bilateral deficit to temporal lobectomy patients whereas, significant left ear suppression or extinction resulted within split-brain patients. Similar results were obtained in individuals who had undergone commissuretomy using dichotically presented monosyllabic rhyme test (Musiek et al., 1989).

de Bode, Sininger, Healy, Mathern, and Zaidel (2007) also showed a massive contralateral ear advantage demonstrating nearly complete ipsilateral suppression of the left ear in right hemispherectomy group but less complete suppression of the right ear in the left hemispherectomy group using dichotic CV nonsense syllables and fused word test. In conclusion, inter-hemispheric dysfunction typically results in left ear deficits on dichotic speech tasks and finding is similar to that of right hemisphere dysfunction.

4) *Intracranial Lesions*

The dichotic listening is most sensitive to cortical lesion than brain stem lesion and it varies with the test material used. The dichotic digit test appeared most sensitive, followed by the Staggered Spondaic Word test and Competing Sentences for their ability to detect abnormal performance on individuals with intracranial lesions (Musiek, 1983b). However, all three tests showed better sensitivity for detecting abnormality in hemispheric than brainstem lesion. Those with hemispheric lesion showed greatest deficit contralateral to the lesion whereas those with brainstem involvement showed greatest deficit to the ipsilateral lesion (Musiek, 1983b). Similar study by Shivashankar, and Herlekar (1991) also found abnormal performance on individuals with confirmed intracranial lesions using dichotic digit test. The test thus seems to have clinical value in detecting brainstem or cortical dysfunction.

5) *Dyslexia*

Several auditory processing deficits have been reported in children with dyslexia. Lamm, Share, Shatil, and Epstein (1999) showed negative correlation between reading acquisition and longitudinal changes in dichotic listening performance by young children from kindergarten to the end of grade one. Most subjects who experienced difficulties in learning to read and in the word dichotic test, also failed in a kindergarten test requiring the matching of syllable combinations with arbitrary letter-like symbols. Thus the kindergarten performance in the word dichotic test was a reliable predictor of failure in reading acquisition.

Sauer, Pereira, Ciasca, Pestun, and Guerreiro (2006) compared the results of dichotic listening with the findings of neuro-imaging examination on dyslexics and found good correlation between the two. Also there exists statistical difference between dyslexics and normal individuals. Hence, dyslexic children may be detected by dichotic listening tests, and by functional imaging exam.

Moncrieff, and Black (2008) performed dichotic listening test on dyslexics and found poorer scores than normal individuals from their left ears when listening to digits and words and from their right ears when listening to CVs. Also the direction of ear advantage varied when tested with digits and CVs, but stable with words. When the children were tested in a directed response mode, degree of ear advantage differed significantly with both words and digits. More dyslexic than normal children demonstrated clinically significant reductions in dichotic listening performance.

Thus, most of the studies done on dichotic listening showed poor performance for the dyslexics compared to that of the normal individuals. Hence, it can be used as a test to differentiate between the two. However, the magnitude and the direction of the ear advantage vary depending on the stimuli used and should be considered while administering the dichotic test.

6) Schizophrenia

Dichotic listening techniques have been used to study hemispheric dominance for language in schizophrenia. Friedman et al. (2001) revealed the largest left hemisphere advantage on patients with paranoid schizophrenia and patients with undifferentiated schizophrenia had the smallest, whereas the asymmetry of healthy subjects was intermediate. The findings support the hypotheses that undifferentiated schizophrenia is associated with under activation of left hemisphere resources for verbal processing and that paranoid schizophrenia is characterized by preserved left hemisphere processing.

In summary, dichotic listening performances is most sensitive in differentiating different kind of central disorder especially cortical lesion and also have been used extensively as a measure of maturation of the auditory system and language dominance. Even though several dichotic listening test are available, dichotic word test have been reported to have advantages over the other materials available. But there is very limited number of studies done on dichotic word listening test. Also many factors may affect the performance of the dichotic listening test which is already discussed earlier in this chapter. Hence it is essential to consider all those factors while developing as well as administrating the test.

3. Method

The primary aim of this study was to develop and obtain the preliminary data for the dichotic word test in English for children. The study was carried out in two stages.

Phase I – Development of the stimuli.

Phase II – Establishing the preliminary data for dichotic word test.

Phase I: Development of the English Dichotic Word Stimuli

Selection of Words

The test stimulus was prepared using monosyllable words developed by Sivaprasad and Yathiraj (2006) as a reference. These words were phonetically balanced using frequencies of occurrences of English speech sounds in India by Ramakrishna et al. (1962). The words were familiarized for the children within the range of 7 years to 7 years 11 months by asking the child to describe the words or show the picture representing the words. Using these familiar words, two lists of twenty five pairs of words in each list were constructed.

Recording of Words

The words were spoken by a female speaker who had a clear articulation using standard spoken Indian English of the Mysore region in an accent widely used in formal speech. This was ensured by a screening procedure by two experienced Speech-Langauge pathologists. The Audio recordings of the words were digitized using the Praat version

5.0.32 software with a sampling rate of 24,000 Hz. The speaker was instructed to say each word clearly and naturally using a constant vocal effort with an interval of two seconds between the utterances. The digitized word signals were then edited and equalized for overall intensity to achieve equal average levels using Adobe Audition version 2.0 software. A goodness test of recorded material was done to ensure that the good quality of the stimuli. This was checked by presenting the recorded material to ten Indian-English speaking normal hearing adults of the Mysore region. The word pairs with more than 90% acceptance by these individuals were selected as stimuli.

Preparation of Dichotic Word Pairs

The duration of the words was calculated and paired in such a way that the onset and offset of the stimulus coincides. The edited word files were interleaved to form combinations of the fifty word pairs, with no word repeated within a pair. Careful measurements were made to ensure that each dichotic set had equal onset and offset times with a deviation in duration not exceeding 0.2 ms as per the guidelines given by Lamm, Share, Shatil, and Epstein (1999) and the paired words were of either voiced or voiceless at the initial position. The word pairs with same phoneme in the same word positions were avoided as per the guidelines of Roup, Wiley, and Wilson (2006). Inter-stimulus interval of about ten seconds was added between word pairs to function as the response time. Two different sets of single word pairs consisting of five practice word pairs followed by twenty test word pairs were formed. A 30-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.

Preparation of the Dichotic Word Test on a Compact Disc

Each member of the word pairs were recorded on two separate channels of a compact disc in such a way that one member of the pair was routed to one ear and the other member of the pair was routed to other ear. The compact disc consists of two lists of 25 word pairs. Instruction of repeating the words heard in both channels was recorded and the stimuli followed the instructions after three seconds.

Phase II – Establishing preliminary data for dichotic word test

Participants

Data were collected from English speaking children of the Mysore region between 7 to 12 years. The mother tongue of all the children was Kannada. All the participants were assigned to one of the five groups.

- 7 years to 7 years 11 months,
- 8 years to 8 years 11 months,
- 9 years to 9 years 11 months,
- 10 years to 10 years 11 months, and
- 11 years to 11 years 11 months.

A total of 100 participants (twenty in each group) with equal number of males and females were taken for the study. Individual class teachers were requested to identify those children with language and or behavior problems based on their observation, and those with below average academic performance and such children were excluded from the list. A list of children who were included in the study was then selected based on their date of birth and gender, to make sure that each age group was represented by an equal number of boys and girls and belongs to appropriate age group. Parental consent was obtained before the children participated in the study. All the children were interviewed and underwent a hearing testing using pure-tone audiometry and tympanometry to make sure that they fulfilled the inclusion criteria. All participants included for the collection of data met the following criteria:

- Bilateral normal-hearing thresholds (0-15 dB HL) at frequencies 250 Hz to 8000 Hz for air conduction thresholds and 250 Hz to 4000 Hz for bone conduction thresholds.
- Bilateral type-A tympanogram with presence of acoustic reflexes (ipsi & contra) in both ears.
- Speech recognition threshold of ±12 dB (re: PTA of 0.5, 1 & 2 kHz).
- Speech identification score of > 90% at 40 dBSL (re: SRT) in both ears.
- Passed the Screening Checklist for Auditory Processing (SCAP) developed by Yathiraj & Mascarenhas (2003), ruling out any auditory processing deficit.
- No otologic and/or neurologic problems.
- No illness on the day of testing.

Testing environment

The testing were carried in a sound treated double room situation and noise levels maintained within permissible limits as per ANSI S 3.1- 1991.

Instrumentation

1. A Calibrated two channel diagnostic audiometer Grasen-Standler Model GSI 61 coupled with acoustically matched TDH 39 headphones housed in MX - 41/AR and Radio ear B-

71 bone vibrator were used to estimate the Pure tone threshold, Speech Recognition Thresholds (SRT), Speech Identification Scores (SIS), and Uncomfortable level for speech (UCL). Audiometer was calibrated according to ANSI 1996 standards.

2. Calibrated middle ear analyzer GSI- Tympstar version 2 was used for Tympanometry and reflexometry.

3. Pentium IV computer with Adobe Audition 2.0 version software for presenting the developed test material.

Procedure: The test was carried out in two stages.

Stage I

1. Screening checklist for Auditory Processing (SCAP) developed by Yathiraj and Mascarenhas (2003) was given to the class teacher which comprises of twelve questions concerning the symptoms of deficits in auditory processing (Auditory perceptual processing, Auditory Memory and other miscellaneous symptoms). The class teacher was asked to score on a two point rating scale (Yes/No). Each answer marked 'Yes' carried one point and 'No' carried zero point. Children who scored less than 50% (< 6/12) were considered for the study (passed SCAP).

2. Pure tone thresholds were obtained at octave intervals between 250 Hz to 8000 Hz for air conduction and between 250 Hz to 4000 Hz for bone conduction (Mastoid placement) using modified version of Hughson and Westlake procedure (Carhart & Jerger, 1959). The minimum intensity at which the child was able to respond is calculated and the average was taken for 500, 1000 and 2000 Hz.

3. Speech recognition threshold was obtained using the spondee word list for children in English developed by Swarnalatha and Rathna (1972). The spondees were presented at 20 dBSL (re: PTA) and the children were asked to repeat the spondees. The minimum intensity at which the child was able to repeat two out of three spondees correctly was considered as speech recognition threshold of the child.

4. Speech identification score was carried out at 40dBSL (re: SRT) using the monosyllabic words in English developed by Rout and Yathiraj (1996). The children were instructed to repeat the words presented. Each correct response was given a score of 4%. The total correct response was calculated and termed as speech identification score.

5. Tympanometry and Reflexometry were carried out to rule out any middle ear pathology. Children were made to sit comfortably and were asked not to swallow during the testing period. Tympanometry was carried out at 226 Hz followed by acoustic reflex carried out at 500, 1000, 2000 and 4000 Hz ipsilaterally and contralaterally.

Stage II – Administration of Dichotic Word Test

The dichotic word test material was played through Pentium IV computer connected to the calibrated GSI 61 audiometer. Equipment testing was done at the beginning of each test session to ensure appropriate routing of signals, and channel balancing. Intensity setting was set to a most comfortable level (40dB SL re SRT, measured using a clinical audiometer). Each subject was asked to listen to the instructions for dichotic tasks that were recorded before each set of dichotic words on the compact disc. The children were instructed as '*You will be hearing two words, one to each ear at the same time. You should repeat both* *the words that you heard*'. Task understanding was ensured using five practice items in each list before proceeding to the real test.

Calculation of Scores for Dichotic Word Tests

The subject's responses were recorded on the scoring form. A correct response was allocated to each word that was repeated correctly, irrespective of the order required. The right-ear score (RES), left-ear score (LES) and double correct score (DCS) were calculated for both the lists. A score of one was given to each correct pair and each correct word. The possible total correct response for each test paradigm was 20 for each ear. The right-ear score was defined as the percentage of correctly repeated words in the right ear. The left-ear score was calculated in a similar manner. The double correct score was calculated as the percentage of correctly repeated words in both ears in any order.

Test Retest Reliability

The test retest reliability of dichotic word test was examined by repeating the tests on two randomly selected subjects from each age group, two to four weeks after the administration of the first test.

Analysis

The data for the dichotic word test was calculated by computing the means and standard deviations for right ear score, left ear score, and double correct score. Also, a test re-test analysis was done for the data. All the statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) 17.0 software.

4. Results and Discussion

The current study was carried out to develop Dichotic word test in English and to have a preliminary data for the developed test. In the present study, the dichotic word test has two different lists of twenty five word pairs which were administered on five groups of children from 7 years to 12 years. Each group had twenty participants with equal number of males and females. The data collected were subjected to statistical analysis using Statistical Package for the Social Sciences (SPSS) version 17.0 software. The following statistical analyses were carried out to analyze the data.

1) Descriptive statistics for lists, ear, and gender across all the age groups.

2) Mixed analysis of variance (ANOVA) was done to investigate overall list, gender, and age effects for both single correct scores and double correct scores and ear effect for single correct scores. For the ease of understanding, the detailed description of the results of the mixed ANOVA for each of these variables has been discussed separately.

3) Multivariate analysis of variance (MANOVA) was done to evaluate the age effect within each of the list.

4) Paired T test was done to investigate the ear effect and the list effect within subjects.

5) Reliability measure was done using Cronbach's Alpha test to check the reliability of the test.

List Effect

The mean, standard deviation and range for single correct scores and double correct scores were obtained for the two lists across five age groups and are represented in Table 1.

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

Age Group		Right Correct Score		Left Correct Score		Double Correct Score	
		List I	List II	List I	List II	List I	List II
7 – 7.11 years	Mean	5.85	6.00	4.25	4.45	2.30	2.25
	SD	1.59	1.29	1.25	1.66	1.52	1.86
	Range	2 - 8	4 - 8	2 - 6	1 - 8	0-5	0 - 6
8 – 8.11 years	Mean	8.15	8.80	6.55	6.50	4.45	4.95
	SD	1.42	1.64	1.14	1.31	0.68	1.57
	Range	6 - 12	6 - 12	4 - 8	4 - 8	3 - 6	2 -7
9 – 9.11 years	Mean	10.45	10.70	8.80	8.55	7.20	7.10
	SD	2.39	2.10	2.33	1.50	1.79	1.55
	Range	6 - 16	6 - 14	6 - 15	6 - 12	5 - 12	4 - 10
10 – 10.11 years	Mean	12.85	12.70	11.05	10.85	9.05	8.95
	SD	2.08	1.68	1.79	1.63	1.82	1.46
	Range	10 - 16	10 - 15	8 - 15	8 - 13	6 - 12	6 - 11
11 – 11.11 years	Mean	14.60	14.20	12.45	12.35	9.65	9.30
	SD	3.84	1.73	3.25	3.01	3.11	2.17
	Range	8 - 20	11 - 17	6 - 17	8 - 19	5 - 14	7 - 14

From the Table 1, it can be seen that the mean values between the two lists for the single correct scores and double correct scores are almost similar. There is not much variation in the mean scores between the lists. Mixed ANOVA was carried out to examine the overall list effect. Mixed ANOVA results showed no significant difference on lists for single correct scores [F (1, 90) = 0.002, $p > 0.05$] and double correct score [F (1, 90) = 0.01, $p > 0.05$] but there was an interaction seen in single correct score for the list, ear, and gender [F (1, 90) = 4.24, $p < 0.05$] and list, ear, gender, and group [F (4, 90) = 3.83, $p < 0.05$]. Hence, to explore these interactions, paired ‘t’ test was done to evaluate the difference in scores between two lists across age groups. Results for the paired t test are shown in Table 2.

Table 2.

‘t’ value, Degrees of freedom and its significance between the two lists across age groups

Age Group	Dependent variable	t - value	df	Sig. (2 tailed)
7 – 7.11 years	RCSI - RCSII	0.39	19	$p > 0.05$
	LCSI - LCSII	0.59	19	$p > 0.05$
	DCSI - DCSII	0.20	19	$p > 0.05$
8 – 8.11 years	RCSI - RCSII	1.94	19	$p > 0.05$
	LCSI - LCSII	0.19	19	$p > 0.05$
	DCSI - DCSII	1.39	19	$p > 0.05$
9 – 9.11 years	RCSI - RCSII	0.36	19	$p > 0.05$
	LCSI - LCSII	0.40	19	$p > 0.05$
	DCSI - DCSII	0.25	19	$p > 0.05$
10 – 10.11 years	RCSI - RCSII	0.28	19	$p > 0.05$
	LCSI - LCSII	0.49	19	$p > 0.05$
	DCSI - DCSII	0.21	19	$p > 0.05$
11 – 11.11 years	RCSI - RCSII	0.58	19	$p > 0.05$
	LCSI - LCSII	0.14	19	$p > 0.05$
	DCSI - DCSII	0.29	19	$p > 0.05$

Note. RCSI – Right Correct Score for List I; RCSII - Right Correct Score for List II

LCSI – Left Correct Score for List I; LCSII - Left Correct Score for List II

DCSI – Double Correct Score for List I; DCSII - Double Correct Score for List II

It can be seen from the Table 2, that the paired 't' test did not reveal significant difference between two lists for both single and double correct scores. This trend is seen in all the age groups which indicate that aligning the two words in two different channels at 0 ms lag time does not alter the performance of the subjects between the lists. Both the lists have equal difficulty and hence either of the lists can be used in clinical practice.

Gender Effect

The mean and standard deviation for males and females across the two lists for all the five age groups are calculated and are listed in Table 3.

Table 3.
Mean and Standard Deviation (SD) for males and females across lists and age group

Age Group	Gender	List I						List II					
		RCS		LCS		DCS		RCS		LCS		DCS	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
7-7.11	M	6.50	1.35	4.80	1.03	2.70	1.49	5.80	1.47	5.10	1.79	2.50	2.17
	F	5.20	1.61	3.70	1.25	1.90	1.52	6.20	1.13	3.80	1.31	2.00	1.56
8-8.11	M	8.30	1.56	6.90	1.10	4.50	0.84	8.60	1.77	6.60	1.34	5.20	1.22
	F	8.00	1.33	6.20	1.13	4.40	0.51	9.00	1.56	6.40	1.34	4.70	1.88
9-9.11	M	10.30	1.70	8.50	1.95	6.90	1.28	10.70	2.00	8.10	1.59	6.60	1.34
	F	10.60	3.02	9.10	2.72	7.50	2.22	10.70	2.31	9.00	1.33	7.60	1.64
10-0.11	M	12.90	2.28	11.50	2.12	9.60	1.64	12.50	1.17	10.70	1.70	8.10	1.44
	F	12.80	1.98	10.60	1.34	8.50	1.90	12.90	2.13	11.00	1.63	8.80	1.47
11-11.11	F	15.20	4.13	10.90	3.17	8.60	2.75	13.60	1.50	11.20	3.48	9.10	1.52
	M	14.00	3.65	14.00	2.62	10.70	3.23	14.80	1.81	13.50	2.01	10.50	2.17

Note. RCS - Right Correct Score; LCS - Left Correct Score; DCS - Double Correct Score; M - Male; F – Female.

From Table 3, it can be seen that mean scores for males and females are almost similar for single and double correct scores for both the lists. Mixed ANOVA was done to find out the overall effect on gender. Results of mixed ANOVA revealed no significant difference in gender for single correct scores [F (1, 90) = 0.243, $p > 0.01$] as well as for the double correct scores [F (1, 90) = 1.04, $p > 0.05$].

Existing literature has shown that girls have more verbal ability than boys though it is not obvious until about the age of 11 years (Maccoby, & Jacklin, 1974). Language performance is generally better among females than males, even in children as young as 2 to 3 years (Dionne, Dale, Boivin, & Plomin, 2003). Young girls, aged 1 to 5 years are more proficient in language skills, talk at an earlier age, produce longer utterances, and have larger vocabularies than boys (Ruble, & Martin, 1998; cited in Plotnik, 1999) and these advantages for verbal and written language persist even through the school years (Lynn, 1992). Although there appear to be a gender difference favoring for females, this difference is relatively small and thus has little practical significance (Hyde, 1994; cited in Plotnik, 1999). Bellis and Wilber (2001) also advocated that the gender effects on the auditory evaluation of inter-hemispheric transfer are small and clinically insignificant.

The results of the present study are also indicating that there exist no significant difference between the performance of the males and females across age and lists for the dichotic word test. The present study 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. Hence it can be concluded that boys and girls in the age range of 7 to 12 years develop in a similar manner in the way they develop binaural integration.

Age Effect

Since there was no difference in the mean scores of males and females, the data of both the gender were combined to see the age effect for both the lists. The means and standard deviation (SD) across the age groups for both the list were obtained and are represented in Table 4.

Table 4.

Mean and Standard Deviation (SD) across age groups for both the lists

Age Group		List I			List II		
		RCS	LCS	DCS	RCS	LCS	DCS
7 – 7.11 years	Mean	5.85	4.25	2.30	6.00	4.45	2.25
	SD	1.59	1.25	1.52	1.29	1.66	1.86
8 – 8.11 years	Mean	8.15	6.55	4.45	8.80	6.50	4.95
	SD	1.42	1.14	0.68	1.64	1.31	1.57
9 – 9.11 years	Mean	10.45	8.80	7.20	10.70	8.55	7.10
	SD	2.39	2.33	1.79	2.10	1.50	1.55
10 – 10.11 years	Mean	12.85	11.05	9.05	12.70	10.85	8.95
	SD	2.08	1.79	1.82	1.68	1.63	1.46
11 – 11.11 years	Mean	14.60	12.45	9.65	14.20	12.35	9.30
	SD	3.84	3.25	3.11	1.73	3.01	2.17

Note. RCS – Right Correct Score; LCS – Left Correct Score; DCS – Double Correct Score

It can be seen from the Table 4, that the mean scores for right correct scores, left correct scores and double correct scores increased as the age increased. On comparison between the ears, the right ear scores have higher scores compared to left ear scores indicating right ear advantage for both the list. Also, we can find that the mean double correct scores are lesser for all the age groups as compared to single correct scores.

Figure 1 shows a graphical representation of the statistical result. It can also be inferred from the figure 1 that the mean right ear correct score increased as the age increases from 7 to 12 years for list I. Similar trend is also seen for the mean left ear correct score and mean double correct score across the age groups. But the mean value is much lesser for double correct score compared to right ear correct score and left ear correct score.

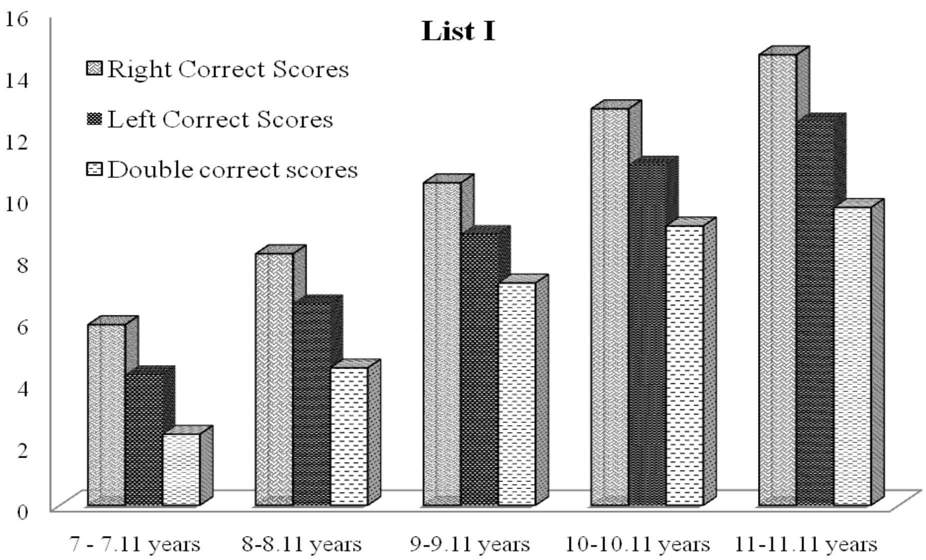

Figure 1. Mean Right Correct Scores, Left Correct Scores and Double Correct Scores across age groups for list I

Similar trend was found for the list II as shown in Figure 2. The mean scores for single correct score and double correct score increases as the age increases for both the lists.

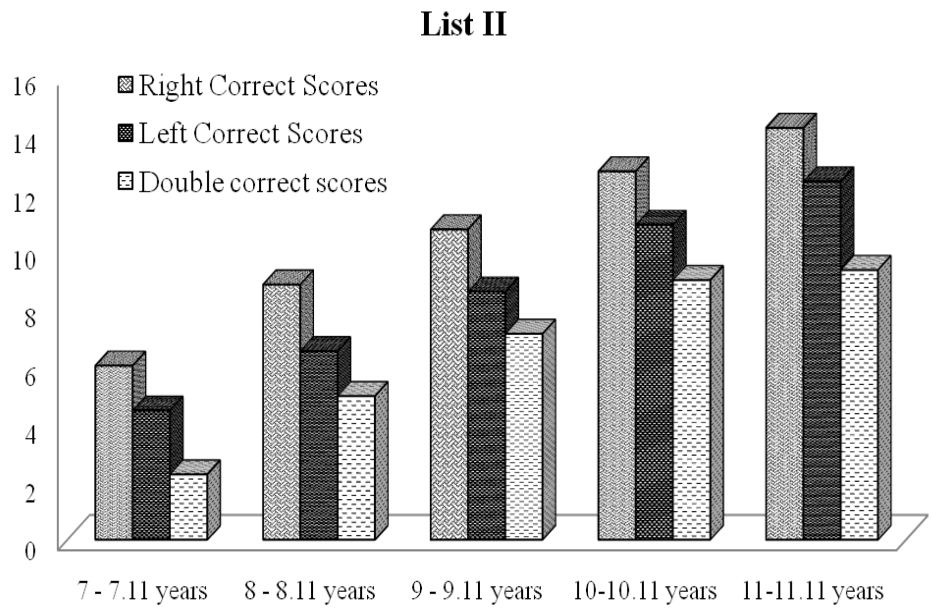

Figure 2. Mean Right Correct Scores, Left Correct Scores and Double Correct Scores across age groups for list II.

Mixed ANOVA was done to investigate overall significant difference between the groups. Results of Mixed ANOVA revealed significant effect on age [F (4, 90) = 108.48, $p < 0.001$] for the single correct scores. There was also a significant interaction for ear, gender, and group [F (4, 90) = 3.376, $p < 0.05$], and for the list, ear, gender, and group [F (4, 90) = 3.83, $p < 0.05$]. But there was no interaction seen for the list, and group [F (4, 90) = 0.24, $p > 0.05$], list, gender, and group [F (4, 90) = 0.13, $p > 0.05$], ear, and group [F (4, 90) = 0.18, $p > 0.05$], and list, ear, and group [F (4, 90) = 0.89, $p > 0.05$]. Similarly for double correct scores, there was a significant difference seen for the group [F (4, 90) = 87.83, $p > 0.01$]. However, there was no significant interaction seen for list, and group [F (4, 90) = 0.45, $p > 0.05$], gender, and group [F (4, 90) = 1.98, $p > 0.05$], and list, gender, and group [F (4, 90) = 1.36, $p > 0.05$] for the double correct score.

MANOVA was done to further investigate for the significant differences in different age groups within each list. Results of MANOVA revealed significant difference across the age groups for both single and double correct scores in both the list ($p < 0.001$). To understand which group is specifically different, Duncan Post-Hoc analysis was carried out. Means of the groups were presented in homogeneous subsets depending on the results of Post-Hoc analysis. Duncan's post Hoc analysis also shows significant difference across all the age groups at 95% of the confidence level for right ear correct scores, left ear correct scores and double correct scores. Mean scores for different age groups fall into different subsets indicating a significant difference between all the age groups.

The improvement in the dichotic word scores with the advancement of age could be due to the differential myelination of the sub-cortical and the cortical structures. Dichotic listening performances do not reach adult values until approximately 10 to 11 years of age (Yakovlev, & Lecouis, 1967; cited in Chermak & Musiek, 1997). This functional development time is consistent with the mylination time course (Yakovlev & Lecouis, 1967; cited in Chermak & Musiek, 1997). However, corpus callosum and certain auditory association areas may not have completed myelinogenisis until 10 to 12 years or older (Salamy, Mendelson, Tooley, & Chapline, 1980). Evidence shows that somatosensory evoked potentials used to measure inter-hemispheric transfer time by comparing ipsilateral to contralatral stimulation latencies indicated that the maturity of the corpus callosum ranges from 10 to 20 years of age (Salamy et al., 1980). Hayakawa et al. (1989) reported that corpus callosum becomes adult like by the age of 11 to 12 years whereas Johnson, Farnsworth, Pinkston, Bigler, and Blatter (1994) reported that the 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 is one among to show significant age related changes. Due to the delay in myelination of higher cortical structures, there is not much information transmitted to the higher level and hence scores may be reduced in the lower age group. As age increases, the myelination of the cortical structures especially the corpus callosum might get completed and the scores of the dichotic listening increases.

The present study can be compared with that of Berlin, Hughes, Lowe-Bell, and Berlin (1973), where the number of CV stimuli presented to both the right and the left ear increased significantly with age, which suggests an increase in the brain's ability to process two channel stimuli as function of age. Similar findings were seen by Willeford and Burleigh (1994) using sentences dichotically. However, ear advantage varies with the type of the stimuli used. More the linguistically load on the stimuli presented, more pronounced are the maturational effects (Bellis, 1996). The dichotic CV had higher right ear advantage (Berlin et al., 1973) where as dichotic sentences had right ear advantage which reduces as the age increases (Willeford & Burleigh, 1994).

A possible explanation for these findings lie in degree of complexity of stimuli utilized. CV nonsense syllable are less linguistically complex than sentences. As such they may require less complex processing demand on two hemispheric and inter-hemispheric connections. In contrast dichotic sentences are more linguistically loaded and hence, they may require more inter-hemispheric communication via corpus callosum as well as integrity of both temporal lobes (Bellis, 1996). But dichotic word are an open stimulus set that may result in recognition performance in the middle of the difficulty continuum i.e. neither too easy nor too difficult, yet sensitive to performance differences between ears and groups (Roup, Wiley, & Wilson, 2006).

The mean scores for left ear are reduced as compared to right ear scores. This poor left ear performance on dichotic listening in children may reflect a decreased ability of the corpus callosum to transfer complex stimuli from the right hemisphere to the left hemisphere. As the child becomes older and myelination of the corpus callosum is completed, the inter-hemispheric transfer of information improves and left ear scores approach to those obtained in adults (Musiek, Gollegly, & Baran, 1984).

The double correct scores are less compared to single correct scores in all the age groups. It is suggested that the single correct scores should be used to calculate the norms rather than double correct scores. Dermody, Mackie, and Katach (1983) also found that the double correct scores do not provide information about the differential ear effects compared to ear correct scores.

Ear Effect

The means and standard deviation (SD) for right and left ear across the age groups for both the lists are tabulated in Table 1. From Table 1, it can be inferred that mean score of right ear was greater than that of left ear in both the lists irrespective of the age groups. This indicates the presence of right ear advantage for all the age groups. Mixed ANOVA was done to investigate the difference in scores across two ears in both the lists. Results of mixed ANOVA revealed significant difference in scores between right and left ear [$F(1, 90) = 113.37$, $p < 0.01$] for both the lists. There is an interaction seen for the ear, gender, and group [F (4, 90) = 3.37, $p < 0.05$], list, ear, and gender [F (1, 90) = 4.24, $p < 0.05$] and list, ear, gender, and group [F (4, 90) = 3.83, $p < 0.05$]. Hence, Paired 't' test was administered to further evaluate difference in the scores between the two ears across age groups for both the lists. Results of the paired 't' test across the age groups are shown in Table 5. Results of paired 't' test revealed a significant difference between the right ear scores and the left ear scores for all the age groups except for the list I in 11 to 11.11 year group, where it reached a significance level and yet, did not show a significant difference.

Table 5.

Paired 't' Test showing t value and its significant difference across two ears

Age Group	Pairs	t - value	df	Sig. (2 tailed)
7 – 7.11 years	RCSI – LCSI	6.02	19	$p < 0.01$
	RCSII – LCSII	4.72	19	$p < 0.01$
8 - 8.11 years	RCSI – LCSI	5.44	19	$p < 0.01$
	RCSII – LCSII	8.15	19	$p < 0.01$
9 – 9.11 years	RCSI – LCSI	5.47	19	$p < 0.01$
	RCSII – LCSII	6.27	19	$p < 0.01$
10 – 10.11 years	RCSI – LCSI	6.28	19	$p < 0.01$
	RCSII – LCSII	7.95	19	$p < 0.01$
11 – 11.11 years	RCSI – LCSI	2.04	19	$p = 0.05$
	RCSII – LCSII	2.90	19	$p < 0.05$

Note. RCSI – Right Correct Score for List I; RCSII - Right Correct Score for List II
LCSI – Left Correct Score for List I; LCSII - Left Correct Score for List II

The presence of a right ear advantage as obtained in the present study is in accordance with the literature reported earlier (Kimura, 1961a, 1961b; Katz, 1962; Berlin et al., 1973; Wexler & Halwes 1983; Musiek et al., 1989). Converging evidence in the field of dichotic listening strongly suggests that the right ear advantage arises through mechanisms postulated by Kimura's structural model (Kimura, 1967). According to this model, the ear difference is attributed to the bilateral asymmetry in brain function as a function of stimulus type and the right ear advantage has been interpreted as resulting from rigid bottom up neural connections (Hugdahl, 2005), that is the contralateral projections of the ascending auditory system consist of more fibers and consequently produce more cortical activity than the ipsilateral projections and the fact that the left hemisphere is dominant for speech in most cases (Rasmussen, & Milner, 1977; Kandel, Schwartz, & Jessell, 1991). In addition, stronger activity in the contralateral system inhibits the processing on the ipsilateral side (Yasin, 2007) thus resulting in a better performance for the right ear than the left ear.

Right ear advantage in dichotic listening has also been attributed to the close proximity of the left temporal lobe which is closer to the left primary speech areas than the right anterior temporal lobe (Berlin et al., 1973). Hence, it is postulated that there is less transmission loss to the left posterior temporal parietal lobe on the basis of proximities within the areas of the brain. Due to this proximity there is more efficient interaction between shorter pathways (Berlin et al., 1973). Similar findings have been reported by Studdert-Kennedy and Shankweiler (1970).

In the present study, 11 to 11.11 year age group did not show significant difference between right ear and left ear scores in list I but the mean scores of right ear scores are higher compared to left ear scores and the significance level for this group was $p = 0.05$. Thus we expect that the right ear advantage was present for this age group also.

Reliability Measure

The reliability measure for 10% of the total subjects participated were analyzed using Cronbach's Alpha test in SPSS 17.0 software. The subjects were retested after a gap of two to four weeks. The results of the reliability measure are shown in Table 6.

Table 6.

Reliability measures for single correct scores and double correct scores for both the lists

Lists	Dependent variable	Alpha values
List I	Right Correct Score	0.84
	Left Correct Score	0.86
	Double Correct Score	0.81
List II	Right Correct Score	0.78
	Left Correct Score	0.76
	Double Correct Score	0.78

Table 6 reveals that all the scores obtained on dichotic word test at two different times are having an alpha value of greater than 0.7 which indicates good reliability of the test.

In conclusion, analysis of the results obtained from the present study revealed significant difference in Ear and Age but did not show significance for list and Gender. Also good reliability of the test was seen across the lists and ears.

5. Summary and Conclusions

Dichotic listening test are among the most powerful of the behavioral test battery for assessment of hemispheric function, inter-hemispheric transfer of information, and development and maturation of auditory nervous system in children and adolescents, as well as the identification of lesions of the central auditory nervous system (Keith and Anderson, 2007). Numerous studies have demonstrated that experimental dichotic listening procedures are sensitive to cerebral dysfunction due to various types of neurologic disease processes and different forms of brain injury and hence should be strongly considered for the inclusion in central test batteries (Musiek & Pinherio, 1985). This task is assessed through a variety of dichotic listening tests with digits, words and consonant-vowels (Bellis, 1996). Briefly, dichotic word listening is assessed by presenting a single word to a subject's ear, while simultaneously presenting a different word to the other ear. The dichotic digit or the sentence tests are easier and CV is the most difficult one and all these test are most sensitive to cortical lesion. Hence the present study was carried out using words which form an open stimulus set that may result in recognition performance in the middle of the difficulty continuum (Roup, Wiley, & Wilson, 2006).

The purpose of the present study was to develop a dichotic word test in English for Indian children and to establish the preliminary data. The test consists of monosyllabic words that were familiar for seven years old children. These monosyllabic words were paired in such a way that they differed in initial syllable and were either voiced or voiceless. The duration of the monosyllables was equal and these paired words were presented dichotically. The test consist of two lists of 25 monosyllables each, with five being trial or the practice words. These paired words were aligned and imposed on a stereo track in such a way that monosyllable pairs were played simultaneously in both ears.

To establish the preliminary data for developed dichotic word test, five groups of children with the age range from 7 to 12 years were taken and each group consisted of twenty children with equal number of males and females. All the children had English as the medium of instruction for at least one year, belonged to the region of Mysore, were right handed and none of them had a history of any otological or neurological disturbances. These children were initially tested with routine audiometric testing (PTA, SRT, SIS & Immittance) and Screening Checklist for Auditory Processing Disorder (SCAP) to ensure normal auditory functioning prior to the administration of the dichotic test stimuli.

Responses were scored in terms of single correct scores (right & left ear) and double correct scores. The raw data was subjected to statistical analysis. The mean and the standard deviation were also calculated for both the list across the age groups. Results of the present study are summarized below.

- There was no significant difference in list and gender for all the age groups.
- Ear advantage was present in all the age groups in both the lists and it was statistically significant
- Right ear scores were greater compared to left ear scores whereas mean double correct score values were less compared to single correct scores (Right & Left correct scores). All the correct scores (single & double correct scores) increased as the age increased for all the age groups irrespective of gender and list.

- Test retest reliability measures showed good reliability indicating the usefulness of the developed test in clinical population.

Future Research:

- The present study was done in limited population in each group (20 subjects with 10 being male and 10 being female). Hence large population should be taken in each group in future research to standardize the developed test.

- The sensitivity of the dichotic word test using the developed test stimuli in assessing the children with auditory processing disorder should be evaluated before using or incorporating in to clinical tool.

- Research done in dichotic word test is very limited in clinical population such as reading disability where it can be used as a tool to identify the poor readers. Hence further research should be done in this area to probe for difficulties faced by the children with auditory processing disorders.

6. **References**

Amala, A. J., & Yathiraj, A. (2003). *Auditory Processing in Children with History of Otitis Media*. Unpublished Master's dissertation. University of Mysore.

American National Standards Institute: ANSI S 3.1 - 1991. Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms. New York.

American Speech Language Hearing Association. (1996). Central auditory processing: Current research and implications for clinical practice. *American Journal of Audiology, 5(2),* 41-54.

American Speech Language Hearing Association. (2005). Technical report: (Central) auditory processing disorders. Retrieved February 25, 2009, from www.asha.org/members/deskref-journals/deskref/default.

American Speech-Language-Hearing Association. (2006). *Auditory Processing Disorders: Technical Report and Guidelines*. ASHA.

Asbjornsen, A. E., & Bryden, M. P. (1996). Biased attention and fused dichotic word tests. *Neurophysiologica, 34(5),* 407-11.

Ayres, J. A. (1977). Dichotic listening performance in learning disabled children. *American Journal of Occupational Therapy, 31*, 441-446.

Bamiou, D., Musiek, F. E. & Luxon, L. M. (2001). A etiology and clinical presentations of auditory processing disorders: a review. *Archives of Disease in Childhood, 85,* 361-365.

Baran, J. A. & Musiek, F. E. (1991). Behavioral assessment of the central auditory nervous system. In W. F. Rintelmann (Eds.), *Hearing Assessment*. Austin, TX: Pro-ed, 549-602.

Bayazit, O., Oniz, A., Ozgoren, M., & Gunturkun, O. (2008). Electrophysiological assessment of brain asymmetry using a dichotic listening paradigm. *New Symposium, 46(3)*, 130-136.

Bellis, T. J. (1996). *Assessment and management of central auditory processing disorders in the educational setting from science to practice*. San Diego: Singular Publishing Group, Inc.

Bellis, T. J. (2003). *Assessment and management of central auditory processing disorders in the educational setting from science to practice* (2^{nd} Ed.). San Diego: Singular Publishing Group, Inc.

Bellis, T. J., & Wilber, L. A. (2001). Effects of aging and gender in interhemispheric function. *Journal of Speech Language and Hearing Research, 44(2),* 46-63.

Berlin, C. I. (1976). New developments in evaluating central auditory mechanisms. *Annuals of Otorhinolaryngology,* 85, 833-841.

Berlin, C. I., Hughes, L., Lowe-Bell, S., & Berlin, H. (1973). Dichotic right ear advantage in children 5 to 13. *Cortex, 9,* 393 - 401.

Berlin, C. I., Lowe-Bell, S. S., Cullen, J. K., Thompson, C. L., & Loovis, F. (1973). Dichotic speech perception: An interpretation of right ear advantage and temporal offset effects. *Journal of the Acoustical Society of America, 53(3),* 699-709.

Berlin, C. L., Lowe-Bell, S. S., Jannetta, P. J., & Kline, D. G. (1972). Central auditory deficits after temporal lobectomy. *Archives of Otolaryngology, 96,* 4-10.

Berlin, C., & Lowe, S. (1972). Temporal and dichotic factors in central auditory testing. In J. Katz (Eds.), *Handbook of clinical audiology (1^{st} Ed.)*. Baltimore: Williams & Wilkins, 280-312.

Bloch, M.I., & Hellige, J.B. (1989). Stimulus intensity, attentional instructions, and the ear advantage during dichotic listening. *Brain and Cognition, 9(1),* 136-48.

Blumstein, S., & Spellicy, F. (1970). Ear preference for language and non-language sounds: a unilateral brain function. *Journal of Audiological Research, 10,* 349-355.

de Bode, S., Sininger, Y., Healy, E. W., Mathern, G. W., & Zaidel, E. (2007). Dichotic listening after cerebral hemispherectomy: Methodological and theoretical observations. *Neuropsychologia, 45(11),* 2461–2466.

Borod, J. C., & Goodglass, H. (1980). Lateralization of linguistic and melodic processing with age. *Neuropsychologia, 18(1),* 79-83.

Branch, D., Milner, B., & Rasmussen, T. (1964). Intracarotid sodium amytal for the lateralization of cerebral speech dominance. *Journal of Neurosurgery*, *21*, 399-405.

Briggs, G. G., & Nebes, R. D. (1976). The effects of handedness, family history, and sex on performance of a dichotic listening task. *Neuropshychologia, 14,* 129-134.

Broadbent, D. E. (1954). The role of auditory localization in attention and memory span. *Journal of Experimental Psychology, 47(3),* 191-196.

Carhart, R., & Jerger, J. (1959). Preferred method for clinical determination of pure-tone thresholds. *Journal of Speech and Hearing Disorder, 24*, 330-345.

Carr, B. M. (1969). Ear effect variables and order of report in dichotic listening. *Cortex, 5,* 63-68.

Chermak, G. D., & Musiek, F. E. (1997). *Central auditory processing disorders: New Perspectives.* San Diego, California: Singular Publishing Group.

Chermak, G. D., & Musiek, F. E. (1998). In Young, M. L. Recognizing and Treating Children with Central Auditory Processing Disorders. Retrieved April, 14, 2009, from www.scilearn.com/alldocs/mktg/10035-952MYoungCAPD.pdf.

Clark, L. E., & Knowles, J. B. (1973). Age differences in dichotic listening performance. *Journal of Gerontology, 28(2),* 173-78.

Committee for Hearing, Bioacoustics and Biomechanics (CHABA). (1988). Working Group on Speech Understanding and Aging. *Journal of the Acoustical Society of America, 83*, 859-894.

Cullen, S., Thompson, C. L., Hughes, L. F., Berlin, C. I., & Samson, D. S. (1974). The effect of varied acoustic parameters on performance in dichotic perception tasks. *Brain and Language, 1,* 307-322.

Cutting, J. E. (1974). Two left-hemisphere mechanisms in speech perception. *Perception and Psychophysics, 16(3),* 601-612.

Damasio, H., Damasio, A., Castro-Caldus, A., & Ferro, J. M. (1976). Dichotic listening pattern in relation to interhemispheric disconnection. *Neuropsychologica*, *4*, 247-250.

Darwin, C. (1969). Laterality effects in the recall of steady states and transient speech sounds. *Journal of the Acoustical Society of America, 46,* 114.

Darwin, C. J. (1971). Ear differences in the recall of fricatives and vowels. *The Quarterly Journal of Experimental Psychology*, *23(1),* 46-62.

Dempsey, C. (1983). Selecting tests of auditory function in children. In J. Katz (Eds.), *Central auditory processing disorders: Problems of speech, language, and learning* (pp. 203-221). Baltmore: University Park press.

Dermody, P., Mackie, K., & Katach, R. (1983). Dichotic listening in good and poor readers. *Journal of Speech, Language, and Hearing Research*, *26,* 341-348.

Dionne, G., Dale, P. S., Boivin, M., & Plomin, R. (2003). Genetic evidence for bidirectional effects of early lexical and grammatical development. *Child Development, 74,* 394-412.

Friedman, M. S., Bruder, G. E., Nestor, P. G., Stuart, B. K., Amador, X. F., & Gorman, J. M. (2001). Perceptual asymmetries in schizophrenia: Subtype differences in left hemisphere dominance for dichotic fused words. *American Journal of Psychiatry, 158,* 1437-1440.

Gramstad, A., Engelsen, B. A., & Hugdahl, K. (2006). Dichotic listening with forced attention in patients with temporal lobe epilepsy: Significance of left hemisphere cognitive dysfunction. *Scandinavian Journal of Psychology, 47(3),* 163-170.

Haggard, M. P. (1971). Encoding and the REA for speech signals. *The Quarterly Journal of Experimental Psychology*, *23(1),* 34-45.

Hallgren, M. (2005). *Hearing and cognition in speech comprehension: Methods and applications.* Unpublished Doctoral Thesis. Linkoping University.

Halpern, D. F. (2000). *Sex differences in cognitive abilities (Rev. 3rd Ed.)* Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Halperin, Y., Nachshon, I., & Carmon, A. (1973). Shift of ear superiority in dichotic listening to temporally patterned non-verbal stimuli. *Journal of the Acoustical Society of America*, *53*, 46-50.

Handel, S. (1989). *Listening: An introduction to the perception of auditory events.* Cambridge, MA: The MIT press.

Hayakawa, K., Konishi, Y., Matsuda, T., Kuriyama, M., Konishi, K., Yamashita, K., Okumura, R., & Hamanaka, D. (1989). Development and aging of brain midline structures: Assessment with MR imaging. Neuro*radiology, 172,* 171-177.

Hugdahl, K. (1995). Dichotic Listening: Probing temporal lobe functional. In R. J. Davidson & K. Hugdahl (Eds.), *Brain asymmetry* (pp. 123-156). Cambridge, MA, USA: MIT Press.

Hugdahl, K. (2005). Dichotic listening in the study of auditory laterality. In K. Hugdahl & R. J. Davidson (Eds.), *The asymmetrical brain* (pp. 441-476). Cambridge, MA, USA: MIT Press.

Hughdahl, K. (2008). The effect of stimulus intensity on the right ear advantage in dichotic listening. *Neuroscience letters, 431,* 90-4.

Hugdahl, K., & Andersson, L. (1984). A dichotic listening study of differences in cerebral organization in dextral and sinistral subjects. *Cortex*, *20(1),* 135-141.

Hugdahl, K., Carlsson, G., & Eichele, T. (2001). Age Effects in Dichotic Listening to Consonant-Vowel Syllables: Interactions with Attention. *Developmental Neuropsychology, 20(1),* 445-457.

Jancke, L. (1993). Do ear advantage s cores obtained in a consonant-vowel recall test vary with respect to the required response condition? *Neurophysiologica, 31(5),* 499-501.

Jerger, J. (2006). Auditory Processing Disorder in Children. *Journal of the American Academy of Audiology*, *17(4),* 304-305.

Jerger, J., Chmiel, R., Allen, J., & Wilson, A. (1994). Effects of age and gender on dichotic sentence identification. *Ear and Hearing, 15*, 274-286.

Jerger. J., & Musiek, F. (2000). Report of the consensus conference on the diagnosis of auditory processing disorders in school-aged children. *Journal of the American Academy of Audiology, 11,* 467-474.

Johnson, C. S., Farnsworth, T., Pinkston, J. B., Bigler, E. D., & Blatter, D. D. (1994). Corpus Callosum surface area across the human adult life span: Effect of age and gender. *Brain Research Bulletin, 35,* 373-377.

Johnson, L. K., & Ryan, W. J. (1975). Test-retest performance of males and females on a verbal dichotic listening task. *Journal of the Acoustical Society of America, 58,* 679-684.

Kalil, K. M. (1994). Is there a sex difference in human laterality? An exhaustive survey of auditory studies from six neuro- psychological studies. *Journal of Clinical and Experi- mental Neuropsychology, 16,* 423-435.

Kandel, E. R., Schwartz, J. H. & Jessell, T. M. (1991). *Principles of Neural Science.* East Norwalk, Connecticut: Appleton & Lange.

Katz, J. (1962). The use of staggered spondaic words for assessing the integrity of the central auditory system. *Journal of Auditory Research, 2,* 327-337.

Katz, J. (2002). *Handbook of Clinical Audiology*. Udgave, USA: Lippincott Williams & Wilkins.

Katz, J., Stecker, N. A., & Henderson, D. (1992). Introduction to central auditory processing. In J. Katz, N.A. Stecker, & D. Henderson, (Eds.), *Central auditory processing: A Tran disciplinary view* (pp. 3 - 8). St. Louis: Mosby Year Book, Inc.

Keith R. (1995). Tests of Central Auditory Processing. In: Roeser, R.J., & Downs, M.P. (3rd eds.) *Auditory Disorders in School Children* (pp. 101-116). New York: Thieme Medical Publishers, Inc.

Keith, R. W. (2000). Diagnosing central auditory processing disorders in children. In R. J. Roeser, M. Valente, & H. Hosford-Dunn, (Eds.) *Audiology Diagnosis* (pp. 337-353). New York: Thieme Medical Publishers.

Keith, R. W., & Anderson, J. (2007). Dichotic listening tests. In Musiek, F. E., & Chermak, G. D. (Eds), *Handbook of central auditory processing disorder, auditory neuroscience and diagnosis* (Vol. I, Ch. 9, pp. 208). United Kingdom: Plural Publishing Inc.,

Kimura, D. (1961a). Cerebral dominance and the perception of verbal stimuli. *Canadian Journal of Psychology, 15,* 166-171.

Kimura, D. (1961b). Some effects of the temporal lobe damage on auditory perception. *Canadian Journal of Psychology, 15,* 157-165.

Kimura, D. (1967). Functional asymmetry of the brain in dichotic listening. *Cortex, 3(2),* 163-178.

Kolb, B., & Whishaw, I. Q. (1990). *Fundamentals of Human Neuropsychology*. New York: W.H. Freeman.

Krishna, G., & Yathiraj, A. (2001). *Dichotic CV revisited: Oral Vs Written response.* Unpublished paper presented at XXXIII National conference of Indian Speech and Hearing Association (ISHA), Hyderabad, India.

Lake, D. A., & Bryden, M. P. (1976). Handedness and sex differences in hemispheric asymmetry. *Brain and Language, 3,* 266-282.

Lamm, O., Share, D. L., Shatil, E., & Epstein, R. (1999). Kindergarten Dichotic Listening as a Predictor of First-grade Reading Achievement. *Dyslexia, 5*, 138-154.

Larsby, B., Hallgren, M., & Arlinger, S. (2000). A system for recording of Auditory Evoked Responses. *Technology and Health Care, 8,* 315-326.

Lowe, S., Cullen, J., Berlin, C., Thompson, C., & Willett, M. (1970). Perception of simultaneous dichotic and monotic monosyllables. *Journal of Speech Hearing and Research, 13,* 812-822.

Lynn R. (1992). Sex differences on the differential aptitude test in British and American adolescents. *Educational Psychology, 12,* 101-106.

Maccoby, E. E. & Jacklin, C. N. (1974). *The psychology of sex differences.* Stanford, CA: Stanford University Press.

Martin, J. S., & Jerger, J. F. (2005). Some effects of aging on central auditory processing. *Journal Rehabilitative Research Development, 42(4, Suppl. 2),* 25-44.

Merrell, H., & Atkinson, C. J. (1965). The effect of selected variables in discrimination scores, *Journal of Auditory Research, 5,* 285-298.

Meyers, J. E., Roberts, R. J., Bayless, J. D., Volkert, K., & Evitts, P. E. (2002). Dichotic listening: expanded norms and clinical application. *Archives of Clinical Neuropsychology, 17,* 79-90.

Milner, B., Taylor, S., & Sperry, R. (1968). Lateralized suppression of dichotically presented digits after commissural section in man. *Science, 161,* 184-185.

Moller, A. E. (2007). *Dichotic word recognition of young adults in noise.* Unpublished Senior Honor Thesis, Ohio State University. Retrieved 11 December, 2008, from https://kb.osu.edu/dspace/bitstream/1811/28361/1/Elizabeth_Moller.pdf.

Moncrieff, D. (2002). Binaural Integration: An Overview. Retrieved April 14, 2009, from http://www.audiologyonline.com/articles/article_detail.asp?article_id=396.

Moncrieff, D. W., & Black, J. R. (2008). Dichotic listening deficits in children with dyslexia. *Dyslexia, 41(1),* 54-75.

Moncrieff, D., & Musiek, F. (2002). Interaural asymmetries revealed by dichotic listening tests in normal and Dyslexic children. *Journal of the American Academy Audiology, 13,* 428- 43.

Mondor, T. A., & Bryden, M. P. (1991). The influence of attention on the dichotic REA. *Neuropsychologia, 29,* 1179-1190.

Musiek, F. E. (1983b). Results of three dichotic speech tests on subjects with intracranial lesions. *Ear and Hearing, 4(6),* 318- 23.

Musiek, F. E., & Pinheiro, M. (1985). Dichotic speech tests in the detection of central auditory dysfunction. In M. Pinheiro, & F. Musiek (Eds.). *Assessment of central* *auditory dysfunction: Foundation and clinical correlates* (pp. 201-209). Baltimore: Williams and Wilkins.

Musiek, F. E., Gollegly, K., & Ross, M. (1985). Profiles of types of central auditory processing disorder in children with learning disabilities. *Journal of Childhood Communication Disorders, 9*, 43-63.

Musiek, F. E., Kurdziel-Schwan, S., Kibbe, K. S., Gollegly, K. M., Baran, J. A., & Rintelmann, W. F. (1989). The dichotic rhyme test: results in spilt brain patients. *Ear and Hearing, 10,* 33-39.

Musiek, F.E. (1983a). Assessment of central auditory dysfunction: The Dichotic Digit test revisited. *Ear and Hearing, 4,* 79-83.

Musiek, F.E. (1999). Central auditory tests. *Scandinavian Audiology, 51(Suppl.),* 33 - 46.

Musiek, F.E. (2005). Differential attention effects on dichotic listening. *Journal of the American Academy of Audiology, 16,* 205-18.

Musiek. F. M., Gollegly, K. M., & Baran, J. A. (1984). Mylienation of corpus callosam and auditory processing problem in children: Theoretical and Clinical correlates. *Seminars in Hearing, 5,* 231-241.

Nachshon, I., & Carmon, A. (1975). Stimulus familiarity and ear superiority in dichotic listening. *Journal of the Acoustical Society of America, 57(1),* 223-227.

Neijenhuis, K., Tschur, H., & Snik, A. (2004). The effect of mild hearing impairment on auditory processing tests. *Journal of the American Academy of Audiology, 15,* 6-16.

Nelson, D. A., & Chaiklin, J. B. (1970). Written down versus talkback scoring biases in speech discrimination test, *Journal of Speech and Hearing Research, 13*, 645-654.

Noffsinger, D., Martinez, C. D., & Wilson, R. H. (1994). Dichotic listening to speech: Background and normative data for digits, sentences, and nonsense syllables (CVs). *Journal of the American Academy of Audiology, 5,* 248-254.

Noffsinger, D., Olsen, W.O., Carhart, R., Hart, C., & Sahgal, V. (1972). Auditory and Vestibular aberrations in multiple sclerosis. *Acta Otolaryngologica, 303 (Suppl.),* 1-63.

Obrzut, J. E., & Hynd, G. W. (1981). Cognitive Development and Cerebral Lateralization in Children with Learning Disabilities. *International Journal of Neuroscience, 14(3, 4),* 139-145.

Obrzut, J. E., Bolick, C. A., & Obrzut, K. (1986). The effect of stimulus type and directed attention on dichotic listening with children. *Journal of Child Psychology, 41((1),* 198-209.

Pettit, J. M., & Helms, S. B. (1979). Hemispheric Language Dominance of Language-Disordered, Articulation-Disordered, and Normal Children. *Journal of Learning Disabilities, 12(2),* 71-76.

Plotnik, R. (1999). *Introduction to psychology*. New York: Wads Worth Publishing Company.

Porter, R. J., Trondle, R., & Berlin, C.I. (1976). Effects of practice on perception of dichotically presented stop consonant-vowel syllables. *Journal of the Acoustical Society of America, 59,* 679-684.

Prachi, P.P. & Yathiraj, A. (2000). *Dichotic CV test-revised normative data for adults.* Unpublished Independent project. University of Mysore.

Prior, M. R., Cumming, G., & Hendy. J. (1984). Recognition of abstract and concrete words in a dichotic listening paradigm. *Cortex, 20*, 149-157.

Pujal, J., Vendrell, P., Junque, C., Marti-Vilalta, J. L., & Capdevila, A. (1993). When does human brain development end? Evidence of corpus callosum growth up to adulthood. *Annals of Neurology, 34,* 71-75.

Rajagopal, L., Ganguly, L., & Yathiraj, A. (1996). *Phonemic analysis of consonants on a dichotic consonant vowel test.* Unpublished paper presented at the XXVII National conference of Indian Speech and Hearing Association (ISHA), Coimbatore, India.

Ramaa, S. (1985). *Diagnosis and Remediation of Dyslexia.* Unpublished Doctorate Thesis. University of Mysore.

Ramaa, S. (2000). Dyslexia news world: Two decades of research non learning disabilities in India. *Dyslexia, 6,* 268-283.

Ramakrishna, B. S., Nair, K.K., Chiplunkar, V. N., Atal, B. S., Ramachandran, V., & Subramanian, R. (1962). Relative efficiencies of Indian languages. Some aspects of the relative efficiencies in Indian languages (pp. 34). Indian Institute of Science, Bangalore.

Rasmussen, T. & Milner, B. (1977). The role of early left-brain injury in determining lateralization of cerebral speech functions. *Annals of the* New York *Academy of Sciences, 299,* 355–369.

Regishia, A., & Yathiraj, A. (2003). *Effect of maturation on dichotic tests: A comparison of Dichotic Digit and Dichotic Consonant Vowel Test.* Unpublished Independent Project. University of Mysore.

Repp, B. (1976). Identification of dichotic fusions. *Journal of the Acoustical Society of America, 60,* 456-469.

Rimol, L. M., Eichele, T., & Hugdahl, K. (2006). The effect of voice-onset-time on dichotic listening with consonant-vowel syllables. *Neuropsychologia, 44(2),* 191-6.

Roberts, M. A., Persinger, M. A., Grote, C., Evertowski, L. M., Springer, J. A., Tuten, T., Moulden, D., Franzen, K. M., Roberts, R. J., & Bagho, C. S. (1994). The Dichotic Word Listening Test: Preliminary observations in American and Canadian samples. *Applied Neuropsychology, 1(1),* 45-56.

Roeser, R. J., Johns, D. F., & Prince, L. L. (1976). Dichotic listening in adults with sensori neural hearing loss. *Journal of the American Academy of Audiology, 2,* 19-25.

Roeser, R.J., Johns, D.F., & Prince, L.L. (1972). Effects of intensity on dichotically presented digits. *Journal of Audiological Research, 12,* 184-186.

Roup, C. M., Wiley, T. L., & Wilson, R. H. (2006). Dichotic word recognition in young and older adults. *Journal of the American Academy of Audiology, 17,* 230-240.

Rout, A., & Yathiraj, A. (1996). *Monosyllabic speech identification test in English for the Indian children.* Unpublished Master's Dissertation. University of Mysore.

Ryan, W., & McNeil, M. (1974). Listener reliability for a dichotic task. *Journal of the Acoustical Society of America*, *56,* 1922-1923.

Salamy, A., Mendelson, T., Tooley, W., & Chapline, E. (1980). Differential development of brainstem potentials in healthy and high risk infants. *Science, 210,* 553-555.

Sandmann, P., Eichele, T., Specht, K., Jancke, L., Rimol, L. M., Nordby, H., & Hugdahl, K. (2007). Hemispheric asymmetries in the processing of temporal acoustic cues in consonant–vowel syllables. *Restorative Neurology and Neuroscience*, *25(3–4),* 227-240.

Santucci, G. (2003). Lecture presented at Washington University, St. Louis.

Sauer, L., Pereira, L. D., Ciasca, S. M., Pestun, M., & Guerreiro, M. M. (2006). Dichotic listening and spect in dyslexic children. *Arquivos de neuro-psiquiatria (Arq Neuropsiquiatr), 64(1),* 108-11.

Schilder, A. G., Snik, A. F., Straatman, H., & Van den Broek, P. (1994). The effect of otitis media with effusion at preschool age on some aspect of auditory perception at school age. *Ear and Hearing, 15(3),* 224-231.

Schminky, M. M., & Baran, J. A. (1999). Central Auditory Processing Disorders: An Overview of Assessment and Management Practices. *Deaf-Blind perspectives Newsletter, 7(1),* 1-6. Retrieved March 23, 2009, from http://www.tr.wou.edu/tr/dbp/pdf/sept99.pdf.

Schminky, M. M., & Baran, J. A. (2000). *Central Auditory Processing Disorders – An Overview of Assessment and Management Practices*. (vol. 5, no. 2). See/Hear Newsletter. Retrieved April 5, 2009, from *www.tsbvi.edu/Outreach/seehear/spring00/centralauditory.htm*.

Sequeira, S. D. S., Specht, K., Hamalainen, H., & Hugdahl, K. (2008). The effects of background noise on dichotic listening to consonant-vowel syllables. *Brain and Language*, *107(1),* 11-15.

Shivashankar, N., & Herlekar, G. (1991). Dichotic Digit Test in Intracranial lesions. *Journal of the Indian speech and Hearing Association, 8,* 67-71.

Singh, S., & Black, J. W. (1966). Study of twenty- six intervocalic consonants as spoken and recognized by four language groups. *Journal of the Acoustical Society of America, 39*, 372-387.

Sivaprasad, B., & Yathiraj, A. (2006). *Binaural fusion test in English for children.* Unpublished Master's dissertation, University of Mysore.

Sommer, I. E., Alemanc, A., Somers, M., Boks, M. P., & Kahn, R. S. (2008). Sex difference in handedness, asymmetry of the planum temporale and the functional language lateralization. *Brain Research*, 1206, 76-88.

Speaks, C., & Bissonette, L. (1975). Interaural-Intensive differences and dichotic listening. *Journal of the Acoustical Society of America, 58,* 893-898.

Speaks, C., & Jerger, J. (1965). Method for measurement of speech identification. *Journal of Speech Hearing and Research, 8,* 185 - 194.

Speaks, C., Gray, T., & Miller, J. (1975). Central auditory deficits and temporal-lobe lesions. *Journal of Speech and Hearing Disorders, 40,* 192-205.

Speaks, C., Niccum, M., & Tasell, D.V. (1985). Effect of stimulus material on the dichotic listening on patients with sensorineural hearing loss. *Journal of Speech and Hearing Research, 28,* 1625.

Stach, B. A. (1998). *Clinical Audiology: An Introduction*. San Diego: Singular Publishing Group, Inc.

di Stefano, M., Maramno, E., & Viti, M. (2004). Stimulus-Dominance effects and lateral asymmetries for language in normal subjects and in patients with single functional hemisphere. *Brain and Cognition, 56,* 55-62.

Stockley, K. B., & Green, W. B. (2000). Inter-list equivalency of the Northwestern University Auditory Test No. 6 in quiet and noise with adult hearing-impaired individuals. *Journal of the American Academy of Audiology, 11*, 91-96.

Stollman, M. H. P., Neijenhuis, K. A. M., Jansen, S., Simkens, H. M. F., Snik, F. M., & van den Broek, P. (2004). Development of an auditory test battery for young children: a pilot study, *International Journal of Audiology, 43(6),* 330-338.

Strouse, A. L., & Wilson, R. H. (1999a). Stimulus length uncertainty with dichotic digit recognition. *Journal of the American Academy of Audiology, 10,* 219-229.

Strouse, A. L., & Wilson,R. H. (1999b). Recognition of 1-, 2-, and 3-pair dichotic digits under free and directed recall. *Journal of the American Academy of Audiology, 10,* 557-571.

Strouse, A., Wilson, R. H., & Brush, N. (2000). Effect of order bias on the recognition of dichotic digits in young and elderly listeners. *Audiology, 39*, 93-101.

Studdert-Kennedy, M., & Shankweiler, D. (1970). Hemispheric specialization for speech perception. *Journal of the Acoustical Society of America, 48,* 579-594.

Swarnalatha, C., & Rathna, N. (1972). *The development and standardization of speech test material in English for Indians.* Unpublished Master's dissertation. University of Mysore.

Tallus, J., Hugdahl, K., Alho, K., Medvedev, S., & Hamalainen, H. (2007). Interaural intensity difference and ear advantage in listening to dichotic consonant-vowel syllable pairs. *Brain Research, 1185,* 195-200.

Tobey, E. A., Cullen, J. K., & Rampp, D. L. (1979). Effects of stimulus-onset asynchrony on the dichotic performance of children with auditory-processing disorders. *Journal of Speech and Hearing Research, 22,* 197-211.

Troast, C., Shewan, T., Nathanson, P., & Samt, K. L. (1968). In Keith, R. (Eds), C*entral Auditory Dysfunction.* NewYork, Grune & Stratton.

Voyer, D., & Techentin, C. (2009). Dichotic listening with consonant–vowel pairs: The role of place of articulation and stimulus dominance. *Journal of Phonetics. 37(2),* 162-172.

Weiss, H. S., & House, A. S. (1973). Perception of dichotically presented vowels. *Journal of the Acoustical Society of America, 53,* 51-58.

Wexler, B., & Halwes, T. (1983). Increasing the power of dichotic methods: the fused rhymed words test. *Neuropsychologia, 21,* 59-66.

Willeford, J. A., & Burleigh, J.M. (1985). *Handbook of central auditory processing disorders in children.* Orlando, FL; Grune & Stratton.

Willeford, J. A., & Burleigh, J. M. (1994). Sentence procedures in central testing. In J. Katz (ed). *Handbook of clinical audiology*. (4thed, 256-268). Baltimore, Williams & Wilkins.

Wilson, R. H., & Jaffe, M. S. (1996). Interactions of age, ear, and stimulus complexity on dichotic digit recognition. *Journal of the American Academy of Audiology*, *7,* 358-364.

Wilson, R. H., & Leigh, E. D. (1996). Identification by Right and Left handed Listeners on Dichotic CV Materials. *Journal of the American Academy of Audiology*, *7,* 1-6.

Yasin, I. (2007). Hemispheric differences in processing dichotic meaningful and non-meaningful words. *Neuropsychologia*, *45*, 2718-2729.

Yathiraj, A., & Mascarenhas, K. E. (2003). *Effect of auditory stimulation in central auditory processing in children with central auditory processing disorder.* AIISH Research Fund, All India Institute of Speech and Hearing, Mysore.

Zaehle, T., Jancke, L., & Meyer, M. (2007). Electrical brain imaging evidences left auditory cortex involvement in speech and non-speech discrimination based on temporal features. *Behavioral Brain Function*, *3*, 63.

Appendix

Dichotic word pairs			
List I		**List II**	
Right	*Left*	*Right*	*Left*
Trial words	*Trial words*	*Trial words*	*Trial words*
Crow	Pig	Live	Had
Loud	Rose	Smooth	Shout
Cage	Sell	Box	Star
Smile	Close	Teach	Shirt
Keep	Frog	Hunt	Wife
Test words	*Test words*	*Test words*	*Test words*
Name	Real	Pen	Thin
Will	New	Raw	Well
Bird	Dog	Save	Fix
Start	Choice	Cap	Fat
Root	Bowl	Bath	Done
Yes	Hole	White	Neck
Cup	Ten	Long	Van
Did	Him	Class	Front
Give	Love	Rest	Gun
Moon	Youth	Please	Wheat
Fan	Case	Guess	Road
Coat	Take	Jar	Duck
Shell	Comb	Note	Rain
Gum	Hit	Tell	Key
Soup	Fish	Nice	Wire
Match	Dress	Dish	Bat
Nine	Hurt	Make	Ring
Ride	Join	Home	Drop
Chair	Team	Bad	Rat
Voice	Neat	Talk	Chain