DICHOTIC RHYME TEST IN KANNADA: A NORMATIVE DATA ON ADULTS

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ALL INDIA INSTITUTE OF SPEECH AND HEARING
NAIMISHAM CAMPUS, MANASAGANGOTHRI
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Dedicated to....

my dear

Father

Mother

Brother &

Sister

CERTIFICATE

This is to certify that this dissertation entitled ***"Dichotic rhyme test in Kannada: A normative data on adults"*** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student (Registration No.06AUD013). 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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DECLARATION

I declare that this dissertation entitled ***"Dichotic rhyme test in Kannada: A normative data on adults"*** is the result of my own study under the guidance of Dr. K.Rajalakshmi, Reader, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted in any other university for the award of any diploma or degree.

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A guide is one,
Who shows you the path of knowledge,
Gives you the lead in the journey,
Walks with you throughout,
Makes you open the doors of wisdom yourself!
Not the one who carries you his way.

My heartfelt thanks to my Guide for her patient listening to my views and the freedom she provided while carrying out this dissertation.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The poetic phrase "words written on water" evokes an ephemeral and transitory image (Kent, 1992). Speech is no less ephemeral, no less transitory. The spoken message is a rapidly decaying acoustic disturbance in an ocean of air. The listener who would try to capture this signal, must follow its, temporal course in environments that are often noisy, reverberant and otherwise disruptive. A substantial amount of evidence points to the fact that speech is perceived, both, on the basis of the acoustic signal and predictions based on its context and familiarity.

It is obvious to both clinicians and researchers that the auditory system is extremely complex. Its influence begins when the pinna shapes the air borne messages that are directed to the outer ear canal. Mechanical transmission through the middle ear provides further filtering and amplification. When sound is delivered to the inner ear, the mechanical properties of inner ear provide a detailed analysis of the stimulus. The wide range of frequencies, intensities and durations of auditory signal are encoded by the hair cells, eighth nerve complex into neural language which then is relayed tonotopically, to higher levels of auditory system. In the past, research dealing with the auditory system has focused primarily on the peripheral portion. Only in the past few decades has attention been extended to clarify the contribution of central auditory nervous system (CANS). Auditory processing involves attention, detection and identification of the signal. At the cortical level, auditory processing involves the decoding of neural message. For this purpose we use many skills from our basic understanding of speech sounds to determine what was said and meant. A breakdown in any of these functions could lead to impairment in the proper use of auditory information (Katz, 1968; Kimura, 1961; Speaks, 1975, Musiek, 1983).

Audiological evaluation of the central auditory nervous system (CANS) dates back to work of Bocca and his collegues in the early fifties. This challenging endeavor has piqued the interest of numerous investigators, but yet, has been slow to gain acceptance throughout the audiology community in general. One factor that has contributed to this delay is the complexity of the system under consideration. Even now, the anatomy and physiology of the CANS is not completely understood, nor have its many different functions been adequately defined. The auditory brainstem is so complex and compact, that a variety of Central auditory effects can be found depending on the specific area and extent of involvement (Calearo and Antoneili, 1968/ Stevens and Thorton, 1976). There are few tests such as ABR (Auditory Brainstem Response), masking level difference (Olsen, Noffsinger, 1976), binaural fusion (Mataker, 1959, Smith and Reaniek, 1972), rapidly alternating speech perception (Lynn and Gilroy, 1977) and synthetic sentence identification with ipsilateral competing message (Jerger and Jerger, 1975) that are reportedly been shown to be of value in identifying both brainstem and cortical lesions but are unable to differentiate between the two areas. These include, low-pass filtered speech (Calearo and Antoneili, 1968/ Stephens and Thorton, 1976), dichotic digits (Stephens and Thorton, 1976; Musiek and Geurkink, 1982), competing sentence (Musiek and Geurkink, 1982), and time compressed speech (Calearo and Antoneili, 1968).

The concept of dichotic listening was first introduced by Broadbent in 1954. Dichotic listening occurs when different auditory stimuli are presented to each ear simultaneously. It has been used historically to assess hemispheric dominance as well as hemispheric asymmetries (Kimura, 1961a, 1961b, 1967; Zattore 1989), with diminished scores on these types of listening tasks suggesting auditory and/or cognitive dysfunction or pathology (Kimura, 1961a, 1961b).

Dichotic listening tasks have been used in the evaluation of both normal and disordered auditory processes at the cortical level (Kimura, 1961; Berlin et al. 1972). The term 'dichotic' refers to the simultaneous competing presentation of two different speech signals to opposite ears. Subjects are asked to repeat back what is heard in one or both ears. Generally when speech is presented dichotically to normal listeners, higher scores are obtained from the material to the right ear, than the left. This has been referred to as right ear advantage and is believed to reflect the dominance of left hemisphere for speech and language perception (Studdert-Kennedy, Shankweiler, 1970). The early work by Kimura has been the foundation for the widely accepted theory that in man, the contralateral (or crossed) auditory pathway has more neural connections than the ipsilateral pathway and is considered the dominant pathway. On dichotic listening task individuals will generally show an ear advantage in the ear contralateral to the hemisphere dominant for language. For most individuals this will result in an right ear advantage (REA), which is believed to be the result of left hemisphere dominance for language and the auditory perception of speech stimuli (Kimura, 1967). Objective evidence for this hypothesis has come from studies of dichotic listening in subjects with surgical sectioning of the corpus callosum. Milner et al (1968) and Sparks and Geschwind (1968) demonstrated complete left-ear suppression of dichotically presented stimuli following surgical sectioning of the corpus callosum.

In a series of experiments, Musiek reveals that sectioning of the posterior portion of corpus callosum, but not the anterior portion results in a suppression of left-ear scores, where as right ear performance remains at preoperative levels (Musiek, Kibbe & Baran, 1984; Musiek et al, 1985; Musiek & Reeves, 1990; Baran, Musiek & Reeves, 1990).

Dichotic speech tasks differ from each other in terms of the stimuli utilized as well as the task required for the listener. Stimuli used in dichotic tests range from digits and nonsense syllables to complete sentences. Depending on the test itself, listeners may require to repeat everything that is heard (binaural integration) or to direct their attention to one ear and repeat what is heard in that ear only (binaural separation). Dichotic stimuli may be viewed on a continuum from least to most difficult. In general most similar and closely aligned the stimuli presented to the ears are the more difficult dichotic task will be (Bellis, 2002).

One such test using most commonly spoken words is Dichotic Rhyme Task (DRT). The dichotic rhyme task (DRT) was first introduced by Wexler and Halwes (1983) and then later modified by Musiek et al (1989). The DRT uses temporally aligned consonant-vowel-consonant pairs that vary only in their initial consonants. Although subjects are presented two words (one word to each ear), the precise alignment of the words, as well as the fact that the final vowel-consonant elements in each pair of words are identical, result in the subjects perceiving only one word the vast majority of the time. As a result of these test features, normal right-handed subjects tend to demonstrate test scores that are slightly greater than 50% in the right ear and slightly less than 50% in the left ear (Musiek et al, 1989). This unique pattern of performance is presumed to be the result of some type of dichotic "fusion" of the signals, which occur low within the central auditory nervous system.

The rationale behind DRT has come from series of experiments carried out by Repp (1976). Fusion in the dichotic listening condition takes place when words with similar spectral shape (waveform envelop) are presented to the listener (Repp, 1976). The waveform envelop for words is generally determined by the low frequency energy (Perrot & Berry, 1969), which is essentially its fundamental frequency (Repp, 1976, 1977a). Therefore if two words are presented dichotically, which have similar spectral envelopes and are temporally aligned, they will fuse and will be heard as one word (Repp, 1977a). The words in DRT for the most part, are words that are perfectly or partially fused. Due to this fusion this test is also called as Fused Dichotic Words Test (FDWT).

Musiek, Kurdzielschwan, Kibbe, Gollegly, Baran, and Rintelmann (1989) reported normative values of 30% - 73% for right ear and 27% - 60% for left ear in a group of 115 normal hearing subjects. Bellis (2006) normative data indicated no significant effect of age or ear on the Dichotic Rhyme test. Normative values (2 standard deviations above and below the mean) were 32% - 60% per ear.

On dichotic tasks, speech signals are preferred to non-speech signals as they can be manipulated in more complex ways than tones or other non-speech stimuli

(Berlin 1973). Speech signals that are linguistically similar and spectrally time aligned short and of similar duration are preferred to other types of speech stimuli in CANS evaluation due to their greater lesion detection capacity (Speaks, 1974).

The present study was taken to generate normative data regarding the performance of young Indian adults on a dichotic rhyme test in Kannada.

NEED FOR THE STUDY

The need of the present study was to incorporate the dichotic rhyme test as part of the CANS evaluation battery, because dichotic measures have demonstrated sensitivity in identifying and differentiating cerebral level lesion (Berlin, 1976/ Noffsinger, 1979). Especially, those with split brain patients and other cortical lesions are known to perform poorly on dichotic rhyme task. In order to identify deviant performance on such tasks, it is necessary to obtain normative data.

To date, no normative data is available on dichotic rhyme test, on the Indian language context. Hence, the data, so obtained on the Indian population in Kannada language can be compared with that of western population to see if a similar trend is observed.

AIM OF THE STUDY

- To develop Dichotic Rhyme Test using commonly spoken words in Kannada.
- To establish normative data on developed Dichotic Rhyme Test on Kannada speaking adults.

CHAPTER II

REVIEW OF LITERATURE

In the quiet to unravel the complex nature of central auditory processing mechanisms in normal's as well as brain-damaged subjects, investigators have relied heavily on the use of dichotic stimuli. A common technique for studying cerebral specialization is dichotic listening. When two different stimuli are presented to the two ears simultaneously, in right handed individuals, there is a consistent ear difference in reporting them. This depends on the nature of stimuli.

BASIS FOR EAR DIFFERENCES IN DICHOTIC LISTENING

When the signals are speech material, the right ear is most frequently favoured. This right ear superiority is seen for both, meaningful speech and non-meaningful speech material such as non-sense syllables (Shankweiler, Studdert-Kennedy, 1967), and backward speech (Kimura, Folb, 1969). In contrast, left ear superiority has been reported for certain complex non-speech sounds e.g. music, sound-effects (Kimura, 1964; Curry, 1967). Kimura (1967) attributes these differences in ear accuracy as a function of stimulus type to bilateral asymmetry of brain function (BAF).

The BAF hypothesis suggest that

The contralateral auditory neural pathways are dominant over the ipsilateral pathways during the dichotic stimulation. Performance superiority of a particular ear is a result of that ear being contralateral to the hemisphere involved in the perception of a given type of sound. In particular, the hypothesis implies that the left cerebral hemisphere is dominant in perception of sounds conveying language information while the right hemisphere is dominant for perception of non-speech sounds such as melodies (Kimura, 1967).

Kimura (1968) demonstrated a right ear superiority of recall for verbal material based on physiological mechanisms and related it to left ear dominance for speech. Zattore's (1989) work that investigated speech lateralization using the carotid Sodium Amytal test supports the validity claims of DRT made by Wexler and Halwes (1983, 1985). Zattore examined the DRT in 61 patients (35 subjects with left hemispheric representation, 4 subjects with right hemispheric representation, and 22 subjects with bilateral representation as determined by the results of the carotid Sodium Amytal test). Those patients who had a significant right ear advantage (REA) on the DRT exhibited left hemispheric speech representation, whereas the reverse was true for those patients with right hemispheric speech dominance. Those patients who showed no significant ear asymmetry demonstrated bilateral speech representation.

Shanhweiler and Studdert- Kennedy (1967) presented synthetic CV syllables and steady state vowels dichotically and found a right ear superiority similar to one found for meaningful words. However, right ear superiority was larger for CV syllables and relatively small for vowels. It could be argued that right ear superiority decreases when some of the normal characteristics of speech are removed. Liberman et al. (1967) interpreted that, the hemispheric dominance is obtained only for highly encoded speech sounds but not for minimally encoded ones. It is well known that recognition of speech is directly dependent on the frequency characteristics of the speech-signal (Miller, 1951). If the high frequency part of the signal is removed, primarily the consonant part of the speech is affected. With large amounts of filtering, speech is eventually reduced to vowel components only.

A study by Spreen and Boucher (1970) investigated the effects of low pass filtering on the recall of dichotically presented words. The results of the study supported the prediction that successive levels of filtering eliminated the right ear superiority for dichotically presented words. Since this successive levels of filtering represents removal of consonants and consequently change the speech signal to a message consisting almost entirely of vowel sounds, the result could be the evidence for the fact that right ear superiority is strictly a language related phenomenon and disappears as the signal becomes more and more dissimilar from normal speech. The results were consistent with the findings of authors like Shankweiler and Studdert-Kennedy (1967). Both the cerebral hemispheres receive fibers from each cochlea. However, the contralateral fibers are more abundant than ipsilateral fibers on each side by a ratio of 5:1 (Rozenwig, 1951). In keeping with the anatomical difference electrophysiologic studies by experts have shown that the contralateral pathway projects stimuli with greater speed and intensity than does the ipsilateral pathway (Tunturi, 1946; Rozenwig, 1954; Hall and Goldstein, 1968). Still other electrophysiological research (Tunturi, 1946; Aitken and Webster, 1972; Monowen and Seitz, 1977) has shown that the ipsilateral pathways are suppressed during dichotic stimulation. This suppression is believed to increase the contralateral pathways role in signal transmission. These findings have led to the notion that ipsilateral pathways role is secondary to contralateral in transmitting information to the cortex (Kimura, 1961). Gordon (1975) reported the contralateral superiority for dichotic stimuli.

Maruszewaki (1975) accounted for the phenomenon of left-hemisphere dominance for speech and language, in a model of the brain as an organ composed of functionally differentiated structures that collaborate in one functional system. Literature has indicated that the left hemisphere is clearly implicated in language processing and appears to be specialized for meaningful as well as non-meaningful speech. The right hemisphere appears to be specialized for non-speech sounds.

Ear asymmetry on dichotic listening tasks has been demonstrated in many studies. Research with children, using dichotic listening paradigms has continued to be prevalent despite limitations. Although most right-handed adults show left-hemisphere language lateralization, the distribution of language functions in children has been hypothesized to be dependent on age of child and method of study used. Studies on normal children using dichotic listening paradigms have shown that most right handed children show a right ear advantage (REA) suggesting adult like asymmetry. Many have interpreted this as supporting an early unilateral lateralization in children much like that in adults. Some researchers have shown that magnitude of REA increases with age, becoming more lateralized (Satz, Bekker, and Goebel, 1975) while others have shown it to be constant throughout development (Berlin and Hughes, 1973; Kinabourne, 1975; Kinabourne and Hiscock, 1977). Still other studies of perceptual asymmetries have suggested that normal children show a development similar to that of adults. Wherein, a right ear advantage is clearly seen by puberty (Bryden and Allard, 1978; Krashen, 1973; Lenneberg, 1967).

STABILITY OF DICHOTIC LISTENING TEST

The dichotic listening technique, originally introduced by Broadbent (1954) and extensively applied by Kimura (1961, 1967) and Milner, (1962) to normal and brain damaged subjects, became one of the most widely used method to asses right or left ear superiority for different kinds of materials. In recent years it has been used as a behavioral indicator of the hemisphere dominance for verbal and non-verbal material in normal children and adults, as well as to different groups of pathological subjects such as dyslexics, stutterers etc. Several studies have also correlated the ear preference, measured by dichotic listening with other lateral specializations in different modalities, mainly with handedness (Bryden, 1970; Satz and Curry, 1967).

Myra A. Fernandes (2000) studied the validity of the Fused Dichotic Words Test (FDWT) in predicting the nature of speech representation, as determined by the Intracarotid Amobarbital Procedure (IAP) in a sample of 28 children with epilepsy. Various methods of analysis (difference score, λ, and λ^*), for the FDWT data were calculated and compared. Results showed the validity of the FDWT did not change depending on the method of analysis. The difference scores showed that 18 of the 19 patients with left hemisphere speech obtained right-ear advantages, while the patient with right hemisphere speech showed a left-ear advantage. As a group, patients with left-hemisphere speech obtained a statistically significant right-ear advantage for the λ and λ^* indices, while the patient with right-hemisphere speech showed a left-ear advantage that was also significant for both λ measures. Patients with bilateral speech, as a group, displayed a non-significant ear advantage. Some of the scores from the left-hemisphere group overlapped with those from patients with bilateral speech representation. Controlling for stimulus dominance effects using the λ^* measure did not improve classification accuracy for nature of speech representation based on FDWT scores.

To provide data on the stability of dichotic listening test, a study was conducted by Pizzamiglic et al (1974). In this study 91 right handed students were tested twice. The test retest correlation was significant.

The interpretation of the results from studies on dichotic listening must take into account such designed factors as practice response mode, and the type of analysis used to score the response. The effects of practice on dichotic listening have been investigated using test retest and multiple session paradigm. Ryan and McNeil (1974) and Johnson and Ryan (1975) found high test-retest correlations for both accuracy (total number of stimuli correctly recalled) and the magnitude of REA using dichotically presented CV syllables.

Porter et al. (1976) presented dichotic CV non-sense syllables to subjects over 8 weekly sessions. A significant improvement in accuracy was noted over the first 3 sessions, while the performance remained stable for the last 5 sessions. The magnitude of REA was not significantly different across the 8 sessions. Most recent experiments have used a forced choice, two response methods, where subjects are required to give two responses for each stimulus pairs presented. The two response method has the advantage of proving a measure of overall accuracy.

Ricketts et al (1999) studied the Effects of increased reliability on the validity of the dichotic listening right-ear advantage. In a series of two dichotic listening experiments with a total of 171 right-handers and 170 left-handers, they tested the hypothesis that increased reliability of measurement will lead to increased classification accuracy. Experiment 1 showed that neither the frequency nor magnitude of the right-ear advantage (REA) for fused rhyming words increased as the number of trials increased from 120 to 480. Ear-difference scores were highly reliable (r = .85), even when based on 120 trials. Experiment 2, which involved lists of dichotic word pairs, yielded similar results. Even though test retest reliability of the ear-difference score for 132 word pairs was only 0.45, neither the incidence nor strength of the REA increased significantly when the number of pairs was increased to 528. The results indicate that the poor classification accuracy of dichotic listening tasks cannot be attributed to unreliability.

FACTORS AFFECING DICHOTIC LISTENING

STIMULUS RELATED FACTORS AFFECTING DICHOTIC LISTENING

i) Effect of stimulus material on dichotic listening tasks

Several test procedures have been developed to measure dichotic listening in normals and to see how the performance varies in abnormals. Most dichotic speech tests aim at reducing the redundancy of a speech signal by either altering the temporal characteristics of the signal (Bocca, 1958; Calearo et al. 1957) or by use of filtered speech (Matzker, 1959). Tests such as dichotic Digits (Kimura, 1961), Dichotic CV by alveolars and labials. This was explained on the basis of variations in voice onset times and the burst intensities for the various CV's.

Di Stefano, Marano & Viti (2004) evaluated stimulus-dominance and ear asymmetry in normal population (48 subjects of both sex and handedness) and in 2 patients with a single functional hemisphere. Results show that in normals the number of stimulus-dominated responses is five times higher than in patients, and is negatively correlated to the index of laterality. It is suggested that dichotic stimuli may interfere one with another during the subcortical acoustic processing and at cortical level, when competing for verbal output. Subcortical interference accounts for stimulus-dominance in the single-hemisphere patients. Thus the presence of high stimulus dominance in the stimuli in dichotic listening task masks the right ear advantage. Hence eliminating stimulus dominance factor is preliminary step one has to follow to construct useful dichotic listening test.

SUBJECT RELATED FACTORS AFFECTING DICHOTIC LISTENING

i) Sex difference in language lateralization using dichotic listening

Kahn et al. (2008) studied sex differences in handedness, asymmetry of the Planum Temporale and functional language lateralization. This study was aimed to provide a complete overview of sex differences in several reflections of language lateralization: handedness, asymmetry of the Planum Temporale (PT) and functional lateralization of language, measured by asymmetric performance on dichotic listemng tests (Right Ear Advantage) and asymmetry of language activation as measured with

the perceived syllables

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Fusion in the dichotic listening condition takes place when words with similar spectral shape (waveform envelop) are presented to the listener (Repp, 1976). The waveform envelop for words is generally determined by the low frequency energy (Perrot & Berry, 1969), which is essentially its fundamental frequency (Repp, 1976, 1977a). Therefore if two words presented dichotically, which have similar spectral envelopes and are temporally aligned, they will fuse and will be heard as one word (Repp, 1977a). The words in DRT for the most part, are words that are perfectly or partially fused. The DRT uses temporally aligned consonant-vowel-consonant pairs that vary only in their initial consonants. Although subjects are presented two words (one word to each ear), the precise alignment of the words, as well as the fact that the final vowel-consonant elements in each pair of words are identical, result in the subjects perceiving only one word the vast majority of the time.

ii) Effect of frequency on Dichotic listening tasks

When two different auditory signals are presented simultaneously, one to each ear one of them is usually perceived as having a greater perceptual salience than the other. Two main types of such perceptual asymmetry have been reported. The first asymmetry has been called the right ear advantage (REA) for speech (Kimura, 1961) and has been assumed to reflect a left hemispheric dominance for the processing of speech sounds. The second type of auditory perceptual asymmetry arises when two dichotic signals are two tones relatively close in frequency (Efron and Yund, 1974, 1976). Ear dominance for pitch is independent of handedness as well as of the ear advantage observed with dichotic speech sounds (Yund and Efron, 1976). On the other hand, ear dominance is correlated with a difference in the frequency resolving power of the two ears (Divenyl, Efron and Yund, 1977). It thus seems reasonable to assume that ear dominance is a consequence of an asymmetry in the processing of spectral information and is produced by a mechanism different from that responsible for the REA observed with time varying auditory signals. However, since speech sounds carry spectral information, one might expect the REA for speech to be confounded with right ear dominance for tones. In subjects who have left ear dominance for tones, any REA for speech must be a consequence of some other (time related) asymmetry that is unique to speech processing.

The dichotomy between the two ears in perception to verbal and non-verbal inputs is not unequivocal. It has been shown that subjects attending to non-verbal properties (pitch or loudness variation) of dichotic verbal input reported better from the left ear than from the right ear (Nachshon, 1970; Spellacy and Blumstein, 1970). Hence, when the non-verbal aspects of verbal input are attended to, the input is mediated in the right hemisphere. Since one of the important features of verbal materials is its sequential character (Lashley, 1951; Neff, 1964; Hirsh, 1967), it may be assumed that non-verbal but sequentially patterned sounds will be mediated by the left hemisphere. Supporting this assumption is the evidence derived from studies showing that tasks involving sequential analysis if stimuli seem to be controlled by the left hemisphere. Specifically, these studies show that lesion of the left hemisphere selectively impair perception of visual and audio-visual stimuli (Efron, 1963; Goldman et al. 1968; Cannon, 1971).

Halperin, Nachshon and Carom (1973) tested this assumption by conducting a study on normal subjects. The subjects were presented with two dichotic listening task in which they were instructed to identify sets of sounds with different sequential complexity of frequency or duration. The sequential complexity was defined by the number of frequency or of duration transitions in a set of 3 sounds. The results of the study showed that the direction of ear superiority in report of dichotic set, varied as a function of the complexity of the temporal patterns. In case of zero transition (i.e. when no transition occurred within a set (left ear superiority) was found similar to that reported by Gordon (1970) for between ears discrimination of pitch. Increase of complexity by increasing the number of transitions was accompanied by a gradual shift from the left ear to right ear superiority. This finding was in accordance with the finding showing a significantly grater right ear superiority in perception of dichotic consonants (which are more complexly encoded than vowels), than in perception of vowels (Studdert-Kennedy, Liberman, Harris and Cooper, 1970).

Thus, studies have reported perceptual asymmetries to occur when two different auditory signals are presented simultaneously. A right ear advantage for speech and a left ear advantage for processing of tones, and other non-verbal stimuli have been reported. It was seen that when non-verbal aspects of verbal material are attended to, the input was mediated in the right hemisphere, where as non-verbal but sequentially patterned sounds will be mediated by the left hemisphere. It thus seems reasonable to assume that ear dominance is a consequence of an asymmetry in the processing of spectral information.

iii) Effect of intensity on dichotic listening tasks

Roeser, Johns and Price (1972) designed a study to investigate the intensity function of the right ear effects and to determine, whether there was intensity or a general range of intensities at which the effect is most observable. Results indicated that there was a significant tendency for subjects to report fewer correct responses at lower intensity levels. Subjects however reported significantly more stimuli from the right ear across intensity that is the right ear scores were not found to vary as a function of intensity. Ryan (1969) showed that REA was held constant even when the left ear signal was 6 dB more intense than the right ear.

Thus, the effect of intensity on dichotic listening has not been very extensively studied. The few studies conducted have shown that the right ear laterality did not differ significantly as a function of sensation level.

Hugdhal et al (2008) examined the effect of differences in the right or left ear stimulus intensity on the ear advantage using dichotic CV test. 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 results showed that: (a) a significant right ear advantage for interaural intensity differences from 21 to -3 dB, (b) no ear advantage for the -6 dB difference, and (c) a significant left ear advantage for differences form -

9 to -21 dB. It was 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. The same can be applicable to DRT.

iv) Effect of temporal aspects on dichotic listening tasks

When normal hearing listeners are stimulated dichotically with speech materials, there is a right ear advantage observed. However, when the stimuli are presented to the ears at onset time asynchronies of approximately 30 to 90msec, the lagging member of the pair is perceived more accurately than the stimuli presented first. In a study by Berlin et al. (1972), the amount of time separation between message onsets to overcome the right ear advantage was investigated. It was found that when one of the CV's trailed the other by 30 to 90 msec, the trailing CV became more intelligible than when it was given simultaneously.

In dichotic rhyme task there is no onset time variations, as both the competing words are aligned temporally to fuse. Thus lag effects may not significantly influence the performance of DRT.

v) Effect of stimulus dominance in dichotic listening

Berlin et al. (1973) reported that scores were higher for voiceless stops than for voiced stops in pairs of natural syllables that contrasted in voicing. The voiceless stops are said to be "dominate" the voiced stops. This finding was replicated by Roser et al. (1976) and by Niccum et al. (1976).

Thus, for natural CV syllables, there appeared to be a "stimulus dominance effect", i.e., higher scores are got for one of the two competing syllables- the "dominant" one -regardless of the ear to which it is presented. Lowe e al. (1970) found that their subjects correctly reported voiceless consonants more frequently than the voiced, in the dichotic tasks. However, in monotonic tasks, perception of the voiced consonants improved. Since both stimuli came to the same ear, the first transition from aperiodicity to periodicity occurs in the voiced CV. Thus, the potential for masking of the aperiodic portion of the voiceless consonant by the initial segment of the voiced consonant is clearly established.

In some respects, stimulus dominance is a more interesting phenomenon in dichotic listening, than is the ear advantage. It occurs with greater frequency than does ear advantage and is of greater magnitude. Speaks et al. (1981) noted that a joint consideration of the dominance of velar place and of the voiceless feature value seemed to provide a fairly complete description of the pattern of stimulus dominance.

Ear advantage, in dichotic listening tasks, has been studied extensively with CV non-sense syllables. It was found that, at simultaneity, the voiceless consonant was more intelligible than the voiced. This finding was explained in terms of a so called lag-effect, where the lagging syllable was found to interrupt the processing of syllable presented first and since the voiceless CV's have a longer voice onset time (VOT) and longer burst duration, the later arriving syllable disrupts the processing of the earlier syllable and hence is perceived better. In terms of place and manner of articulation, the voiceless velars were the most intelligible during dichotic presentations followed by alveolars and labials. This was explained on the basis of variations in voice onset times and the burst intensities for the various CV's.

Di Stefano, Marano & Viti (2004) evaluated stimulus-dominance and ear asymmetry in normal population (48 subjects of both sex and handedness) and in 2 patients with a single functional hemisphere. Results show that in normals the number of stimulus-dominated responses is five times higher than in patients, and is negatively correlated to the index of laterality. It is suggested that dichotic stimuli may interfere one with another during the subcortical acoustic processing and at cortical level, when competing for verbal output. Subcortical interference accounts for stimulus-dominance in the single-hemisphere patients. Thus the presence of high stimulus dominance in the stimuli in dichotic listening task masks the right ear advantage. Hence eliminating stimulus dominance factor is preliminary step one has to follow to construct useful dichotic listening test.

SUBJECT RELATED FACTORS AFFECTING DICHOTIC LISTENING

i) Sex difference in language lateralization using dichotic listening

Kahn et al. (2008) studied sex differences in handedness, asymmetry of the Planum Temporale and functional language lateralization. This study was aimed to provide a complete overview of sex differences in several reflections of language lateralization: handedness, asymmetry of the Planum Temporale (PT) and functional lateralization of language, measured by asymmetric performance on dichotic listening tests (Right Ear Advantage) and asymmetry of language activation as measured with functional imaging techniques. Meta-analysis of studies that assessed handedness in males and females yielded more left-handedness in males (mean weighted odds ratio: 1.25, $p<0.001$). Meta-analysis of studies on PT asymmetry yielded no sex difference (Hedges g=-0.11, p=0.68). Results of the meta-analysis on dichotic listening studies also retrieved no sex difference in lateralization (Hedges g=0.09, p=0.18). When the studies were subdivided according to the paradigm they applied, studies that used the consonant-vowel task yielded a sex difference favoring males, while studies that applied other paradigms yielded no sex difference. The subdivision into applied paradigm largely overlapped with the subdivision into studies that did or did not focus on sex differences as their main topic. The observed sex effect may therefore be caused by publication bias. Meta-analysis of functional imaging studies yielded no sex difference (Hedges g=0.01, p=0.73) in language lateralization. Sub-analyses of studies that applied different paradigms all yielded no sex difference. In conclusion, males are more frequently non-right handed than females, but there is no sex difference in asymmetries of the Planum Temporale, dichotic listening or functional imaging findings during language tasks.

Elliot and Welsh (2001) studied gender differences in a dichotic listening and movement task. Although the dichotic listening procedure has been used as a non-invasive neuropsychological technique for assessing laterality of speech perception, it has tended to underestimate the proportion of the right-handed population that is left-hemisphere lateralized for speech perception [Segalowitz SJ, Bryden MP. Individual differences in hemispheric representation of language. In: Segalowitz SJ (Ed.), Language Functions and Brain Organization. Toronto: Academic Press, 1983, pp.

age range. In contrast to these results in Indian context finding by Gowri Krishna (1996) reveals that even at the age of 12 the results were not matched with adult score on dichotic CV test.

Cross-sectional dichotic listening study by Pohl (1984) using thirty pairs of one-syllable words and thirty pairs of four-syllable numbers reveal the developmental course of ear asymmetry. Middle-class children with age range of 4 to 10 were taken as subjects. A significant decrease in REA for both word and number pairs was found. Although right-ear and left-ear performance both increased with age, the developmental gain in left-ear performance was greater than the gain in right-ear performance, thus resulting in a decrease in REA with age. But contrasting results were found using dichotic sentence identification by Jerger, Chmiel, Allen and Wilson (1994). They have analyzed the clinical records of 356 individuals, 203 males and 153 females, to whom the Dichotic Sentence Identification (DSI) test had been administered as part of routine audiometric assessment. The age range considered for study was 9 to 91 years. Results revealed that larger right-ear advantage, or left-ear deficit, was observed with increasing age. Comparison of male and female data suggested gender difference in the effect of age on the left-ear deficit. Males show a larger effect than females in both modes of test administration. Poor left-ear performance on dichotic sentence tasks 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, inter-hemespheric transfer of information improves and left-ear scores approach those found in adults (Musiek, Gollegly & Baran, 1984).

341-72]. These underestimations may be due to traditional dichotic procedures being susceptible to attentional biases, order of report effects, and/or memory effects that obscure functional differences between the cerebral hemispheres. In this study, they used an adaptation of the dichotic listening procedure that was designed to be less sensitive to these confounding effects. Participants were required to move as quickly as possible to one of the two color-coded targets following verbal cues presented via headphones. Conditions of cue-word presentation were monaural, (e.g. 'blue' in one ear and a blank track in the other), dichotic-same (e.g. 'blue' in both ears), and dichotic-different (e.g. 'green' in one ear and 'blue' in the other). Ninety-three percent (26 of 28) of the participants demonstrated a right ear advantage (REA) for correct responses. There was also a REA for reaction time, movement time, and the total response time. The pattern of reaction time and movement errors, however, suggest that gender differences found utilizing this dichotic procedure may be due to differences in strategic approach to the task rather than to differences in cerebral laterality. Overall, results suggested that this new adaptation of the dichotic listening procedure is very sensitive to lateralization for speech perception.

Kalil et al. (1994) did an exhaustive survey of auditory laterality studies from six neuropsychology journals to see if there is a sex difference in human laterality. The entire contents of six neuropsychology journals (98 volumes, 368 issues) were screened to identify auditory laterality experiments. Of the 352 dichotic and monaural listening experiments identified, 40% provided information about sex differences. Among the 49 experiments that yielded at least one significant effect or interaction involving the sex factor, 11 outcomes met stringent criteria for sex differences in laterality. Of those 11 positive outcomes, 9 supported the hypothesis of greater hemispheric specialization in males than in females. The 9 confirmatory outcomes represent 6.4% of the informative experiments. When less stringent criteria were invoked, 21 outcomes (14.9% of the informative experiments) were found to be consistent with the differential lateralization hypothesis. The overall patterns of results were compatible with a weak population-level sex difference in hemispheric specialization.

Hiscock and Hiscock (1988) studied an anomalous sex difference in auditory laterality. Eighty right-handed adults (40 females, 40 males) performed a task that entailed detecting and localizing targets within series of dichotic digit names. Analysis of sensitivity scores for each ear revealed an overall right-ear advantage (REA). However, a significant Sex x Ear interaction showed that the degree of asymmetry was greater among females than among males. This sex difference, which is opposite to that previously reported in some dichotic listening studies, contradicts the conclusion that language processing is more completely lateralized in males than in females.

ii) Effect of age on dichotic listening

The effect of age on dichotic listening may be different depending on the type of stimuli used. Dichotic listening on children suggest that the more linguistically loaded stimuli presented, the more pronounced the maturational effects are likely to be.

Berlin, Hughes and Lowe-Bell (1973) studied the performance of normal hearing children between ages 5 and 13 on a set of dichotic CV test. Their results showed a right-ear advantage (REA) that remained relatively constant throughout the age range. In contrast to these results in Indian context finding by Gowri Krishna (1996) reveals that even at the age of 12 the results were not matched with adult score on dichotic CV test.

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iii) Effect of practice on dichotic listening

Porter, Troendle and Berlin (1976) studied practice effects on dichotic listening task using dichotic CV material. They investigated long-term effects of practice on performance by testing once a week over a period of 8 weeks. Results revealed that a slight increase in double correct responses (28% - 38%), a slight drop in both single correct responses (65% - 58%) and decreased either correct responses (7% - 4%). However, overall dichotic performance does not become a stable measure (i.e., does not reach an asymptote) until subjects have experienced at least 300 dichotic trials. Similar results were also reported earlier by Ryan and McNeil (1974); Johnson and Ryan (1975).

iv) Effect of response mode on dichotic listening

The response of the listener can be of number of ways on dichotic listening task. These include written down response, or orally repeating the heard stimuli and also visual recognition. As the process involved in these activities varies, there could be some differences exists on responses. Lutz Jancke (1993) evaluated the difference in results with respect to the three response conditions using dichotic CV test. Testing was administered three times to 56 male right handers and 50 male left handers. During each experimental session the subjects had to perform this dichotic test using a different response condition. On one occasion they were required to verbally report the perceived syllables *(speak* condition), on another occasion they were asked to write down the syllables they had heard *(write* condition), and lastly, they were asked to visually recognize the stimuli *(visual* condition) which were presented onto a monitor screen. Results revealed that there is no significance influence of response mode on right ear advantage.

PERFORMANCE ON DICHOTIC LISTENING USING DIFFERENT REPORT STRATEGIES

The studies on dichotic listening have evaluated the performance of normal subjects using two response modes or report strategies. The response modes are free-recall and directed recall. Free -recall is one in which the subject reports the stimuli in any order, and directed recall is one in where in the subject is instructed to report the stimuli heard in one of the ears (either right or left). Bryden (1962) found that right ear superiority consistently occurred when a free-recall procedure was used, as well as when the order of report was controlled. Similar findings were reported by Satz et al. (1965). Gerber and Goldman (1970) conducted a study, where subjects were tested in different reporting conditions (free-recall and directed response). It was found that a significant right ear preference for dichotically presented stimuli existed regardless of the report strategy employed.

The findings of other study conducted by Keith et al. (1985) were in contrast to that of Bryden (1962). Keith examined the response of adult subjects to directed listening tasks using the dichotic consonant-vowel (CV) test. Results indicated that subjects showed right ear advantage in directed right listening condition and a left ear advantage in directed left listening condition. Free-recall listening conditions showed a right ear advantage.

Baran and Musiek (1987) studied the performance of adult subjects on a dichotic speech test under both directed and free recall listening conditions. Twenty-five young adult subjects with negative otologic histories were administered a dichotic rhyme test under three different listening conditions: (1) free recall, (2) directed listening to the right ear, and (3) directed listening to the left ear. The dichotic rhyme test used was composed of 30 well-aligned synthetic CVC words that were presented at 50 dB SL *(re:* speech reception thresholds). The nature of the test was such that under normal conditions (i.e., free recall), listeners tend to repeat either the word presented to the left ear or to the right ear. Normal performance was approximately 50% correct identification in each ear, with a slight right ear advantage evident. In an earlier investigation using a dichotic CV test, Keith *et al.* [Ear Hear. 6, 270-273 (1985)] demonstrated a clear left ear advantage on a directed left ear task and an obvious right ear advantage on a directed right ear task. This investigation showed no significant differences in the test scores observed when the right and left ear scores were compared with the same ear scores across the three test conditions. In all three test conditions, a slight right ear advantage was noted.

Musiek et al. (2005) studied the Differential attention effects on dichotic listening. The purpose of this study was to assess the performance of normal listeners on a dichotic consonant-vowel and a dichotic rhyme (fusion) test. Both test procedures were administered to 20 young adults in three different listening conditions (free recall, attention directed to the left ear, and attention directed to the right ear). Results from this study supported the hypothesis that dichotic rhyme tests are resistant to alterations in the laterality of attention and have implications for the development of test paradigms that can be used to segregate attention from pure auditory deficits in the clinical domain.

Asbjornsen and Bryden (1996) studied the effect of biased attention on the fused dichotic words test (FDWT) and the CV syllables dichotic listening test (CVT). Eight males and eight females were given both tests with two different instructions: to direct attention to the left ear (DL), or to the right ear (DR). These instructions led to highly significant differences in response on the CVT, but only a marginal shift in performance on the FDWT. While the FDWT is not completely unaffected by attentional manipulations, it is far less influenced by such effects than the CVT. This indicates that subject-initiated shifts of attention are much less likely to affect performance on the FDWT than on other dichotic tests and makes it a more valuable task to assess cerebral speech lateralization.

Hiscock et al. (1999) studied allocation of attention in dichotic listening and differential effects on the detection and localization of signals. 96 normal right-handed adults attended selectively to the left and right ear and divided their attention equally between both ears. Participants listened for specified targets and reported the ear of entry. The material consisted of pairs of consonant-vowel syllables in Experiment 1 and pairs of rhyming consonant-vowel-consonant words in Experiment 2. Both experiments yielded a right-ear advantage for detection and for localization. Attention instructions had no effect on detection. However, focusing attention on 1 ear increased the number of targets attributed to that ear while decreasing the number of targets attributed to the opposite ear. The dissociation between detection and localization indicates that volitional shifts of attention influence late (response selection) processes rather than early (stimulus identification) processes. Selective-listening effects can be accounted for by a 2-stage model in which a fixed input asymmetry is modulated by a biased selection of responses.

STUDIES OF DICHOTIC LISTENING IN ABNORMAL POPULATION

The following discussion is aimed at reviewing studies of dichotic listening tasks used in the abnormal population. Audiologists have been involved in central auditory testing for over three decades. Bocca and his associates were the first to use special test to evaluate problems at various levels of the central auditory nervous system (CANS). The audiologists can hence assess auditory function to provide the best management strategies. Audiometric evaluations of lesions of the central auditory paths have now become very fashionable and the question is being debated by increasing number of investigators. In the course of about a decade, experiences have allowed the establishment of a series of tests which have been found to be practical and adequate for in this particular branch of audiology.

The following section deals with the studies of dichotic listening conducted on patients with different disorders.

Temporal Lobe Lesion

Berlin et al. (1972) measured central auditory deficits in patients after temporal lobectomy. They used dichotic simultaneously and time staggered speech material on four patients with temporal lobectomies and compared the results with that of normals. In their test, competing non-sense syllables were used in following manner: /ba/ was presented to the right ear /ta/ was presented to the left ear, both at the same time. The patient was asked to repeat what he heard. The message to the ear ipsilateral to the lesion was usually reported accurately, the one to the contralateral ear was either not perceived at all or was distorted. Thus, if /ba/ was given in the right ear of patient with right temporal lobectomy, he would report /ba/ and miss the /ta/. The syllables, in Berlin et al. (1972) study were presented simultaneously, then with the separations ranging from 15 to 500 msec. it was seen that with simultaneous onset normals showed right ear superiority, and with time separation of 30 msec to 90 msec, normals showed a lag-effect, i.e., better scores for the trailing stimulus. In sharp contrast, temporal lobectomy patients showed poorer contralateral ear function than ipsilateral ear function, and no lag-effect. Comparing preoperative and postoperative scores, it was seen that postoperatively there was additional degradation of contralateral ear scores and enhanced ipsilateral ear function in dichotic listening. Patients with both left and right temporal lobectomies behave similar in this respect. It is clear from this data that the advantage which normal listeners achieve when they hear a lagging message in a pair is lost to patients with temporal lobe lesions. Patients show a distinct failure to accurately perceive messages in the ear contralateral to the lesion, independent pf the temporal sequence of the syllables. Berlin et al. (1972) believed that both right and left anterior temporal lobes must participate in some type of preliminary speech information processing, otherwise there would be no prospective laterality effects following temporal lobe lesions. Such patients generally show an almost complete separation of dichotic speech information sent to their contralateral ears. It was suggested that the anterior temporal lobe play a critical role in either preliminary speech analysis or in the relay of speech information to the posterior temporal cortex via association pathways. It was hypothesized that the information coming right anterior temporal lobe to the left posterior temporal areas need not pass through the left anterior areas. If such a serial relationship existed, than a left anterior temporal lobectomy would have devastating results on all speech and hearing functions. On the contrary, it is only the left 'posterior' temporal parietal removals that have such serious effects (Berlin et al. 1972). Sparks et al. (1970) have suggested that if deep left hemisphere lesions interfere with connection from the right to the left temporal lobe, one might also see ipsilateral "extinction" in the left ear with a left hemisphere lesion.

When two competing stop consonant-vowel (CV) syllables were presented dichotically to a listener with a temporal lobe lesion, the scores for syllables in the ear contralateral to the lesion usually was much lower than scores for syllables in the ipsilateral ear. Ample documentation exists to show that the weak ear score for temporal lobe patients was suppressed markedly in dichotic tasks. The existence of separation has been documented with CV syllables (Berlin et al. 1972, 1973), digits or words (Kimura, 1961; Speaks, Goodglass, 1970), sentences (Jerger et al. 1969, speaks et al. 1973). The inference seems to be that the cortical processing areas for speech presumably located in the left hemisphere; do not receive an effective dichotic input. Because of the temporal lobe lesion the signal was degraded sufficiently such that correct processing of the weak ear signal was unlikely.

Split-Brain patients

The DRT was also used in studying dichotic listening performance in split-brain patients (Musiek et al, 1989). In this study, two significant observations were made for the population of patients. The first of these was that the subjects in this investigation consistently demonstrated the "expected" left ear deficit due to the compromise of the normal inter-hemispheric pathways, and the second was that the subjects not only showed the expected REA but that the size of this advantage was noticeably greater than that noted for normal subjects. The results of this study demonstrated that in addition to being clinically feasible for use with patients with compromise of the central auditory nervous system, this test was highly sensitive in assessing the integrity of inter-hemispheric transfer of auditory information.

Zaidel et al (2007) studied two commonly used dichotic listening tests for measuring the degree of hemispheric specialization for language in individuals who had undergone cerebral hemispherectomy: the Consonant-Vowel (CV) nonsense syllables and the Fused Words (FW) tests, using the common laterality indices f and λ. Hemispherectomy on either side resulted in a massive contralateral ear advantage, demonstrating nearly complete ipsilateral suppression of the left ear in the right hemispherectomy group but slightly less complete suppression of the right ear in the left hemispherectomy group. The results are consistent with the anatomical model of the ear advantage (Kimura, 1961). Most syllables or words are reported for the ear contralateral to the remaining hemisphere, while few or none are reported for the ear ipsilateral to the remaining hemisphere. In the presence of competing inputs to the two ears, the stronger contralateral ear-hemisphere connection dominates/suppresses the weaker ipsilateral ear-hemisphere connection. The λ index was similar in the two tests but the index f was higher in the CV than the FW test. Both indices of the CV test were sensitive to side of resection, higher in the right hemispherectomy than in the left hemispherectomy groups.

Luxon et al (2005) studied auditory Interhemispheric Transfer in Patients with Congenital Abnormalities of the Commissural Pathways due to a PAX6 Mutation. Patients with a heterozygous PAX6 mutation have absent or hypoplastic anterior commissure and may have a reduced size corpus callosum. Both these formations contain auditory interhemispheric fibers. They assessed central auditory function in 8 patients with a PAX6 mutation and 8 age- and sex-matched controls. Brain MRI results were available for all PAX6 subjects. Subjects and controls had baseline audiometric tests, and central auditory tests, which included the dichotic digits, rhyme and CVs, frequency and duration pattern, and a Gap in Noise tests. The anterior commisure was absent in 5 and hypoplastic in 1 subject. The callosal area was reduced in 3 subjects. All subjects and controls had normal peripheral hearing. The PAX6 group had a greater left ear deficit in the dichotic digit and the dichotic CVs tests and a greater right ear advantage in the dichotic rhyme test than controls ($p<0.05$). The PAX6 group gave worse scores than the control group in the frequency and duration pattern tests ($p<0.05$). The Gap in Noise test result was similar in patients and controls. The PAX6 group had significantly worse results in tests that require interhemispheric transfer (dichotic speech and pattern tests) than the control group, but similar results in the Gap in Noise test, which does not require such transfer. The results may reflect deficient auditory interhemispheric transfer in the PAX6 group. The profile in the PAX6 group was very similar, albeit less severe, than the profile of patients who have undergone surgical section of the corpus callosum. This profile could be attributed to the absence/aplasia of the anterior commisure and/or deficiency of the corpus callosum, although other subtler abnormalities of the central auditory pathway, undetected by MRI may also have contributed to their findings.

Luxon et al (2007) studied auditory inter-hemispheric transfer deficits, hearing difficulties and brain magnetic resonance imaging abnormalities in children with congenital aniridia due to *PAX6* mutations. Eleven case subjects with *PAX6* mutations and 11 age-matched and sex-matched healthy control subjects participated in the study. Results indicated that the corpus callosum area was significantly smaller on brain volumetry in the cases compared with the controls. The anterior commissure was small in 7 cases and was normal in 3 cases on visual inspection of brain MR images (conducted in 10 of 11 cases). Audiograms showed no abnormalities in any of the children. Central auditory test results were normal in all the controls and were abnormal in all the cases except for 1 case with a pattern of abnormalities consistent with reduced auditory inter-hemispheric transfer. The cases had greater difficulty localizing sound and understanding speech in noise than the controls. Authors concluded that despite normal audiograms, children with *PAX6* mutations may experience auditory inter-hemispheric transfer deficits and have difficulty localizing sound and understanding speech in noise. In view of their additional visual difficulties, thorough audiological evaluation of these children is indicated to initiate appropriate management.

Screzophenics

Gorman et al (2001) used Dichotic listening techniques to compare subjects with paranoid and undifferentiated subtypes of schizophrenia. The Fused Rhymed Words Test was used to compare perceptual asymmetries in 16 patients with paranoid schizophrenia, 28 patients with undifferentiated schizophrenia, and 29 healthy comparison subjects. Results indicated that Patients with paranoid schizophrenia had the largest left hemisphere advantage and patients with undifferentiated schizophrenia had the smallest. The asymmetry of healthy subjects was intermediate. Hemisphere advantage varied as a function of gender only in the patients with undifferentiated schizophrenia. 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.

CHAPTER III

METHOD

The present study was carried out with an aim of developing the dichotic rhyme test and also to generate the normative data. The test was developed in Kannada language.

The study was carried out in two phases.

Phase I- Development of test material

Phase II - Establishing the normative data for the developed test material.

Phase I:

Procedure for developing test material

Construction of test material

18 pairs (36 members) of Kannada rhyming words consisting of /p,th,k,b,dh,g/ in the initial position and which has a syllable structure of CVCV was taken from a standard Kannada dictionary. Members of each pair differed from each other only in the initial consonant and the members of the pair differed only on one phonetic feature (either voicing or place of articulation).

Familiarity test

These 36 words were given to 10 adult native speakers of Kannada (5 males and 5 females) to rate on a 5 point scale, with following rates:

0 - Very unfamiliar (Not heard)

1 - Unfamiliar (Heard but not commonly used)

2- Quite familiar (Less commonly used)

3- Familiar (Commonly used)

4- Very familiar (Most commonly used)

The rating score of two or more was set as the criteria for inclusion in the test material. All of the words had a rating of greater than or equal to 2. So, all the 36 words were considered as familiar and were taken for the construction of test material.

Recording of test stimulus:

An adult native speaker of the language was asked to produce each of these 36 words 3 times in a continuous manner and the words were recorded using "PRAAT" software with a sampling frequency of 22050 Hz and digitization of 16 bits. For the test material, the middle word of the 3 continuous words was considered to get a flat frequency spectrum. These words were analyzed using Adobe Audition 1.0 computer software.

Construction of Stimulus:

The final portions of the members of each pair were made identical using cross-splicing, (i.e, the initial, distinctive portion of the one member of each pair was cross spliced onto the final, non-distinctive portion of the other member, making the final portion of the members of each pair identical).

E.g., in /pennu/ - /bennu/, the portion of /ennu/ in either /pennu/ or /bennu/ was selected and positioned in both the words, thus the portion /ennu/ was same in both the words.

After cross splicing, the total duration of rhyming words were made equal by reducing the voicing bars or by reducing the steady state portion of the vowel, of the initial CV portion of the word. Cross splicing was done to reduce the intrinsic variability among the final syllables in a rhyming pair.

Using Adobe Audition 1.0 Software, the two members of each Rhyming pair were recorded on stereo tracks with 0 millisecond delay between each member of the pair. The word pairs were 10 seconds apart on stereo tracks.

Stimuli were placed on a stereo track such that one member of the pair was routed to one ear and the other member of the pair was routed to the other ear. These 18 rhyming pairs (randomly) along with initial calibration tones were recorded onto the Compact Disk. These 18 rhyming pairs were randomly chosen again and words in each pair were counterbalanced (i.e, in the first 18 pairs if "Pennu" was presented to the right ear and "bennu" was presented to the left ear, then in the second 18 pairs the channel designations were reversed).

Thus, the list consisted of a total of 36 pairs of rhyming words.

Phasell

Establishing Normative data

Subjects:

- 50 young normal hearing adults (25 males and 25 females) with Kannada as mother tongue were taken as subjects.
  The age ranges of the subjects were 18 to 30 years.

Subject selection criteria:

The subjects selected for the study had

> No history of Hearing loss

> No Chronic otological problems

> No neurological problems or Trauma to the brain

> No previous experience with dichotic listening tasks

> Right-handedness

> Pure-tone thresholds less than 15dB in both ears for both air conduction and bone conduction measurements

> Speech identification scores of 80% or greater

Instrumentation:

> A calibrated two channel (ANSI S3.6-1996) diagnostic audiometer Madsen Orbiter 922 with TDH-39 headphones housed in MX-41 AR ear cushions and B71 bone vibrator was used to check the hearing threshold in all the participants.

> GSI TympStar tympanometer was used to evaluate the status of the middle ear in all the participants.

> A CD player was used to play the compact disc. The signal from the CD player was fed to the tape input of the audiometer.

w **Test Environment:**

The testing was carried out in a well lit air conditioned sound treated double room and ambient noise levels were within 35 dB SPL (ANSI 1999).

Test procedure:

1. Puretone thresholds were obtained at octave intervals between 250Hz to 8000 Hz for air conduction and between 250 Hz to 4000 Hz for bone conduction.
2. Immittance audiometry was carried out with a probe tone frequency of 226 Hz. Ipsilateral and contralateral acoustic reflexes thresholds were measured for 500 Hz, 1000 Hz, 2000Hz, and 4000Hz.

3. Subjects who passed the subject selection criteria were administered the dichotic rhyme test. The VU meter was adjusted to the 1 kHz calibration tone. The 36 pairs of dichotic stimuli were presented at an intensity level of 60 dB HL. Subjects were instructed to respond on an open set answer sheet (APPENDIX-B). The task involved writing down the rhyming words heard after each presentation. All subjects were encouraged to guess when unsure of the word or words.

Scoring:

The subject responses were scored in terms of

Single correct scores: Total number of correct responses for the right ear or the total number of correct responses for the left ear.

Double correct scores: Scores obtained when subject correctly responded both the stimuli presented to the two ears.

Ear correct scores: To get total ear correct scores, the double correct score was added to single correct score of respective ear and were used for analysis.

Statistical analysis:

The raw data was subjected to statistical analysis where the mean, the range and standard deviation were calculated. 'Repeated measure of ANOVA for ears with independent factor as gender' was used to evaluate the main effect and the interaction between gender and ear. Independent and paired t-test was also used to reveal the significant difference between genders on ear correct scores and between ear correct scores with-in gender. Further details on results are discussed under results and discussion chapter.

CHAPTER IV

RESULTS AND DISCUSSION

The aim of present study was to develop Dichotic Rhyme Task in Kannada and to have normative data for the developed test. To have normative values, data collected on 25 male subjects and 25 female subjects in the age of 18 to 30 years was used. The data was subjected to statistical analysis using the software program SPSS version 10.0.

The following statistical analyses were done:

- Repeated measures of ANOVA to see the main effect and the interaction between gender and ear
- Paired sample "t" test was done to see the significant difference between right and left ears. And also to see the significant difference between single correct and double correct scores.
- Independent 't" test was done to see the significant difference between genders on ear correct scores and double correct scores.

The results were analyzed by calculating the mean, standard deviation and the range. Analysis was done to obtain information on:

(i) Ear correct scores: Total number of correct responses for the right ear or the left ear plus the double correct scores.

(ii) Double correct scores: Scores obtained when subject correctly responded both the stimuli presented to the two ears.

I. Comparison of ear correct scores with-in gender

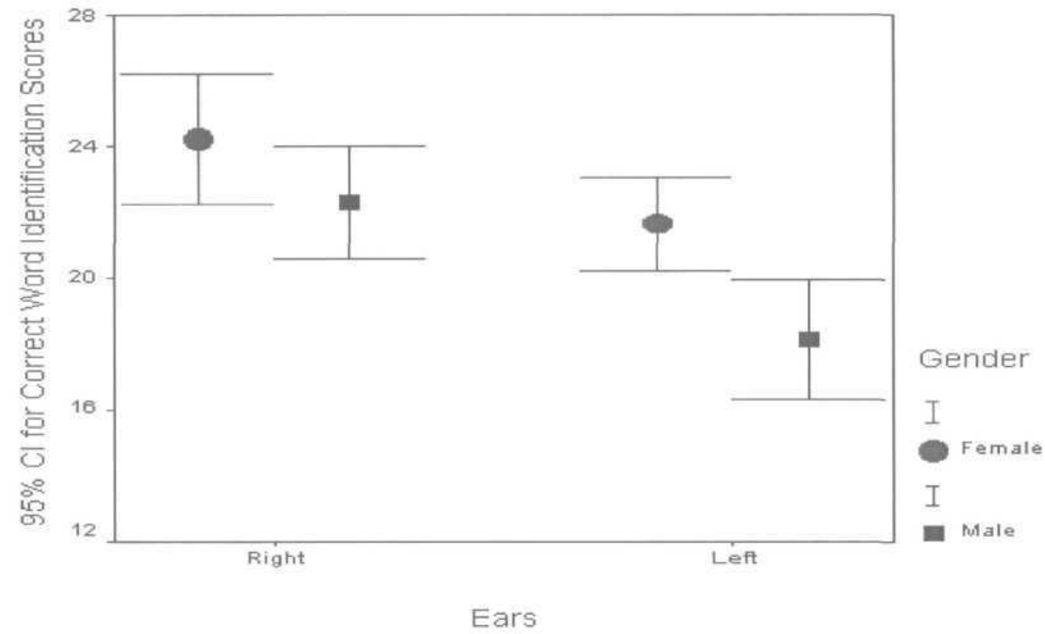
The mean and the standard deviations for male and females were calculated separately. As it can be seen form the table, the mean scores for the right ear were better than the left ear scores for both males and females. Repeated measures of ANOVA revealed a significant main effect for the ears [F (1, 48) =34.560 (p<0.00l)] but it did not show the interaction effect for the ear and gender [F (1, 48) = 1.840 (p>0.05)].

Table 1

The mean values, standard deviation, the range and the t-scores along with the level of significance for the ear correct scores

	Gender	Mean	SD	t	Sig. (2-tailed)
Females	Right	24.24	4.75	3.76	.001
	Left	21.64	3.45		
Male	Right	22.32	4.16	4.52	.001
	Left	18.16	4.35		

Maximum score = 36



Figure!: Error bars showing the mean values and the standard deviation for the ear correct scores for the right and left ears.

As it can be seen from figure 1, the scores for right ear were better than the left ear for both males and females, which was statistically significant. As depicted in table 1, the mean scores for the right ear was 23.28 and the mean scores for the left ear was 19.90. Paired sample "t" test results revealed a significant difference ($p<0.01$) between the left and the right ear scores for both males and females.

The results obtained from the present study are consistent with results from studies conducted on the western population by Musiek et al. (1989), Wexler and Halwes (1983) and Berlin et al. (1973). Musiek, et al. (1989) reported normative values of 30% - 73% for right ear and 27% - 60% for left ear in a group of 115 normal hearing subjects.

Berlin et al. (1973) reported a right ear advantage (REA) for dichotic speech stimuli. This REA is seen in normals because the left anterior temporal lobe is closer to the left primary speech areas than the right anterior temporal lobe. Therefore, it is postulated that there is less 'transmission loss' to the left posterior- temporal- parietal lobe on the basis of proximities within areas of the brain. Due to this proximity there is more efficient interaction between the shorter pathways (Berlin et al. (1973). Similar findings have been reported in studies conducted by Studdert-Kennedy and Shankweiler (1967). They reported of right ear superiority in the perception of speech stimuli when normal hearing listeners are stimulated dichotically with speech stimuli.

Kimura (1967) attributed this difference in ear accuracy as a function of stimulus type to bilateral asymmetry in brain function (BAF).

The BAF hypothesis suggest that

(i) The contralateral auditory neural pathways are dominant over the ipsilateral pathways during the dichotic stimulation.

(ii) Performance superiority of a particular ear is a result of that ear being contralateral to the hemisphere involved in the perception of a given type of sound.

In particular, the hypothesis implies that the left cerebral hemisphere is dominant in perception of sounds conveying language information while the right hemisphere is dominant for perception of non-speech sounds such as melodies (Kimura, 1967).

Thus, the results of the present study indicated that there existed a significant REA for the dichotic rhyme stimuli.

II. Comparison of ear correct scores and double correct scores across gender

II. A) Comparison of ear correct scores across gender

As it can be seen from table 2, the mean ear correct scores for females were better than males for both left and right ears. For the right ear, the mean score for females were 24.24 and the mean score of males were 22.32. For the left ear, the mean score for females were 21.64 and the mean scores for the males were 18.16.

Table 2

The Mean values, standard deviation and "t" test results for the comparison across genders for the ear correct scores

	Gender	**Mean**	**SD**	**t**	**Sig.(2-tailed)**
Right	Female	24.24	4.75	1.519	.135
	Male	22.32	4.16		
Left	Female	21.64	3.45	3.13	.003
	Male	18.16	4.35		

Maximum score = 36

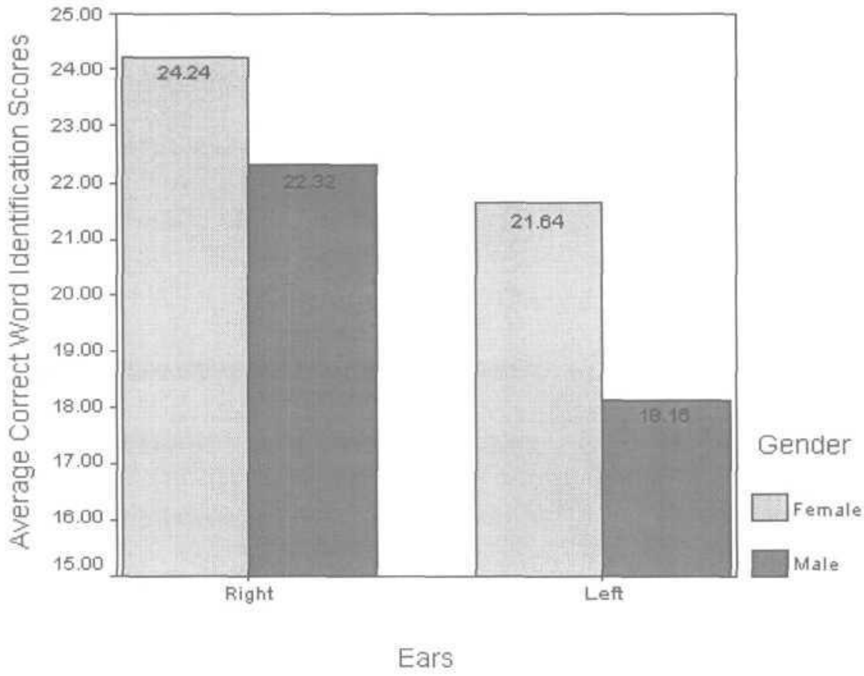


Figure2: The mean values of ear correct scores for males and females.

As it can be seen from figure 2, females had higher scores compared to males for both right and left ears.

Independent t-test was carried out for comparison of gender within each ear. Independent sample "t" test revealed a significant difference between males and females for the left ear ($p < 0.05$). Although the mean ear correct scores, for the right ear, for females were higher compared to males independent "t" test did not reveal any significant difference ($p > 0.05$).

II. B) Comparison of double correct scores across gender

As it can be seen form table 3, the mean double correct scores were better for females as compared to males. The mean double correct scores were, 11.52 for females and 7.16 for males, respectively. As it can be seen from figure 3, the mean scores for females were higher than males for double correct scores. Independent "t" test was done to find out the significant difference between the scores for males and females. Independent "t" test revealed a statistically significant ($p < 0.05$) difference between males and females for double correct scores.

Table 3

The mean values, standard deviation, the range and results of independent "t" scores for the double correct scores

Gender	Mean	95% Confidence Interval for Mean		SD	t	Sig. (2-tailed)
		Lower Bound	**Upper Bound**			
Females	11.52	5.87	16.16	9.41	2.54	.014
Males	7.16	4.80	12.51	7.70		

Maximum score = 36

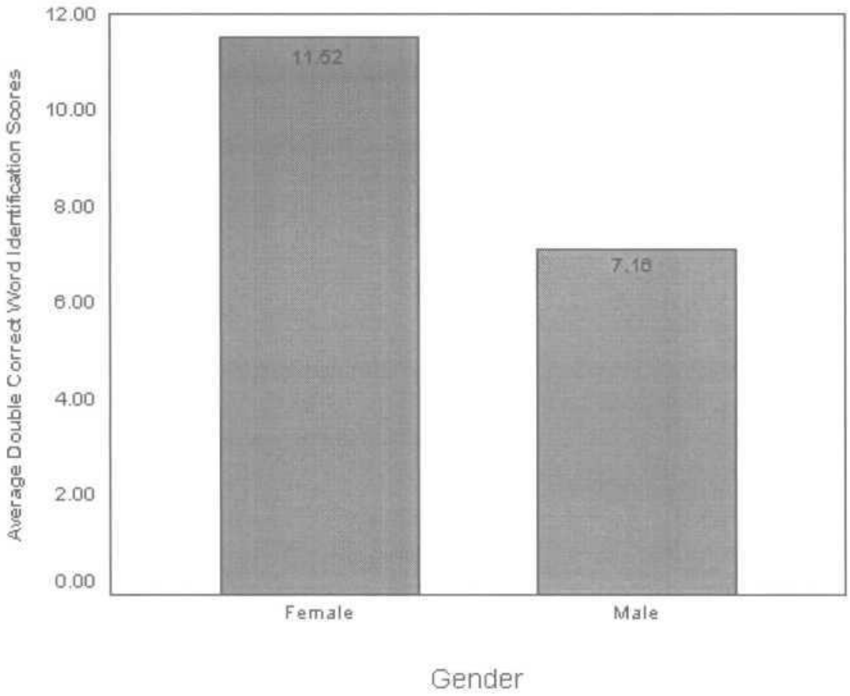


Figure3. The mean values of double correct scores for both males and females.

Elliot and Welsh (2001) concluded that gender differences found utilizing dichotic procedure may be due to differences in strategic approach to the task rather than to differences in cerebral laterality. Although the dichotic listening procedure has been used as a non-invasive neuropsychological technique for assessing laterality of speech perception, it has tended to underestimate the proportion of the right-handed population that is left-hemisphere lateralized for speech perception (Segalowitz & Bryden, 1983) and individual differences in hemispheric representation of language. These underestimations may be due to dichotic procedures being susceptible to attentional biases, order of report effects, and/or memory effects that obscure functional differences between the cerebral hemispheres.

Kalil et al. (1994) did an exhaustive survey of auditory laterality studies from six neuropsychology journals to see if there is a sex difference in human laterality. The entire contents of six neuropsychology journals (98 volumes, 368 issues) were screened to identify auditory laterality experiments. The overall patterns of results were compatible with a weak population-level sex difference in hemispheric specialization.

Kahn et al. (2008) studied sex differences in handedness, asymmetry of the Planum Temporale and functional language lateralization. This study was aimed to provide a complete overview of sex differences in several reflections of language lateralization: handedness, asymmetry of the Planum Temporale (PT) and functional lateralization of language, measured by asymmetric performance on dichotic listening tests (Right Ear Advantage) and asymmetry of language activation as measured with functional imaging techniques. Based on the results they concluded that there is no sex difference in asymmetries of the Planum Temporale, dichotic listening or functional imaging findings during language tasks. The observed sex effect may therefore be caused by publication bias.

Thus, gender difference seen for the left ear in the present study, can be the result of procedural variability or underestimation of this dichotic test to individual differences in hemispheric representation of language. It is difficult to attribute this difference in scores on dichotic task between males and females to sex difference in hemispheric lateralization.

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III. Comparison of ear correct scores with double correct scores

As it can be seen from Table 4, the double correct scores were lower when compared to the ear correct scores. The mean values were, 21.59 for the ear correct scores and 9.34 for the double correct scores, respectively. Standard deviation and ranges were higher for the double correct scores as compared to single correct scores.

Table 4

The Mean values, standard deviation and the ranges for the comparison between ear correct scores and double correct scores

	Mean	SD	95% Confidence Interval for Mean		t	Sig. (2 tailed)
			Lower Bound	Upper Bound		
Ear correct scores	21.59	4.39	19.85	23.3	3.37	.003
Double correct scores	9.34	8.55	5.33	14.33		

The double correct scores were found to be lower when compared to the ear correct scores. Paired sample "t" test was done to see the difference between single correct scores and double correct scores. The difference in scores between ear correct scores and double correct scores were statistically significant ($p < 0.05$). This is in agreement with the previous reports by Wexler and Halwes (1983) and Musiek et al.

4) The double correct scores were found to be lower when compared to the ear correct scores.

5) Since the variability is lesser for the ear correct scores as compared to double correct scores, it is recommended that ear correct scores be utilized while scoring the responses on the dichotic rhyme test.

In conclusion, the findings of the present study in Indian language context are consistent with the findings obtained on the western population.

Future Implications:

Dichotic listening tasks can be used in the identification of cortical lesions. Hence, the dichotic rhyme test developed can be incorporated as part of the CANS evaluation battery, to evaluate central auditory processing in adults with Kannada as their mother tongue.

(1989) that on a dichotic rhyme task although subjects are presented two words (one word to each ear), the precise alignment of the words, as well as the fact that the final vowel-consonant elements in each pair of words are identical, result in the subjects perceiving only one word the vast majority of the time.

The range was also calculated which showed the double correct scores to be highly variable across subjects. It is suggested that the ear correct scores be used to calculate the norms than the double correct scores because of its larger variability among subjects. This finding is in accordance with the finding by Dermody et al. (1983) where they found that the double correct scores do not provide information about differential ear effects, when compared to the ear correct scores.

CHAPTER V

SUMMARY AND CONCLUSION

The purpose of the present study was to generate normative data for the dichotic rhyme test on adults with Kannada as their mother tongue. The 36 pairs of dichotic stimuli were presented at an intensity level of 60 dB HL. Subjects were instructed to respond on an open set answer sheet (APPENDIX-B). The task involved writing down the rhyming words heard after each presentation.

The subjects taken for the study were fifty young normal hearing adults with Kannada as their mother tongue in the age range of 18 to 30 years. None of the subjects had any history of neurological involvement and were initially tested to ensure normal auditory functioning prior to administering the dichotic rhyme test. The responses were scored in terms of ear correct and double correct responses. The raw data was subjected to statistical analysis. The mean, standard deviation and range were also calculated. The results obtained from the present study were consistent with results from studies conducted on the western population by Musiek et al. (1989), Wexler and Halwes (1983) and Berlin et al. (1973).

The results from the present study are as follows:

1) There existed a significant right ear advantage for the dichotic stimuli.
2) Females had greater mean ear correct scores as compared to males for both right and left ears.
3) Females had greater men double correct scores as compared to males.

4) The double correct scores were found to be lower when compared to the ear correct scores.

5) Since the variability is lesser for the ear correct scores as compared to double correct scores, it is recommended that ear correct scores be utilized while scoring the responses on the dichotic rhyme test.

In conclusion, the findings of the present study in Indian language context are consistent with the findings obtained on the western population.

Future Implications:

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APPENDIX A

Track 1

Right ear

1) ಬಗೆ /bage/
2) ದರ /d̪ara/
3) ಬರ /bara/
4) ಬಾಳಿ /ba:ḷi/
5) ಗಂಡ /ganḍa/
6) ದಂಟು /d̪anṭu/
7) ಬಿಳಿ /biḷi/
8) ಗಡಿ /gaḍi/
9) ಪಾಲು /pa:lu/
10) ತಪ್ಪು /t̪appu/
11) ಗರಿ /gari/
12) ಪಾರು /pa:ru/
13) ತಿವಿ /t̪hivi/
14) ಪಡಿ /paḍi/
15) ಬೆನ್ನು /bennu/
16) ಪಂಟ /panṭa/
17) ಪಡೆ /paḍe/
18) ದಂಡ /d̪anḍa/

Left ear

1) ದಗೆ /d̪age/
2) ತರ /t̪ara/
3) ದರ /d̪ara/
4) ಗಾಳಿ /ga:ḷi/
5) ದಂಡ /d̪anḍa/
6) ಗಂಟು /ganṭu/
7) ಗಿಳಿ /giḷi/
8) ಕಡಿ /kaḍi/
9) ಕಾಲು /ka:lu/
10) ಕಪ್ಪು /kappu/
11) ಕರಿ /kari/
12) ಕಾರು /ka:ru/
13) ಕಿವಿ /kivi/
14) ತಡಿ /t̪aḍi/
15) ಪೆನ್ನು /pennu/
16) ಬಂಟ /banṭa/
17) ತಡೆ /t̪aḍe/
18) ತಂಡ /t̪anḍa/

Track 2

Right ear

1) ದರ / ḓara/
2) ಗಂಟು /ganṭu/
3) ಕಾಲು /ka:lu/
4) ಕಿವಿ /kivi/
5) ಪೆನ್ನು /pennu/
6) ತರ /ṯara/
7) ದಂಡ /ḓanḍa/
8) ಕಡಿ /kaḍi/
9) ಕಾರು /ka:ru/
10) ತಡಿ /ṯaḍi/
11) ಗಾಳಿ /ga:ḷi/
12) ದಗೆ /ḓage/
13) ಕರಿ /kari/
14) ಬಂಟ /banṭa/
15) ಗಿಳಿ /giḷi/
16) ತಂಡ /ṯanḍa/
17) ಕಪ್ಪು /kappu/
18) ತಡೆ /ṯaḍe/

Left ear

1) ಬರ /bara/
2) ದಂಟು /ḓanṭu/
3) ಪಾಲು /pa:lu/
4) ತಿವಿ /ṯhivi/
5) ಬೆನ್ನು /bennu/
6) ದರ /ḓara/
7) ಗಂಡ /ganḍa/
8) ಗಡಿ /gaḍi/
9) ಪಾರು /pa:ru/
10) ಪಡಿ /paḍi/
11) ಬಾಳಿ /ba:ḷi/
12) ಬಗೆ /bage/
13) ಗರಿ /gari/
14) ಪಂಟ /panṭa/
15) ಬಿಳಿ /biḷi/
16) ದಂಡ /ḓanḍa/
17) ತಪ್ಪು /ṯappu/
18) ಪಡೆ /paḍe/

APPENDIX B

Name:

Age/ Sex :

Native Language:

Date:

Responses:

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