EFFECT OF FILTERING AND COMPRESSION ON RIGHT EAR ADVANTAGE

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A Dissertation Submitted in Part Fulfilment of Final Year

Master of Science (Audiology)

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June - 2011

CERTIFICATE

This is to certify that this dissertation entitled "***Effect of filtering and compression on right ear advantage***" is a bonafide work submitted in part fulfilment for the degree of Master of Science (Audiology). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree.

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June, 2011

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CERTIFICATE

This is to certify that this dissertation entitled "***Effect of filtering and compression on right ear advantage"*** has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

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DECLARATION

This is to certify that this master's dissertation entitled "***Effect of filtering and compression on right ear advantage"*** is the result of my own study under the guidance of **Mr. Niraj Kumar Singh**, Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore **Register No. 09AUD011**

June, 2011

Dedicated To:

Lord Ganesha,

AND

To the people who mean the world to me, my dear parents, brother and my dear friends Chai, Ashu, Anoop. U guys are the best!!!!!!

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CHAPTER 1

INTRODUCTION

Communication through speech is a process unique to humans. Human auditory system is a dynamic system that performs a remarkable job right from converting the incident physical pressure waves into neural impulses at the peripheral level, to analyzing the input information resulting in understanding of the underlying message at the central level. There is existence of special, localized neural mechanism for speech and language processing.

Central auditory processing:

Central auditory processing is the efficiency and effectiveness by which the central nervous system utilizes the auditory information. It encompasses perceptible processing of the auditory information in the central nervous system and the neuro-biologic activity that underlies that processing and gives rise to electrophysiologic auditory potentials (ASHA 2005). These include sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition such as temporal integration, temporal discrimination, temporal ordering, temporal masking, as well as auditory performance with degraded acoustic signal. Major processes involved are discussed below in brief

Binaural interaction:

Binaural interaction refers simply to the way in which the two ears work together. Functions that rely on behavioral interaction include localization and lateralization, binaural release from masking, detection of signal in noise and binaural fusion (Durlach, Thompson and Colburn, 1981)

Temporal processing:

Auditory temporal processing can be defined as the perception of sound or alteration of sound within a restricted time domain (Musiek, Shinn, Jirsa, Baran and Zaiden 2005). Temporal processing is important in wide variety of everyday listening tasks, including speech perception and perception of music.

Binaural integration and binaural separation:

Binaural integration involves processing of information presented to the two ears simultaneously, with the information being presented to the two ears being different from one another. Binaural separation refers to the process of attending to the stimulus presented to one ear while ignoring the stimulus in the opposite ear. Both these processes are important while encountering everyday situations, where person might be in a situation where he has to attend to two persons speaking, or at certain times when he has to ignore unimportant message and pay attention to the one that is required. This is typically assessed through dichotic speech tests that span the linguistic continuum from consonant vowel syllables to sentences.

Dichotic listening:

The term dichotic refers to the simultaneous presentation of two different auditory stimuli to the two ears (Bellis, 1996, 2003; Chermak and Musiek, 1997). Thus, dichotic listening literally means listening to two different signals at the same time, one in each ear. Depending on the instructions given to the listener, dichotic tasks may assess the process of binaural integration or binaural separation. To assess the former, subject is instructed to listen to and repeat back the stimuli presented to both the ears. In the latter task, the subject only repeats what is presented to the ear designated by the examiner. The literature has abundance of research on laterality effects in normal populations using the dichotic listening procedure (Obrzut et al, 1980; Hugdahl 1999).

Various dichotic listening tasks have been used to measure language laterality. Dichotic tasks differ in acoustic content, memory load, and response format which may be tapping different aspects of information processing and laterality (Berlin and McNeil 1976). Dichotic tests include: Dichotic digit test (Musiek, 1983; Shivashankar and Herlekar, 1991); Dichotic consonant vowel test (Berlin Lowe bell et al., 1973; Yathiraj, 1999); Dichotic sentence identification test (Keith, 2000); Staggered spondaic word test (Katz, 1962; Chandrashekar, 1973); Competing sentence tests (Willeford, 1977; Keith, 1998); Competing words (Keith, 2000).

Most consistent finding in dichotic tests are presence of right ear advantage. The term right ear advantage (REA) refers to obtaining more correct responses of verbal stimuli administered to the right than to the left ear during dichotic listening when the subject is asked to report what is being heard in a free recall procedure. Right ear advantage in dichotic speech perception is a well-documented phenomenon (Kimura, 1961, 1967; Studdert-Kennedy et al., 1966; Darwin 1969; Berlin 1972). Different varieties of the dichotic listening tests have revealed a clear right-ear advantage (REA), with corresponding left hemisphere dominance for digits, words, nonsense syllables, formant transitions, backward speech, Morse code, difficult rhythms, phonological tone, and many other speech and language-related stimuli. Satz (1976) reported that a strong REA is an extremely probable predictor of left hemisphere specialization for speech and language function.

Need for the study:

Differential effects in performance in dichotic speech recognition tasks have been found secondary to the amount of lexical content introduced by the stimulus used in the task (Carter & Wilson, 2001; Dirks, et al., 2001; Studdert-Kennedy & Shankweiler, 1970), the amount of cognitive loading introduced by the test response condition, the age of the listener and so on (Carter and Wilson, 2001; Hugdahl and Andersson, 1986; Carlsson, and Eichele, 2001)

Dichotic speech recognition studies that have included a wide range of stimuli have shown a systematic change in the overall performance and ear advantage as a function of phonetic and lexical content. Specifically, tasks using consonant- vowel stimuli reflect relatively lower levels of performance and larger right ear advantages, while tasks using stimuli with more lexical content such as digits, words, and sentences typically reflect higher performance levels and smaller ear advantages (Obrzut, Boliek, & Obrzut, 1986; Noffsinger et al 1994). Phonemic intelligibility, familiarity, and stimulus dominance, as well as phonemic contrast, or difference in phonemic information present across the stimulus set, have been cited as contributing to these differences (Studdert-Kennedy & Shankweiller, 1969; Repp, 1977). This is in contrast with the report by Satz (1976) who reported that the greater the linguistic content of the signal (going from consonant vowels to words, spondees and sentences) the larger the right ear advantage. Thus there is a need to know the linguistic influence on right ear advantage. There are very few studies in literature which assessed the effect of reduced linguistic load (redundancy) on ear advantage. Also studies have compared different kinds of stimuli like CV to natural speech but there are no studies that investigate the effect of reducing redundancy in the same kind of stimuli which is meaningful speech (Noffsinger et al., 1994; Steven, 2011). Current study the tries to achieve the same by investigating differences in performance across dichotic speech recognition tasks that use speech stimuli, with relatively limited lexical content versus stimuli with relatively more lexical content. Thus the current study aimed at investigating the effects of filtering and compression on right ear advantage and compare the performance to the unchanged stimuli.

Aim of the study:

To find the effect of filtering and compression on right ear advantage

CHAPTER 2

REVIEW OF LITERATURE

Humans have brain mechanisms specialized for language. There is existence of special, localized neural mechanism for speech and language processing. For more than a century it has been held that language, at some level, is localized in one of the hemispheres. In most of the people, this dominant hemisphere is left (Kimura, 1961; Muller H.G., Beck W.G., Sedge R.K., 1987). Some of the most interesting research on right-left brain hemisphere differences has been conducted on clinical populations. Conrad (1954) found more aphasic tendencies in motor speech when there was a left side lesion on the margin of the central sulcus. Since several language areas are located in the left hemisphere, any injury to this site might result in impaired speech production. Some authors have suggested that stutteres suffer from incomplete cerebral lateralization for speech (Orton 1928; Beech and Fransella, 1968). Dichotic recall tasks on subject with split brain with disconnected hemisphere (lesion in the corpus callosum) revealed their inability to recognize stimuli presented to the left ear (Geshwind, Sparks, 1968). Thus an absence of normal cerebral dominance is thought to result in an incoordination of cortical areas underlying speech production and perception.

The literature has abundance of research on laterality effects in normal populations using the dichotic listening procedure (Obrzut et al, 1980; Hugdahl 1999). Dichotic listening is a noninvasive technique for the study of brain lateralization, or hemispheric asymmetry. The term dichotic refers to the simultaneous presentation of two different auditory stimuli to the two ears. This is contrasted with the use of the term diotic or binaural**,** which involve simultaneous binaural presentation of identical stimulus.

Thus, dichotic listening literally means listening to two different signals at the same time, one in each ear.

Broadbent (1954) was the first person to utilize a technique of presenting competing sets of digits to both ears simultaneously. Kimura (1961a) is generally credited with the introduction of dichotic speech tests into the field of central auditory assessment. She adapted Broadbent's technique for assessing hemispheric asymmetry and unilateral lesion effects, and her research has served as the basis for many of the current theories regarding dichotic listening. Dichotic listening has been taken, to a large extent, as a valid measure for hemispheric language dominance (Kimura 1961; Geffen, G & Caudrey, 1981). In a recent review on dichotic listening (Westerhausen & Hugdahl, 2008) authors came to the conclusion that the dichotic listening test should be considered not only as one for the lateralized temporal lobe language function but also as one of functional inter-hemispheric interaction, supporting both bottom-up and top-down processing.

Bryden (1963) in a dichotic listening experiment, reported that normal adult subjects identified numbers presented to the right ear more accurately than numbers presented to the left ear and preferred to report the material from the right ear first. The findings of the study are suggestive of better organization of auditory system for the perception of verbal material presented to the right ear.

Studdert-Kennedy and Shankweiler (1966) in their study compared identification of dichotically presented pairs of synthetic CV syllables and pairs of steady state vowels. Results showed significant right ear advantage for CV syllables but not for vowels. Obrzut, Boliek, & Obrzut, (1986) hypothesised that perceptual asymmetries can be strongly influenced by the type of stimulus material used and the effect of attentional strategy. They used 4 types of dichotic stimuli (words, digits, CV, melodies) in three conditions (free recall, directed right, directed left) and found the existence of clear right ear advantage for words and CV on free recall. However results for the melodies tended to indicate a clear left ear advantage on free recall. These findings throw light towards the lateralization of speech and language to left hemisphere, on the contrary the melody seems to be a function lateralized to right hemisphere.

The above findings may be explained on the basis of a widely accepted theory known as ‘the structural model’ (Kimura, 1967) and an alternative theory known as ‘the attentional model’ (Kinsbourne, 1970). The structural model explains the REA based on the anatomy and functionality of ascending auditory pathways. According to the Kimura’s theory, signals carrying auditory information originating in the cochlear nucleus of each ear end up in the primary auditory cortex of both cerebral hemispheres after passing relay stations in the superior olivary complex, the inferior colliculus and the medial geniculate body of the thalamus. Even though both contralateral and ispilateral projections exist, the contralateral ones are more predominant in nature, resulting in a stronger representation of the auditory information in the contralateral hemisphere (opposite to the originating ear). In addition, during dichotic stimulation, the weaker ipsilateral projections are supposed to be blocked or inhibited, and as a result only the information from the right ear directly reaches the left hemisphere which is language dominant. Auditory signals from the left ear first reach the right cerebral hemisphere and need to be transferred through the corpus callosum to the left hemisphere where language receptive areas are located, resulting in a ‘time delay’ which results in a further enhancement of the auditory signals administered to right ear (Zaidel, 1983).

Thus, the explanation for the REA effect that has received most empirical support is the structural or neuroanatomical model originally suggested by Kimura which suggests that the REA is caused by several interacting factors. First, a monaural auditory input is more strongly represented in the contralateral hemisphere. Second, the left hemisphere (especially for right-handers) is specialized for language processing. Third, auditory input delivered to the left ear that is sent along the ipsilateral pathways is suppressed, or blocked, by the contralateral information. Fourth, left-ear input that first reaches the contralateral right hemisphere has to be transferred via the corpus callosum to the left hemisphere language processing areas. As a consequence, the REA is thought to indicate a left temporal lobe specialization for processing of speech sounds

The alternative theory of ‘the attentional model’ is based on an automatic activation of the left hemisphere in the anticipation of incoming verbal stimuli. This activation results in formulating a priming advantage for processing of auditory information and sets an attentional bias favoring stimuli administered to the right ear. In other words, it suggests that REA in dichotic listening is not due to structural factors but due to a grater preactivation of the language dominant left hemisphere. According to this model, asymmetries in the processing of input to either side of the midline are related to hemispheric specialization in man. These asymmetries arise when preponderant activation of one hemisphere biases attention to the contralateral side. This unbalanced cerebral activation is a function of the nature of the subject's task or expectancy

Berlin and his colleagues (1973) referred to “proximity” to help explain right ear advantage. They reasoned that the right ear advantage is seen in normals because the left anterior temporal lobe is closer than the right anterior temporal lobe to the left primary speech areas. Therefore, the transmission loss is lesser for signals reaching from the right ear to the left temporal parietal lobe. Cullen et al (1974) further speculated that degradation or transmission loss for speech in the left ear may be the result of a poorer internal signal to noise ratio due to additional neural relays required to transmit information from right primary auditory cortex to left temporal-parietal cortex for final processing.

Irrespective of the reasoning for its existence, right ear advantage is a common finding in dichotic listening tests having verbal stimuli. REA reflects left hemisphere dominance for language processing.

Factors affecting dichotic listening

There are several factors that affect the performance on a dichotic listening test. These factors could be related to the stimulus such as intensity, signal to noise ratio, type of stimulus material used and so on. Other factors which may be subject related include the age of the client, presence of any pathological condition. Few factors affecting the dichotic listening are discussed below:

Effect of stimulus intensity on dichotic test results:

In general, dichotic tests are presented at equal intensity to the two ears. Cullen et al (1974) found that signals must be at least 30 to 50 dB SL to assure maximum performance. When testing normal hearing subjects, 50 dB HL or subject's MCL is commonly used (Silman, Silverman, & Emmer, 2000). Hugdahl et al (2007) manipulated the strength of intensity difference between the right-ear and left-ear speech inputs in order to make the REA either weaker (left-ear input>right-ear input) or stronger (left-ear input<right-ear input). The results showed that the interaural intensity difference significantly affected the ear advantage in the predicted way

Speaks and Bissonette (1975) used 6 CV syllables and presented them in pairs dichotically using 4 intensities levels of 80, 70, 60, 50 dBSPL. Results showed a cancellation of the REA (Right ear advantage) following attenuation of signal level in the right ear, but the amount of attenuation to cancel the REA varied with reference.

Hugdahl (2008) investigated the effect of differences in the right or left ear stimulus intensity on the ear advantage. For this purpose, interaural intensity difference were gradually varied in steps of 3 dB from -21 dB in favour of the left ear to +21 dB in favour of the right ear, also including a no difference baseline condition. The dichotic listening paradigm was based on consonant-vowel stimuli pair. They concluded that the right ear advantage in dichotic listening to CV syllables withstands an interaural intensity difference of -9 dB before yielding to a significant left ear advantage.

Temporal effect or dichotic lag effect

The trailing behind or lagging behind of a stimuli in terms of time in perception is called as “lag effects”. When one signal lags another signal in an ear, the lagging signal will be perceived better. Berlin et al (1972) investigated the amount of time separation necessary between message onsets to overcome the right ear advantage. They found that when one of the CV lagged the other by 30-60 msec the lagging CV became more intelligible than when it was given simultaneously. This time advantage occurred to the lagging syllable and not to the leading syllable

Studdert-Kennedy, et al (1970) have reported an experiment where in the subjects were required to identify CVs presented dichotically with a temporal offset between them. They found that offsets between about 15-120 msec the lagging syllable was reported more accurately than the leading stimulus. Similar results were obtained by Lowe, S.S, Cullen, Thompson, Berlin, Kirkpatrick and Ryan (1970)

Berlin et al (1973) attributed this effect to a single left hemisphere speech processor being entered from two channels. This hypothetical processor require a finite time of 30-90 ms to handle a CV accurately provided it were not interrupted by different information arriving from another channel. Evidence for the fact that speech perception is unaffected by short interaural time difference comes from Cherry and Taylor (1954) who showed that most listeners do not perceive the same speech signal as broken until separation between the two dichotic channels exceed 10- 15 ms. Dropping of intelligibility of speech syllables with an interruption of 50-70 ms has been reported by studies of interrupted speech (Huggins, 1972; Gerber, 1972; Hopkinson, Gerber & Wang, 1972)

Physiological support for the importance of 30mesc separation between the signals before the lag effects comes from Hazemann et al., (1979). They suggested that short latency (< 30msec) responses recorded from cortex ipsilateral to the side of stimulation arrival by the way of corpus callosum in the somatosensory system. In contrast the long latency ones are conveyed by the ipsilateral pathway. Thus, a lag of 30msec or more to the left ear might take both its ipsilateral information and contralateral information out of competition with right ear information.

Prachi (2000) in her study administered dichotic presentation of CVs in simultaneous as well as with 30 and 90 msec lag condition. Results revealed right ear scores to be higher than left ear scores during simultaneous presentation. However at both (30 and 90 msec) lag times for both right ear and left lag condition, right ear scores were better. That is REA was seen. Similar results were found by Gowri Krishna (2001).

Phonetic effects

The better perception of one consonant compared with the other consonant is called the **“**phonetic effect or stimulus dominance**”**. Some consonants seem to elicit a better REA compared to other consonants. Berlin, Willet, Thompson, Cullen, and Lowe, (1970) reported that scores were higher for voiceless stops than for voiced stops in pairs of natural syllables contrasting in voicing. The voiceless stops are considered to be more ‘dominant’ than the voiced stops. The findings were also supported by Roser, John and Price (1972).

Porter and Berlin (1976) and Rajagopal, Ganguly and Yathiraj (1996) reported a lack of order effect in terms of ear of presentation. Regardless of the ear of presentation, they always obtained higher correct repetitions for voiceless syllables when compared to the voiced counterparts.

Rimol, Eichele, & Hugdahl (2007) investigated the effect of voice-onset-time (VOT) in dichotic listening with consonant-vowel (CV) syllables. The results obtained showed a significant effect of VOT on the 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 REA effect.

Berlin et al (1976) used 6 CV combinations /pa, ta, ka, ba, da, ga/ paired randomly. Results revealed maximum frequency of correct responses for velars followed by alveolars and then by labials. Speaks et al., (1985) used 8 pairs in which velar competed with non velar (bilabials and alveolar). Results revealed domination of velars over the non velars for 6 of the 8 pairs. Rajgopal et al., (1996) found similar results in his study where velars were best perceived followed by labials and alveolar. These studies are in support with earlier studies saying velars are more correctly identified than other non velar sounds.

Most of the studies show little or no REA for vowels. Shenkwniler and Studdert Kenndy, (1967), Darwin, (1969) and Studdert Kennedy and Shank Weiler, (1970) found REA for vowels in a consonant context. This was interpreted to mean that vowels surrounded by transition or acoustic correction of vocal tract adjustments towards a given target will have a REA. Berlin et al., (1973) suggested that the REA in speech like task may be related to the use of any acoustic event which is perceptually linkable to a rapid gliding motion of the vocal tract, as in a transition.

Even in vowels some are better perceived than the others, Weiss et al., (1973) presented 10 vowels in CVC syllable dichotically where the consonant was kept constant and vowels were varied. The vowels were classified into Long vowel and short vowel. Results showed REA more for long vowels compared to short vowels.

Quite a few studies have been done on different positions of the consonants. Darwin (1969) reported stronger REA for final consonants position when presented dichotically. Studdert-Kennedy & Shankweiler (1970) also reported strong REA to final consonant in natural speech stops.

Effect of signal to noise ratio in dichotic listening

Signal to noise ratio (SNR) affects the perception of dichotic speech stimuli as it does with the monaurally, or binaurally presented speech stimuli (Berlin and Cullen, 1975). Different types of masking have different type of effects on the performance of DL tasks (Samson, 1973; Cullen & Berlin 1976). Cullen et al (1974) investigated effect of SNR. They found that performance decreased with low SNR, but right ear advantage was maintained as long as SNR was varied between two channels with 12 dB SNR difference between channels.

Weiss & House, (1973) performed a Dichotic competing vowels task at two SNR (0 dB SNR & - 10 dB SNR). They observed a tendency towards reduction in the overall scores and enhancement in the REA with reduction in the overall SNR values. At favorable SNR (0 dB SNR) ear preference were not apparent

Hugdahl (2008) presented CV-syllables either in silence or with traffic background noise vs. 'babble'. Both 'babble' and traffic noise resulted in a smaller REA compared to the silent condition. The traffic noise, moreover, had a significantly greater negative effect on the REA than the 'babble', wherein a decreased right ear response as well as an increased left ear response was observed, when compared to the no noise condition. This differential effects of conversation and traffic noise, was explained with reference to the mechanisms in terms of Kinsbourne’s model (1970) were suggested, where the presentation of “babble” primes the left hemisphere, counteracting the decreasing effect of noise on the right ear stimulus and preventing right ear performance from decreasing as expected as a consequence of interference or degradation. In the case of non-verbal traffic noise, pre-activation of the right hemisphere, i.e. directed attention to the left ear, leads to an even greater benefit for the right hemisphere, and at the same time to a more pronounced reduction of the right ear stimuli since a decrease due to interference or degradation should not be counteracted, as it was in the “babble” condition.

Stimulus material used:

Dichotic speech recognition studies that have included a wide range of stimuli have shown a systematic change in overall performance and ear advantage as a function of phonetic and lexical content. Specifically, tasks using consonant-vowel (CV) stimuli reflect relatively lower levels of performance and larger ear advantages, while tasks using stimuli with more lexical content such as digits, words, and sentences, typically reflect higher performance levels and smaller ear advantages

Noffsinger, Martinez, Wilson (1994) used 3 tests of dichotic listening utilizing speech signal as stimuli, monosyllabic digit, synthetic sentence, nonsense syllable (CV). Result revealed that listener had little difficulty in identifying digits or synthetic sentence. In case of dichotic CV, frequency of correct responses were less when compared to the other two stimuli used.

In a study by Obrzut et al (1996), the authors supported the hypothesis that perceptual asymmetries can be strongly influenced by the type of stimulus material used and the effect of attentional strategy. They used 4 types of dichotic stimuli (words, digits, CV, melodies) in three conditions (free recall, directed right, directed left). Results revealed a right ear advantage for words and CV on free recall and left ear advantage for melodies on free recall.

Age effects

In dichotic listening tests, REA has been investigated for developmental/ maturational changes. Ingram (1975) reported that a right ear advantage was indicated on dichotic listening task at the age of early as 3 years. This study supports the finding of Kimura (1961, 67) where it was found that the right ear advantage appeared no later than the age of 6 years for speech and language hemisphere dominance

Jerger et al., (1994) investigated the effect of age and gender on dichotic sentence identification (DSI). Results showed a tendency for the REA to increase, with increasing age (above 80 years). He argued the reason being age related decline in cognitive function – memory or information processing strategies and loss in efficiency of interhemispheric transfer due to compromise of auditory pathways in corpus callosum. They also assumed that the auditory structures subserving the left ear are somehow more affected by aging than the right ear pathways.

Zenker et al (2009) studied effect of age on dichotic digit test in 60 right handed individuals in the age range of 6-72 years. They found greater REA in the oldest and the youngest groups than the middle aged groups. Greater REA in younger subjects may be due to decreased ability of the corpus callosum to transfer stimuli from right hemisphere to the left hemisphere. With increase in age, myelination of corpus callosum completes and hence the left ear scores approach those found in adults (Musiek et al 1984).

Attention

Most of the researchers agree that attentional factors play a role in dichotic listening, and may modify REA. Hugdahl (1986) studied the effects of directional attention on the right-ear-advantage (REA) in dichotic listening. The results showed a significant REA in all groups during the non-forced condition. During the forced-right condition, significantly more correct recalls were obtained from the right compared to the left ear in all groups. During the forced-left condition, significantly more correct recalls from the left compared to the right ear was obtained only in the two adult groups, but not in the children groups

Other authors have also investigated the extent to which attention may bias the frequency of correct reports to either right or left ear. Hiscock and Stewart (1984) showed that if subjects are required to focus attention to one ear first, and are then given a non focused (NF) divided attention instruction, their ear advantage during the NF task seemed to have been “primed” by focused attention instruction.

Hugdahl et al (2001) administered dichotic CV test on 240 individuals in the age range of 7-70yrs in three different conditions: non forced, forced right and forced left. They found REA in forced right as well as in non forced condition, and left ear advantage was seen in the forced left condition. Attention can affect the ear advantage either through enhancing reports from the attended ear, or suppressing reports from the unattended ear (Asbjornsen and Hugdahl, 1993)

Pathological condition

Unilateral temporal lobectomy impairs the recognition of digits arriving at the ear contralateral to the removal (Kimura, 1961). This finding in agreement with other studies (Jerger & Mier, 1960; Sinha, 1959). Berlin et al (1972) Compared preoperative and postoperative scores on dichotic CV test with simultaneous presentation as well as with time separation ranging from 15 – 500 ms. They found that postoperatively there is additional degradation of contralateral ear scores and enhanced ipsilateral ear function in dichotic listening. No lag effect was seen. Patients with both left and right temporal lobectomies behaved similarly in this respect.

Studies in literature have suggested that dichotic digit test is not affected significantly by mild to moderate cochlear hearing loss. (Musiek 1983, Speaks et al 2000). Speaks et al 1985 studied the effect of stimulus material on dichotic performance on SN hearing loss patients. Dichotic speech test was carried out using digits and CV nonsense syllables. Results showed that dichotic digit material was least affected by hearing loss.

Sparks and Geschwind (1968) and Milner et al (1964) reported complete or near complete extinction in the left ear scores in commissurotomized patients on dichotic tests. In order to report the stimuli heard in the left ear, the signal has to reach the left hemisphere from the right hemisphere via corpus callosum. Damage to the pathway anywhere along this route yields left ear extinction.

Archana Guruprasad (2000) evaluated CAPD in children with LD using battery of tests. One of the behavioral tests included dichotic CV test. Subjects were presented with dichotic CVs at 0 msec and 90 msec lag condition. Dichotic CV test showed bilateral deficits in children. Both single and double correct scores were depressed. Majority of them showed left ear advantage. Lag effect was not seen in 50 % of the subjects.

Iliadou, Kaprinis, Kandylis, Kaprinis (2010) assessed hemispheric laterality in an adult sample of individuals with dyslexia, with auditory processing disorder (APD), and adults experiencing comorbidity of the two mentioned disorders against a control group with normal hearing and absence of learning disabilities. Results exhibit a right hemispheric dominance for the control and APD group, a left hemispheric dominance for the group diagnosed with both dyslexia and APD, and absence of dominance for the dyslexia group. Assessment of laterality was repeatable and produced stable results, indicating a true deficit.

Pinheiro et al (2010) compared the performance of 40 students of both genders, ranging from 8 to 12 years with and without learning disabilities in dichotic listening tests. The performance of each subject on dichotic digit test, SSW test and SPIN (at 5 dB SNR) was assessed. The evidence found suggests that the group of children with learning disabilities shows inferior performance compared to the group without problems, reflecting difficulties on the processing of auditory information.

Thus various factors affect the performance on a dichotic listening task, each having differential effects. One must be aware of all these factors while carrying any clininal testing.

CHAPTER 3

METHOD

Subjects: the present study incorporated 100 normal hearing subjects in the age range of 18 to 36 yrs. The participants were selected based on their fulfillment of the following criteria:

a) Native Kannada speaker
b) No history of any otological and/ or neurological problems
c) Had normal auditory acuity, middle ear function and auditory processing abilities.
d) Right handers, indicated by a high score for left cerebral preference in laterality preference schedule (Venkateshan, 2010)

Stimulus: The recorded Kannada word list developed by Sreela (2010) was used for the stimulus preparation. These words were used as the stimulus along with the modifications done as per the requirements of the study with the author's permission.

Stimulus preparation:

The original word list was edited for construction of various lists using adobe audition (Version 3). The recorded words were scaled first to avoid dissimilarity in intensity among the word pairs. Duration of each word was measured and words with similar duration were paired for dichotic presentation. Following this, the word pairs were edited to obtain separate pair lists as mentioned below:

1. Untruncated word pair list (List A): 20 scaled, paired words with similar duration were included in this list.

2. Time compressed word pair list (List B): Another set of 20 word pairs were used and each word in the list was compressed by 40% of its total duration using the Adobe audition software.

3. Low pass filtered word pair list (List C): A different set of 20 paired words were considered and each of these words were low pass filtered using a cut off frequency of 800 Hz with a falling slope of 12 dB per octave.

4. Low pass filtered and compressed word pair list (List D): Last set of 20 paired words, which were also non overlapping from the above 3 lists, were subjected to both time compression as well as low pass filtering with the same criteria used to prepare list B and C respectively.

The prepared materials were then recorded as dichotic stimuli with 0 msec lag onto a audio CD, with each pair of dichotic stimuli followed by a gap of 10 sec. A 1 KHz calibration tone was recorded before each list for the VU meter calibration.

Instrumentation:

Routine audiological tests were carried out as a part of the preliminary evaluation using the following equipments.

- A clinical audiometer (Madsen Orbiter-922 Version 2 diagnostic audiometer) with TDH 39 supra aural earphones housed in MX-41/AR ear cushions for air conduction and speech audiometry testing. Bone conduction testing was done using Radio ear B-71 BC vibrator.

- Grason Stadler Inc. – Tympstar (Version 2) clinical immittance meter was used to rule out the existence of middle ear pathology in the participant ears.

- As a part of actual evaluation of the REA, the recorded dichotic material was played to the participants by routing the CD output through the same set of air conduction audiometry equipments as mentioned above.

Procedure:

- Otoscopic evaluation of all subjects was done to rule out any outer ear and/or tympanic membrane pathologies.
- To ensure hearing thresholds within 15 dB for all the subjects, air conduction thresholds of each subject were obtained in octave frequencies of 250 Hz through 8Khz using modified Hughson and Westlake procedure using the above mentioned audiometry equipment. Similar procedure was used to obtain the bone conduction thresholds as well in the octave frequencies of 250 Hz through 8KHz.
- Immittance evaluation was done to rule out any middle ear pathologies. Tympanometry was done using 226 Hz probe tone frequency followed by which both ipsilateral and contralateral acoustic reflex thresholds were obtained at 500 Hz, 1KHz, 2KHz and 4KHz.

- The Scan A (Keith, 1986) test was administered as a screening test to rule out auditory processing disorder.
- MCL for speech was obtained to be used as the level for word recognition and dichotic speech testing.

Subjects passing all the preliminary tests were included for the experimental procedure. Prior to the presentation of the lists, it was ensured that the VU meter indicated zero when the calibration tone was presented.

The dichotic test was administered at MCL with 0 msec lag between the two ears under the following 4 conditions:

1. Dichotic presentation of the originally recorded and scaled words (list A).
2. Dichotic presentation of Low pass filtered words (list B).
3. Dichotic presentation of time compressed words (list C).
4. Dichotic presentation of low pass filtered and time compressed words (list D).

The presentation of word lists was randomized to eliminate any kind of order effect. The subjects were asked to write down what is heard in both ears. The total scores for each ear was calculated separately. The double correct scores was also calculated.

CHAPTER 4

RESULTS AND DISCUSSION

Statistical analysis was carried out using SPSS software (version 17) to investigate the aims of the present study. The analyses involved the following:

- Descriptive statistics was done for right and left ear scores separately for each of the groups and stimulus conditions. This was also done for the right ear advantage and double correct score.
- Paired t-test was used to find the significant difference of scores for the two ears.
- Mixed analysis of variance (mixed ANOVA) was done to see the overall effect of different conditions and age on REA and double correct scores.
- Bonferroni's Post hoc test for multiple pairwise comparison was done to check for the significance of difference between different stimulation conditions.
- MANOVA was used to check the interaction between age and conditions.
- Duncan's post hoc test was done to further analyse significant difference among the groups if MANOVA revealed a significant difference.
- Repeated measure ANOVA was done to check for interaction within subjects of each group.

The results that were obtained have been categorized under the following headings:

1. Single ear score

Total correct scores for each ear was calculated separately for all the subjects under each condition (untruncated dichotic condition, dichotic compressed, dichotic filtered and compressed+filtered condition). Table 4.1 shows the mean scores obtained for the two ears separately in all the conditions.

Table 4.1.

Mean scores for the left and the right ear.

	Right		Left	
	Mean	SD	Mean	SD
Untruncated dichotic	18.45	1.50	16.60	2.30
Compressed	16.90	2.02	15.27	2.63
Filtered	7.06	3.29	3.91	2.55
Compressed+filtered	5.61	2.75	2.67	2.25

Note: SD- Standard deviation

It is evident from the above table that the mean scores for the right ear were better than that of the left ear in all the conditions. There also existed a trend towards reduction in scores for the left and the right ears, with highest score for untruncated condition followed by compressed, filtered and compressed+filtered condition. The same can also be seen from Figure 4.1.

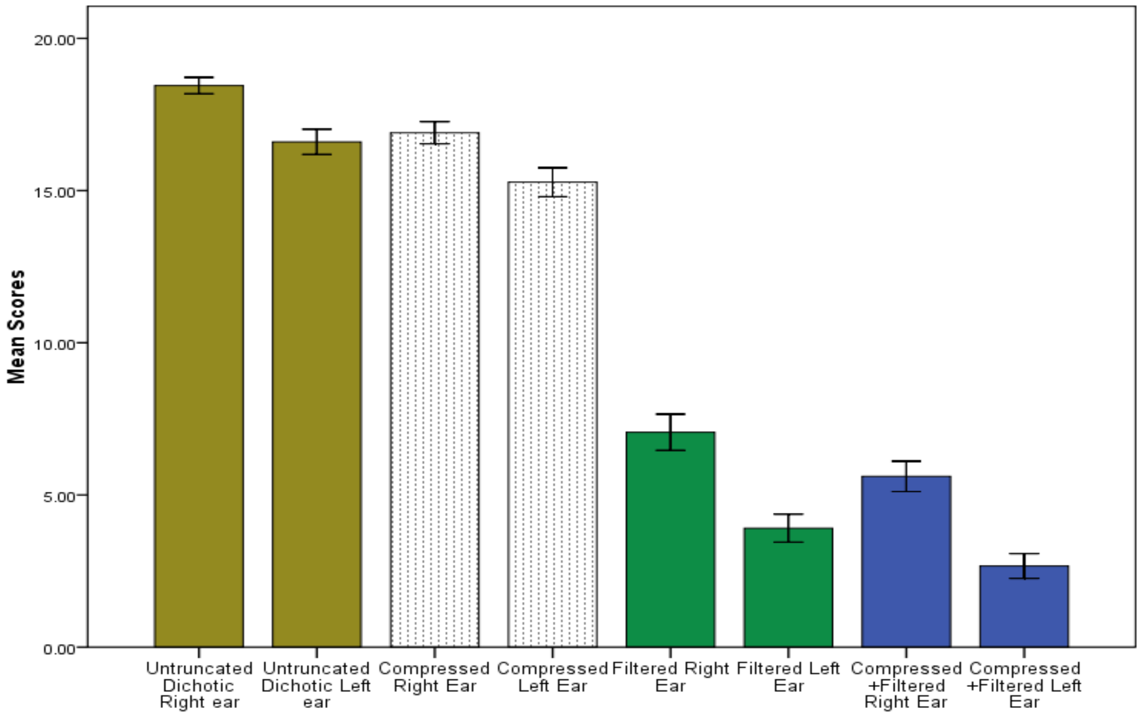

Figure 4.1: Mean right ear and left ear scores across conditions

Paired sample t-test was carried out to see if the above observed ear scores were significantly different within each of the conditions. Table 4.2 shows the results of this comparison. It can be seen from table that there was significant difference seen between the right ear and the left ear scores (P<0.01) for each of the conditions. The difference of the right ear and left ear scores was positive indicating towards a significant right ear advantage.

Table 4.2.

Comparison between right and left ear scores.

	T	Df	Significance
Pair 1: UDRES-UDLES	11.263	119	.000
Pair 2: DCRES-DCLES	9.497	119	.000
Pair 3: DFRES-DFLES	14.094	119	.000
Pair 4: DCFRES-DCFLES	15.008	119	.000

Note: UDRES: un-truncated dichotic right ear score; UDLES: un-truncated dichotic left ear score; DCRES: dichotic -compressed right ear score; DCLES: dichotic-compressed left ear score; DFRES: dichotic-filtered right ear score; DFLES: dichotic-filtered left ear score; DCFRES: dichotic- compressed+filtered right ear score; DCFLES: dichotic- compressed+filtered left ear score

A comparison of the individual ear scores indicated towards a significantly better performance ($P< 0.01$) for the stimuli presented to the right ear compared to the left. This finding was consistent across different stimulus conditions. Similar findings were reported for only the unaltered dichotic task by several previous researchers (Kimura, 1963; Bryden, 1963; Hugdahl, 1999; Prachi 2000; Gowri Krishna 2001). The better performance for the right ear could be explained by two theories that have been put forth by Kimura (1967) and Kingsbourne (1970). The former explains the phenomenon through an inhibitory action that the dichotic task introduces on the ipsilateral pathway whereas the latter explains it through a hypothesis of automatic activation of the left hemisphere which results in an attentional bias favouring the stimuli administered to the opposite ear. A combination of the two theories could explain this phenomenon. When the dichotic stimuli are presented, the left hemisphere gets automatically activated and sends the inhibitory signals to the ipsilateral pathway. This, in effect, would cause only the contralateral pathway to transmit the signal. The contralateral pathway for the left, being routed through corpus callosum, is longer (Berlin, 1973) resulting in earlier arrival of the stimuli from right ear to left hemisphere. This would effectively start processing the signal from right ear before the arrival of the signal from left ear which would result in a so called "line busy effect". This would, thus, affect the processing of signals from left ear.

2. Right ear advantage

Analysis of scores for each of the conditions revealed that the performance of the right ear was better than that of left ear indicating towards a right ear advantage. To further analyse, in this regard, right ear advantage was found out by subtracting the scores of the left ear from the right ear in all the conditions considered. The ear advantage obtained was then statistically analysed to obtain the mean and standard deviation across all the conditions which is shown in table 4.3. Right ear advantage across all the conditions is evident from the table. A closer observation of the findings shows that the REA were comparable for untruncated and compressed conditions and appear to increase in filtered and compressed+filtered condition. However, a comparison between the dichotic filtered condition and dichotic filtered+compressed condition revealed comparable performance across the two conditions. The same can be seen in figure 4.2.

Table 4.3.

Descriptive statistics for right ear advantage across conditions.

	Mean	SD
UD-REA	1.86	1.79
DC-REA	1.75	2.06
DF-REA	2.98	2.38
DCF-REA	2.93	2.14

Note: UDREA: un-truncated dichotic right ear advantage; DC-REA: dichotic - compressed right ear advantage; DF-REA: dichotic-filtered right ear advantage; DCF-REA: dichotic- compressed+filtered right ear advantage

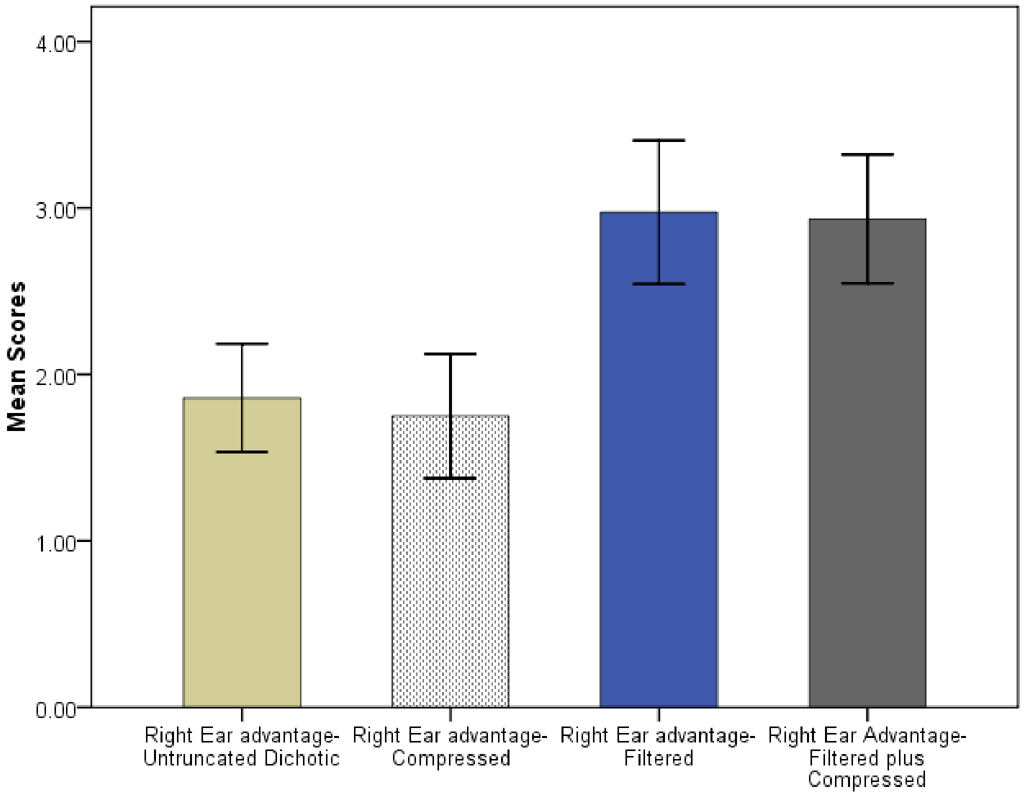

Figure4.2: mean scores for right ear advantage across conditions

Mixed analysis of variance was carried out to see the overall effect of the conditions and age on the right ear advantage. Results revealed a significant difference in the right ear advantage across different conditions [F (3, 6) =8.778, P<.01]. There was no interaction observed between age and the conditions [F (3, 6) =1.124, P>.05], which eliminated the need to carry out any post hoc test.

Table 4.4.

Comparison across conditions

	Unaltered dichotic	Dichotic filtered	Dichotic compressed+filtered
Dichotic compressed	P>0.05	P<0.05	P<0.05
Dichotic filtered	P<0.05		P>0.05
Dichotic Compressed+filtered	P<0.05		

To check for the existence of significant difference across the conditions, a Bonferroni test was used for multiple pairwise comparisons among different conditions. Table 4.4 shows results of this comparison. Results of the pairwise comparison, as evidenced by the above table, revealed the existence of a significant difference between untruncated dichotic condition and dichotic filtered condition. This was also the case when untruncated dichotic condition was compared with compressed+filtered dichotic condition. Similar results were also seen between dichotic compressed condition and dichotic filtered condition, and also when compressed condition was compared with compressed+filtered condition. However, there was no significant difference between dichotic unaltered and dichotic compressed conditions, and also between dichotic filtered and dichotic compressed+filtered condition.

Analysis of REA, through the raw mean scores, indicated towards a trend towards increase in REA with increase in the stimulus difficulty (reducing extrinsic redundancy). Comparison of mean scores revealed that the dichotic task with unaltered words was the easiest followed by compressed, filtered, and compressed+filtered. The statistical analysis though revealed a different story. This trend did not apply to the comparison of REA between dichotic untruncated and dichotic compressed as well as between dichotic filtered and dichotic compressed+filtered conditions. Both of these pairs produced comparable results. The difference between untruncated and compressed was found to be insignificant. This could probably be due to the fact that, a 40% compression does not yield high enough spectral changes to cause significant worsening of scores. This probably is the reason why even normal individuals obtain good performance, since external redundancy is not greatly affected. Performance is noticed to deteriorate in normals when 60 % or higher rates of compression are used, leading to more evident right ear advantage (Wilson et al., 1994; Zemlin, Daniloff & Shiner, 1968). Similarly, there was no significant difference between filtered and compressed+filtered condition. This could be probably because the above two conditions differ only by the addition of the compression parameter. As stated earlier, 40% compression shows no significant reduction in the redundancy which makes the low pass filtering as the sole factor governing the performance in the two conditions.

The present study shows a general trend towards enhancement in REA with increased degradation of the signal. This phenomenon could be explained through

Berlin’s (1973) hypothesis of a transmission loss for the signal routed through the left ear. Since the signal gets degraded along its path from left ear to left hemisphere, it is likely that an already degraded signal could undergo larger volumes of degradation. This would result in an even poorer perception of the stimuli for left ear, thereby effectively enhancing an already existing right ear advantage.

There are studies in the literature that talk about the effect of decreasing the linguistic load on the right ear advantage (Obrzut et al., 1986; Noffsinger et al., 1994; Steven, 2011). These studies, however, have used entirely different set of stimuli (sentences to CVs) for changing the linguistic load. The present study has achieved the same through modifications of alike stimuli, which is a monosyllabic word. The two set of stimuli become comparable in terms of availability of lesser number of cues in the stimuli through change in type, as evidenced by earlier studies, or through spectral modifications, as seen in the present study. Hence, the results of the present study could be compared to the above mentioned ones.

3. Comparison across age groups

The participants were equally divided into three groups based on the age range (Group 1: 18-24years; Group 2: 24-30 years; Group 3: 30-36 years). Mixed ANOVA was carried to see the existence of a significant difference among the three age groups. Analysis of right ear advantage across the considered age groups revealed no significant difference between the groups [F (2) = 1.898, P>0.05]. Table 4.5 shows mean scores for REA across the three age groups.

Table 4.5.

REA across age groups.

	18-24		24-30		30-36	
	Mean	SD	mean	SD	Mean	SD
UD-REA	1.97	1.84	1.74	2.07	1.78	1.28
DC-REA	1.66	1.83	1.69	1.71	1.78	2.86
DF-REA	3.52	2.75	2.49	1.88	2.04	1.89
DCF-REA	3.19	2.35	2.94	1.94	2.37	1.84

Note: UDREA: un-truncated dichotic right ear advantage; DC-REA: dichotic - compressed right ear advantage; DF-REA: dichotic-filtered right ear advantage; DCF-REA: dichotic- compressed+filtered right ear advantage

Absence of significant difference in REA obtained across the three age groups (18-24; 24-30; 30-36 years) shows that there is neither improvement nor decrement in the scores with advancing age, indicating that the maturation is complete before the age of 18 years. It can also be inferred from the above results that there would be no decrement in the left ear scores because of aging at least till the age of 36 years. Most common finding obtained in the studies that address effect of age is the presence of a greater right ear advantage in individuals above 60 years and also in children below 7 years (Jerger et al., 1994; Bellis & Wilber, 2001; Rout, Wiley & Wilson, 2006; Zenker et al., 2009).

Poor left ear scores in children may reflect a decreased ability of the corpus callosum to transfer complex stimuli from right hemisphere to left hemisphere. As the child becomes older and myelination of corpus callosum is completed, the interhemispeheric transfer of information improves and left ear scores reach to the levels found in adults (Musiek, Gollegly, and Baran, 1984). Larger REA in older subjects is attributed to the decline in cognitive function, loss in efficiency of interhemispheric transfer due to compromise of auditory pathways in corpus callosum (Jerger et al., 1994).

4. Double correct score

Even though finding out about the outcome for double correct scores was not the main aim of the study, it was still analyzed to find out its trend across all the four conditions. Double correct score was given whenever both the words presented to the two ears were reported correctly. Mean and standard deviation of the double correct scores obtained for all the subjects in all the conditions is shown in table 4.6. The table illustrates decreasing trend in the double correct scores from untruncated dichotic condition to dichotic compressed+filtered condition, with highest score for untruncated condition and least for the compressed+filtered condition.

Table 4.6.

Mean and SD of double correct scores across condition

	Mean	SD
UD-DCS	15.39	3.13
DC-DCS	13.33	3.39
DF-DCS	1.9	1.92
DCF-DCS	1.03	1.3

Note: UD-DCS: untruncated dichotic double correct score; DC-DCS: dichotic compressed double correct score; DF-DCS: dichotic filtered double correct score; DCF-DCS: dichotic compressed+filtered double correct score

Mixed analysis of variance (mixed ANOVA) was carried out to further examine the data to see the overall effect of the conditions and age on double correct score. Results revealed a significant difference in the double correct scores across different conditions [F (3, 351) =1528.45, P<0.01] and also across the three age groups [F (2, 117) = 4.918, P<0.05]. Significant interaction was also observed between age group and the conditions [F (3, 6) = 2.96, P<0.01].

Results of mixed analysis of variance revealed significant main effect of conditions, thus Bonferroni's multiple pairwise comparison was done to check for pairwise comparison of different conditions. Results revealed significant difference across all the conditions which is depicted in the table 4.7 below.

Table 4.7

Comparison of double correct scores across conditions

	Unaltered dichotic	Dichotic filtered	Dichotic compressed+Filtered
Dichotic compressed	P<0.05	P<0.05	P<0.05
Dichotic Filtered	P<0.05		P<0.05
Dichotic compressed+filtered	P<0.05		

Since effect of age was also seen on double correct scores, Duncan's post hoc test was used to know which age group was different in specific. The results revealed significant difference between group I (18-24 yrs) and group III (30-36 yrs) (P<0.05). There was no significant difference between group I and II as well as between group II and III.

As there was significant main effect present between age and the conditions, Multiple analysis of variance (MANOVA) was carried out to understand the main effect. Test of between subject effects revealed significant difference in dichotic untruncated condition [F (2, 117) = 6.531, P< .05], as well as in dichotic filtered condition [F (2, 117) = 4.006, P<0.05]. This was followed by post hoc analysis using Duncan's test to see which of the considered age groups significantly differed in the above mentioned conditions. Results revealed that, in untruncated condition, there was significant difference seen for group I and group III (P<0.05). Same groups were also found to be significantly different in dichotic filtered condition. There was no significant difference seen among any other age group.

Repeated measure ANOVA was done for comparison within each age group across the four conditions. In age group I, there was significant difference seen in all the conditions [F (3, 171) = 1348.29, P<0.01]. Therefore Bonferroni's post hoc analysis was done to see pairwise difference. Results revealed significant difference among all the conditions, as shown in table 4.8

Table 4.8.

Comparison within age group 1

	Unaltered	Dichotic	Dichotic

	dichotic	filtered	compressed+Filtered
Dichotic compressed	P<0.05	P<0.05	P<0.05
Dichotic Filtered	P<0.05		P<0.05
Dichotic compressed+filtered	P<0.05		

In group II also, repeated measure ANOVA revealed effect of condition [F (3, 102) = 383.93, P< 0.05]. Further analysis using Bonferroni's pairwise comparison revealed that untruncated dichotic condition was significantly different from the other conditions. Similar results were obtained with respect to compressed condition. But there was no significant difference seen for filtered and compressed+ filtered condition.

Table 4.9

Comparison within age group II

	Unaltered dichotic	Dichotic filtered	Dichotic compressed+Filtered
Dichotic compressed	P<0.05	P<0.05	P<0.05
Dichotic Filtered	P<0.05		P>0.05
Dichotic compressed+filtered	P<0.05		

Repeated measure ANOVA for group III revealed effect of condition [F (3, 78) = 251.39, P<0.0]. Trend similar to that of group 2 was seen on pairwise comparison using Bonferroni test. The same is shown in table 4.10

Table 4.10

Comparison within age group III

	Unaltered dichotic	Dichotic filtered	Dichotic compressed+Filtered
Dichotic compressed	P<0.05	P<0.05	P<0.05
Dichotic Filtered	P<0.05		P>0.05
Dichotic compressed+filtered	P<0.05		

The results revealed a decreasing trend for double correct scores as the complexity of the stimulus increased. There was clear effect of age and conditions on double correct scores. Detailed analysis revealed the scores to be significantly different for group I and group III only in the untruncated and filtered condition. A comparison of scores of different stimulus conditions within group I revealed a trend towards reduction in scores with increasing complexity from unaltered condition to compressed + filtered condition. Similar trend was also observed for groups II and III with the exception of the conditions between filtered alone and compressed+filtered condition, which did not show any significant difference for both the groups. A combination of the reasons may help in understanding the obtained results. First, as can be seen by the scores, filtered condition produced significantly poorer scores compared to compressed condition. This indicates that a dichotic task using filtered words is a lot more difficult than compressed alone in dichotic mode. Since filtering is itself a difficult task, the addition of compression over it probably did not result in any further lowering of the cues available for speech perception. In addition, the scores for filtering are so low that it probably may have caused a floor effect, thus preventing further lowering of the scores with addition of compression to it. A part of it could also be to do with presence of significantly poorer scores obtained by 2 of the 27 participants for the age group III compared to no such occurrence for group I.

Overall the results of the present study reveals that right ear advantage shows an increasing trend as the linguistic load of the stimuli decreases, in all the age groups considered. The magnitude of right ear advantage obtained was comparable across the three age groups. Analysis of the double correct scores revealed effect of age as well as condition on double correct scores, with decreasing number of double correct scores as the stimulus complexity increased, with maximum scores for the unaltered condition and least for filtered and compressed+filtered condition. In short, there was a clear effect of linguistic load on both single as well as double correct scores.

CHAPTER 5

SUMMARY AND CONCLUSION

Right ear advantage refers to obtaining more correct scores for the verbal stimuli administered to the right ear than to the left ear during dichotic listening when the subject is asked to report what is being heard in a free recall procedure. Performance on dichotic task varies with amount of lexical content, which might, inturn, result in variation in the right ear advantage. The effect of linguistic load on the magnitude of right ear advantage is not clearly stated in the literature. There are only a few studies (Noffsinger et al., 1994; Steven 2011) which compare performance of dichotic sentence identification to dichotic CV identification. These studies have reported an increase in right ear advantage for CVs compared to sentences. The sentences and CVs though speech material, are different set of stimuli with sentences being meaningful and CVs being nonsense. So, a comparison of the performance with them is not exactly desirable. The more desirable comparison should be the use of similar stimuli and reduce the redundancy within them. There are no studies in literature which have used such kind of stimuli to check for the differences in right ear advantage. To achieve this scenario, the present study aimed at investigating the effect of filtering and compression of the monosyllabic words of dichotic pair on right ear advantage.

Study incorporated 120 native Kannada speaking participants who were in the age range of 18-36 years, were right handed and had hearing sensitivity within normal limits. The participants were also ontologically and neurologically normal. The participants were required to repeat the dichotically presented stimuli and each correct response was given a score of 1. Each participant was randomly evaluated using four different dichotic stimuli list which included untruncated, compressed, filtered and compressed+filtered stimuli.

Results revealed right ear scores to be significantly higher compared to the left ear ones which is consistent with reports by various other studies on dichotic testing (Broadbent 1954; Kimura, 1961, 1967; Berlin 1972; Studdert et al 1966; Darwin 1969; Bryden 1963). This can be explained with the combination of the two theories given by Kimura (1967) and Kingsourne (1970). Automatic activation of the left hemisphere and also stronger contralateral representation, leads to inhibition of the ipsilateral pathway leading to more effective transmission of the stimuli presented to the right ear. This would thus, affect the processing of signals from left ear.

Results of right ear advantage showed an increasing trend across the conditions with lowest scores for unaltered condition and highest for the compressed+ filtered condition. The amount of REA obtained was comparable between untruncated and compressed conditions as well as between filtered and compressed+filtered condition. This could be owing to the fact that a 40% compression does not reduce the linguistic load to a greater extent, thus explaining the insignificant differences between the comparisons.

There was also no difference in the right ear advantage across the three age groups, indicating the completion of maturation before the age of 18 years and absence of degenerative changes at least till 35 years. This is similar to the outcomes of the studies by (Jerger et al., 1994; Bellis and Wilber, 2001; Rout, Wiley and Wilson, 2006; Zenker et al., 2009).

A decreasing trend for double correct scores was seen as the complexity of the stimulus increased. There was clear effect of age and conditions on double correct scores. The scores were significantly different only for group I and group III in untruncated condition as well as in filtered condition. This could be explained by the inherent higher difficulty for the filtered condition, floor effect due to very poor scores and group III having a couple of participants with significant poorer scores unlike group I.

Thus, it can be concluded that there is a clear effect of linguistic load on right ear advantage, with greater advantage for the right ear for stimulus having lesser linguistic load. Also, age does not have an affect on the right ear advantage, especially for the age range of 18-36 years.

Clinical implications:

Current study provides an insight into method of assessing the central processing of information more accurately. Use of stimuli that compares the performance in an unaltered versus degraded conditions, thereby reducing the linguistic load, may reduce the possibility of underestimating the ear advantage obtained because of the influence of linguistic load. Knowledge of the above findings can be used to develop test that assesses the underlying process more precisely in this regard, and specifically help in assessing individuals with temporal processing disorders.

REFERENCES

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.

Beech, H. R., & Fransella, F. (1968). *Research and experiment in stuttering*. Oxford: Pergamon

Bellis, T. J. (1996). *Assessment and management of central Auditory Disorders in the Educational Settings: From Science to Practice*. California Singular publishing group. Inc.

Bellis, T. J. (2003). *Assessment and management of central Auditory Disorders in the Educational Settings: From Science to Practice* (2nd ed). California Singular publishing group. Inc.

Berlin, C. I., Lowe-Bell, S., Cullen, J., Thompson, C., & Stafford, M. (1972). Is speech special? Perhaps the temporal lobectomy patient can tell us. *Journal of Acoustical society of America,* 52, 702-705.

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

Berlin, Mc Neil, M. (1976). Dichotic listening In: Lass N, Contemporary issues in experimental phonetics. New York: Academic press.

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

Bryden, M. P. (1963). Ear preference in auditory perception. *Journal of Experimental Psychology*, 65, 103-105.

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

Cherry, E. C., & Taylor, W. K. (1954). Some Further Experiments upon the Recognition of Speech with one and with two Ears. *Journal of Acoustical society of America*, 26, 544-599.

Chandrashekar, S. S. (1973). Exploratory study of the performance of normal Indian listeners on Staggered Spondiac Word test developed in English for Indian population. Unpublished Masters dissertation, University of Mysore, Mysore.

Chermak, G. D., & Musiek, F. E., (1997). Central auditory processing disorders: New perspectives. San Diego, California: Singular publishing group.

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

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

Ganguly, L. & Yathiraj, A. (1996). Dichotic CV test: Normative data on children. Unpublished Dissertation, University of Mysore, Mysore.

Geffen, G., Caudrey, D. (1981). Reliability and validity of the dichotic monitoring test for language laterality. *Neuropsychologia*, 19, 413-23.

Gowri, K., & Yathiraj, A., (2001). Dichotic CV test- Revised normative data on children. Unpublished Independent project, University of Mysore, Mysore.

Guruprasad, A., & Vanaja, C. S. (1999). Evaluation of central auditory processing disorders in children with learning disability. Unpublished Dissertation, University of Mysore, Mysore.

Hopkinson, N. T., Bilger, R. C., & Wang, M.D. (1972). Effects of Interruption on noncontextual Speech. *Journal of Acoustical society of America*, 174 A, 18-21.

Hugdahl, K., Andersson, L., (1986). The “forced-attention paradigm” in dichotic listening to CV-syllables: a comparison between adults and children. *Cortex*, 22, 417–432.

Hugdahl, K., Bronnick, K., Kyllingsbaek, S., Law, I., Gade, A., & Paulson, O. B. (1999). Brain activation during dichotic presentations of consonant-vowel and musical instrument stimuli: A 15 OPET study. *Neuropsychologia,* 38, 431–440.

Hugdahl, K. (2008). The effect of stimulus intensity on right ear advantage in dichotic listening. *Neuroscienec letters,*90, 431-435.

Huggins A. W. F. (1972). Temporally segmented speech. *Journal of Acoustical society of America*, 51, 176A.

Illadou, V., Kaprinis, S., Kandylis, D., Kaprinis, G. S. (2010). Hemispheric laterality assessment with dichotic digit testing in dyslexia and auditory processing disorder. *International Journal of Audiology*, 49(3), 247-252.

Jerger, J., Chmiel, R., Allen, J., & Wilson, A. (1994). Effects of age and gender on dichotic sentence identification. *Ear and Hearing*, 15(4), 274–86.

Jerger, J., Alford, B., Lew, H., Rivera, V., & Chmiel R. (1995) . Dichotic listening, event-related potentials, and interhemispheric transfer in the elderly. *Ear and Hearing*, 16 ,482-498 .

Jerger, J., & Martin, J. (2004). Hemispheric asymmetry of the right ear advantage in dichotic listening. *Hearing Research*, 198(1–2), 125–36.

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

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

Kimura, D. (1961). Cerebral dominance and perception of verbal stimuli. *Canadian Journal of Psychology*, 15, 156-165.

Kimura, D. (1963). Speech lateralization in young children as determined by an auditory test. *Journal of Comparative and Physiological Psychology*, 59, 899-902.

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

Kinsbourne M. (1970a). The cerebral basis of lateral asymmetries in attention. *Acta Psychologia*, 33, 193–201.

Milner, Brenda , B., Ranch, C., & Rasmusset, N. (1964). Observations on cerebral dominance. In de Reuck, A. V. S., & O'Connor, M. (Eds), Ciba Foundation Symposium on Disorders of Language, London, Churchill. (pp. 200) .

Muller, H .G., Beck, W. G., Sedge, R. K., (1987). Comparison of the efficiency of cortical level speech tests. *Seminars in Hearing*, 8, 279–98.

Musiek, F. E. (1983). Assessment of central auditory dysfunction: the dichotic digit test revisited. *Ear and hearing*, 4, 79-83.

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

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.

Obrzut, J. E., & Hynd, G. W. (1980). Cognitive development and cerebral lateralization in children with disabilities. *International journal of Neuroscience*, 14(3), 139-145.

Orton, S. T. (1928). Studies in stuttering. *Archives of Neurology and Psychiatry*, 18, 671-672.

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

Pinheiro, F. H. , Oliveira A. M., Cardoso, A.C., & Capellini, S. A. (2010). Dichotic listening tests in students with learning disabilities. *Brazilian Journal of otolaryngology,* 76 (2), 257-262.

Porter, R. J., Trondle, R. J., & Berlin, C. I. (1978). Effects of practice on perception of dichotically presented stop consonant syllables. *Journal of Acoustical society of America*, 59, 679-684.

Rimol, L. M., Eichele, T., & Hugdahl, K. (2007). The effect of voice onset time on dichotic listening consonant vowel syllables. *Neuropsychologia,* 45 (11), 2643.

Repp, B. H. (1977a). Dichotic competition of speech sounds: The role of acoustic stimulus structure. *Journal of experimental psychology,* 3, 53-70.

Repp, B. H. (1977b). Measuring laterality effects in dichotic listening. *Journal of Acoustical society of America,* 62, 720-737.

Roeser, R. J., Johns, D. F., Price, L. L. (1972). Effects of intensity on dichotically presented digits. *Journal of auditory research,* 12, 184-186.

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

Satz, P. (1976). Cerebral dominance and reading disability: an old problem revisited. In R.M. Knights, D.J. Bakker (Eds.), The Neuropsychology of learning disorders: Theoretical approach. (pp 273-294).

Shankweiler, D., & Studdert-Kennedy, M. (1966). Lateral differences in perception of dichotically presented synthetic consonant vowel syllables and steady state vowels. *Journal of Acoustical society of America,* 39, 1256(A).

Shankweiler, D., & Studdert-Kennedy, M. (1967). Identification of consonants and vowels presented to left and right ears. *Quarterly Journal of Experimental Psychology,*19(1), 59-63.

Sparks, R., & Geschwind, N. (1968). Dichotic listening in man after section of neocortical commissures. *Cortex*, **4**, 3–16.

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

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

Studdert-Kennedy, M., Shankweiler, D., & Schulman, S., (1970). Opposed effects of delayed channel perception of dichotically and monotically presented CV syllables. *Journal of Acoustical society of America,* 48, 599-602.

Shivashankar, N., & Herlekar, G. (1991). Dichotic digit test in intracranial lesions. *Journal of Indian Speech and Hearing Association*, 8, 67-71.

Stevens, M. (2011). The Effects of Stimulus Type and Response Condition on Dichotic Speech Recognition. Published thesis, Ohio state University.

Venkatesan, S. (2010). Laterality preference checklist (modified). Cited in Neurophysiological Functional Assessment Battery (NFA-B). New Delhi: Psychogen.

Weiss & House (1973). Perception of dichotically presented words. *Journal of Acoustical society of America, 53, 51-58.*

Westerhausen R., & Hugdahl K. (2008). The corpus callosum in dichotic listening studies of hemispheric asymmetry: a review of clinical and experimental evidence. *Neuroscience and Behavioral Reviews,* 32, 1044-1054.

Willeford, J. (1977). Assessing central auditory behavior in children: a test battery approach In R.W. Keith, Ed. Central Auditory Dysfunction. New York: Grune and Stratton.

Yathiraj, A. (1994). Dichotic CV test. Developed at central institute for the Deaf, St. Louis.

Zaidel, E. (1983). Advances and retreats in laterality research. *Behavioral and Brain Sciences*, 6, 523-533.

Zenker , F., Espino, R. M., Cosialls, M. S., Carmona, D. L. G., Belda, R F., & Barajas, J. J. (2009). The effect of age over dichotic digit test. In, 8th EFAS Congress /10th Congress of the German Society of Audiology.