BINAURAL FUSION TEST IN KANNADA FOR CHILDREN

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Certificate

This is to certify that this dissertation "Binaural Fusion Test in Kannada for Children" is a bonafide work in part fulfilment for degree of Masters of (Audiology) of the student (Registration No. 07AUD019). 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

This Dissertation entitled "Binaural Fusion Test in Kannada for Children" is the result of my own study under the guidance of Dr. Vijayalakshmi Basavaraj, Director, All India Institute of Speech and Hearing and has not been submitted to any other university for the award of any other Diploma or Degree.

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Chapter I

INTRODUCTION

“The study of central auditory processing disorders has been the cause celebre of countless researchers and practitioners across disciplines for several decades.” (Ferre, 2002). Central auditory processes are the auditory system mechanisms and processes responsible for the following behavioural phenomena: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition including, temporal resolution, temporal masking, temporal integration, and temporal ordering; auditory performance with competing acoustic signals; and auditory performance with degraded acoustic signals. (ASHA, 1996).

A central auditory processing disorder is defined as “An observed deficiency in one or more of the above listed behaviours. For some, CAPD is presumed to result from the dysfunction of processes and mechanisms dedicated to audition; for others, CAPD may stem from some more general dysfunction, such as an attention deficit or neural timing deficit, that affects performance across modalities. It is also possible for CAPD to reflect co-existing dysfunctions of both sorts.” (ASHA, 1996).

Comprehensive evaluation of individuals with (C)APD is a challenging task. As (C)APD represents a heterogenous group of auditory deficits, it is important that a test battery approach be used so that different underlying processes, as well as different levels of functioning within the central auditory nervous system can be assessed. There are numerous tests of central auditory processing that have been developed over the years. However, not all of these tests are equal in their ability to identify auditory processing disorders. Therefore, a battery of tests needs to be developed for assessing the different auditory processes.

Historically, tests of central auditory function have been categorized in a variety of ways. Bellis (1996) categorized central tests as: dichotic speech tests, temporal ordering tasks, monaural low redundancy speech tests, and binaural interaction tests. Tests of binaural interaction generally assess the ability of central auditory nervous system to process disparate, but complementary, information presented to the two ears. Unlike dichotic listening tasks, the stimuli utilized in binaural interaction tasks typically are presented in a non simultaneous, sequential condition, or the information presented to each ear is composed of a portion of the entire message, necessitating integration of the information in order for the listener to perceive the whole message. The tests of binaural interaction include- rapidly alternating speech perception test (RASP), masking level difference test, interaural just noticeable differences and binaural fusion test.

Binaural fusion tasks involve the presentation of different portions of a speech stimulus to each ear, necessitating fusion of the information in order for the listener to perceive the entire word. Matzker (1959) was the first to develop binaural fusion test in which bi-syllabic PB words were filtered through a low pass band in one ear and a high pass band in the other ear. Matzker theorised that the two signals were integrated within the brainstem, most likely at the level of the cochlear nuclei and medial geniculate bodies resulting in better intelligibility scores than those obtained by independent presentation of filtered signals. Matzker (1959) and Lynn and Gilroy (1972) presented data indicating that adult patients with confirmed brainstem or temporal lobe pathology tended to perform poorly than normal adults on a measure of binaural fusion.

Binaural fusion test has been found to be sensitive tool to identify auditory processing problems in children. It has been used to study subtle auditory processing disorder in children. Martin and Clark (1977), using the word intelligibility by picture identification found that 50% of their learning disabled children could be found using the binaural fusion task.

Need of the study-

As it has been reported that binaural fusion test is sensitive in identifying APD in children suspected to have processing problems (Roush & Tait, 1984; Singer, et al. 1998, Welsh & Healy, 1980), the need to develop such a test arises.

1. In the Indian scenario, Shivaprasad (2006) developed a binaural fusion test in English for children in the age range of 7 – 12 years using high band pass and low band pass CVC words. This is the only test developed in Indian population. Owing to the various languages being spoken in different parts of the country and the performance variations dependent on the language (Saleh, 2003), there's a need to develop such a test in Indian languages.
2. Maturational effects are seen on the performance on a majority of the central tests (Bellis, 1996). However, adult values are reached by 11-12 years of age. Hence, there is a need to obtain age specific norms on these tests.

Due to the apparent lack of such tests for assessing auditory processing disorder in children, in the Indian context, there is a need to develop it in various Indian languages and obtain age appropriate norms.

Aim of the study-

1. To develop a binaural fusion test in Kannada.

2. To obtain normative values using the developed test for different age groups of children.

3. To ascertain if there are any differences in the performance as a result of gender or age.

Type of research- The kind of research carried out in the present study is Normative research or Developmental research. This kind of research focuses on establishing behavioural differences across age groups.

Chapter II

REVIEW OF LITERATURE

The act of hearing does not end with the mere detection of an acoustic stimulus. Rather, several neurophysiological and cognitive mechanisms and processes are necessary for the accurate decoding, perception, recognition and interpretation of auditory input. (Bellis, 2003).

The ASHA task force on Central auditory processing (ASHA,1996) defined central auditory processes as the auditory mechanisms and processes responsible for the following behavioural phenomena-

- Sound localization and lateralization
- Auditory discrimination
- Auditory pattern recognition
- Temporal aspects of audition, including:
  - Temporal resolution
  - Temporal masking
  - Temporal integration
  - Temporal ordering
- Auditory performance with competing acoustic signals
- Auditory performance with degraded acoustic signals

Historical overview of auditory processing disorder

Auditory processing disorder testing can trace its origins back to the 1950s. Bocca, Calaero, & Cassinari (1954) and Bocca, Calaero, Cassinari & Migliavacca (1955) were first to report that patients with temporal lobe lesions had complaints of difficulty understanding speech. Owing to the inability of peripheral auditory assessment procedures to uncover any disturbance, these physicians developed a monaural low redundancy speech test. Further, they reported that patients with temporal lobe lesions, even though they had normal peripheral hearing sensitivity, also had difficulty discriminating between sounds. These investigators reported that patients with temporal lobe disorders acted as though they had a hearing loss and concluded that unilateral lesions of the temporal lobe could impair integration and synthesizing ability of the central auditory nervous system (Musiek & Baran, 1987). Later, Kimura (1961a, b) administered digit triads dichotically to subjects with temporal lobe lesions. She reported deficits in the ear contralateral to the temporal lobe lesion and ipsilateral ear deficits in subjects with left hemisphere lesions. According to Luria, (1973), lesions in the superior temporal lobe are also found to be associated with abnormalities in phonemic perception There were also reports by other investigators of a difficulty in understanding speech with brainstem lesions (Jerger & Jerger, 1974), and dysfunction in interhemispheric transfer of auditory information by way of the corpus callosum (Damasio & Damasio, 1979; Keith, 1977, Sparks & Geschwind 1968).

Terminology

The term central auditory processing disorder came into usage only in the late 1960s and 1970s to describe children with similar symptoms as adults with a central auditory nervous system lesion (Chalfant & Scheffelin, 1969; Manning, Johnson & Beasley, 1977; Martin & Clark, 1977).

The major controversy surrounding APD has been the terminology used to describe the disorder. “Central” has been used to distinguish the VIII nerve, brainstem and cortical areas as the anatomical site of dysfunction in contrast to the cochlea as a “peripheral” site of lesion. The term central auditory processing is used interchangeably with central auditory function, central auditory perception, auditory language processing, and auditory language learning. This has caused many investigators to adopt APD which relates to no specific anatomical site of dysfunction (Jerger & Musiek, 2000). However, other investigators continue to use “central” to emphasize that the disorder occurs central to the peripheral hearing mechanism (Bellis, 2003). The other terminology used to describe auditory processing disorders include central hearing loss, auditory perception disorder, central deafness, word deafness, auditory agnosia, auditory memory deficit, auditory sequencing problem, and auditory dysfunction.

Another controversy linked to auditory processing disorder lies in its definition. Butler (1983) defined auditory processing as the abstraction of meaning from an acoustic signal and the retrieval of that meaning. On the other hand, according to ASHA (1996) it is a description of symptoms of functional deficits. Owing to the lack of a clear definition of what constitutes APD, a task force was convened by ASHA to develop a consensus statement. The 1996 ASHA Task Force defines central auditory processing as “the mechanisms and processes responsible for the following behavioral phenomena: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition including temporal resolution, temporal masking, temporal integration, temporal ordering; auditory performance decrements with competing acoustic signals; and auditory performance decrements with degraded acoustic signals." A central auditory processing disorder is an observed deficiency in one or more of the above-listed behaviours. (ASHA, 1996).

The 2000 Bruton Consensus Conference on the "Diagnosis of Auditory Processing Disorders in School Aged Children" defined an auditory processing disorder as "a deficit in the processing of information that is specific to the auditory modality. The problem may be exacerbated in unfavourable acoustic environments. It may be associated with difficulties in listening, speech understanding, language development, and learning. In its pure form, however, it is conceptualized as a deficit in the processing of auditory input" (Jerger & Musiek, 2000)

Etiology of auditory processing disorder

The underlying causes of APD in children are not completely understood. Not all cases of APD have an underlying structural deficit, therefore, APD may be difficult to diagnose with computerized tomography or magnetic resonance imaging scans of the brain. Researchers have suggested that the problem underlying APD "may be invisible to many neurologic and radiologic studies" (Musiek & Lamb, 1994, p. 198). The prenatal or perinatal factors that may be indicated in APD are: hyperbilirubinemia, ototoxic drugs, anoxia, low birth weight, RH incompatibility, prematurity, abnormal secretion that affects brain cell development prior to birth, and unspecified birth problems (Willeford & Burleigh, 1985). Hereditary factors may also play an important role (Willeford & Burleigh, 1985; Bellis, 2003). Maternal factors which may adversely affect the development of the central nervous system include diabetes, rubella, syphilis cytomegaloviruses, and toxemia (Willeford & Burleigh, 1985).

Sub-types of auditory processing disorder

Over the past, researchers have attempted to sub-group APD or describe the characteristics in terms of commonalities (Bellis & Ferre, 1999; Katz, 1992; Musiek & Gollegly, 1988). However, no sub-grouping system or model is universally accepted. Musiek & Gollegly (1988) report three types of APD in children with learning disabilities. These three types are based upon an underlying neurophysiological deficit or neuromaturational delay: neuromorphological disorder, maturational delay of the CNS, and neurologic diseases and insults. These types are theoretical and have not been directly investigated due to the invasive nature of necessary research procedures.

The Buffalo Model (Katz, Smith, & Kurpita, 1992) focuses on the relationship between patterns of performance on one particular test of auditory processing, and learning difficulties in children. This model contains four subtypes: Decoding, Tolerance-Fading Memory, Integration, and Organization. Decoding describes individuals who "have difficulty keeping up with the flow of communication, have poor phonemic skills, are slow responders, often have articulation errors, have difficulty following directions, and have weak oral reading and spelling skills" (Stecker, 1992).

Persons with integration problems have difficulty integrating the auditory modality with other nonverbal aspects of speech such as word finding, morphological and syntactical errors, or an expressive language disorder. Persons with tolerance-fading memory have difficulty in understanding speech with competing background noise and have short-term memory problems. These individuals are often described as impatient and are easily over-stimulated. They tend to have poor reading comprehension and may have handwriting difficulty. Persons with organization problems are described as having difficulty in sequencing events and have sequencing errors. These individuals are often disorganized at home or school. Often a person will exhibit characteristics of more than one sub-type.

The Bellis/Ferre model of APD (Bellis and Ferre, 1999) is based upon the underlying neurophysiology of the brain and the relationship among different types of APD and language, learning, and communication difficulties. This model proposes three primary and two secondary subtypes of APD. The primary subtypes being: Auditory Decoding Deficit, Prosodic Deficit, Integration Deficit. The two secondary subtypes are Associative Deficit and Output Organization Deficit. The subprofiles of the Bellis/Ferre model represent the auditory and related sequelae that arise from dysfunction in the left hemisphere, right hemisphere, and interhenispheric pathways (Bellis, 2003). Individuals with an Auditory decoding deficit are characterized as having difficulty understanding speech in noise, and poor speech sound discrimination and temporal processing abilities. Persons with integration deficit have difficulty with multimodality tasks that require interhemispheric transfer. Prosodic Deficit is characterized with difficulty in comprehending the intent of communication along with poor pragmatic and social communication abilities. Associative Deficit is described as an underlying inability to apply the rules of language to incoming acoustic information. Output-Organization Deficit is characterized by an impaired ability to sequence, plan and organize responses. (Bellis, 2003)

Assessment of central auditory processing

Historically, tests of central auditory function have been categorized in a variety of ways. The ASHA committee on disorders of Central Auditory Processing (ASHA, 1990) divided central tests into monotic, dichotic and binaural tests. Katz (1994) proposed a division of central auditory processing tests into speech based, monosyllabic, spondaic and sentence procedures. On the other hand, Bellis and Ferre (1996) separated tests of central auditory function into two broad categories- a) those that add information to the signal and b) those that take away information from the signal.

The more recent categorization of central auditory tests was given by ASHA(1996), Bellis (1996), Bellis and Ferre (1999) and Chermak and Musiek (1997). The categorization was made on the basis of the process(es) the tests assess and/or the manner in which the auditory signals are delivered to the ears. These authors categorized behavioural tests of central auditory function into- dichotic speech tests, monaural low redundancy tests, tests of temporal ordering and binaural interaction tests.

Dichotic speech tests-

Dichotic speech materials have long been recognized as sensitive tools for defining central auditory dysfunction (Musiek & Pinheiro, 1985). Dichotic listening involves the presentation of stimuli to both the ears simultaneously, with the information presented to one ear being different from that presented to the other. (Bellis, 2003). Stimuli used in dichotic tests range from digits and nonsense syllables to complete sentences.

Amongst the dichotic tests, the most commonly used test is the Dichotic Digit Test (Kimura, 1961) where triads of digits were presented dichotically for assessing central auditory function. This test was found to be sensitive to brainstem and cortical lesions (Musiek, 1983a) as well as to lesions of the corpus callosum (Musiek, Kibbe and Baran, 1984).

The dichotic consonant vowel (CV) test (Berlin et al, 1972) makes use of six CV segments (pa, ta, ka, ba, da, ga) for assessment. Here, single CV segments are presented to each ear using a dichotic paradigm and the listener is asked to choose both segments heard from a printed list. The dichotic CV test has been shown to be sensitive to cortical lesions (Berlin, et al. 1975, Olsen, 1983).

A dichotic procedure using monosyllabic words is the dichotic rhyme test (Wexler and Hawles, 1983) which comprises of rhyming, consonant- vowel – consonant words. The dichotic rhyme test has been reported to be particularly sensitive to detection of dysfunction in the interhemispheric transfer of information via the corpus callosum (Musiek, Kurdzeil- Schwan, Kibbe, Gollegly, Baran & Rintelmann, 1989).

Another widely used dichotic speech test is the Staggered Spondaic word Test (Katz, 1962). This test involves the dichotic presentation of spondees in such a manner that the second syllable of the spondee presented to one ear overlaps the first syllable of the spondee presented to the other ear. The ear specific spondees and the overlapping spondees form separate words. The SSW has been shown to be sensitive to brainstem and cortical lesions (Katz, 1962).

There are two dichotic procedures which use sentences as stimuli. These are the Competing Sentences Test (Willeford, 1968) and the Synthetic Sentence Identification Test with Contralateral Competing Message (Jerger and Jerger, 1974, 1975). The former consists of simple sentences presented dichotically. The target sentence is presented to one ear at a quieter level than the competing sentence which is presented to the other ear. The listener is instructed to repeat the sentence heard in the target ear only and ignore the competing sentence. The competing sentence test has been suggested to be valuable in investigation neuromaturation and language processing abilities (Willeford & Burleigh, 1994).

The synthetic Sentence Identification test with Contralateral Competing Message (Jerger and Jerger, 1974, 1975) makes use of sentences which are presented to the target ear while a competing message consisting of continuous discourse is presented to the contralateral ear. The listener's task is to choose from a printed list, which of the sentences was heard. This test has been found to be useful in differentiating brainstem from cortical pathology (Jerger & Jerger, 1975; Keith, 1977).

Temporal processing tests-

Temporal processing tasks have been used for many years in order to investigate lesion effects on temporal aspects of audition. (Efron, 1985; Jerger et al. 1972).

One of the tests for temporal processing is the Random Gap Detection Test (Keith, 2000) where the stimuli consisting of clicks and brief tones of octave frequencies from 250- 4 KHz are presented in pairs and the silent interval between each pair randomly increases and decreases in duration from 0 – 40 ms. Listeners are required to indicate whether they hear one stimulus or two. The gap detection threshold is defined as the smallest interval at which the listener consistently identifies two stimuli. The gap detection paradigms have been shown to be sensitive to cortical, particularly temporal lobe, dysfunction (Lackener & Teuber, 1973).

A second temporal processing test designed to investigate both pattern perception and temporal sequencing abilities is the Frequency Pattern Test or the Pitch Pattern Test (Pinheiro & Ptacek, 1971; Ptacek & Pinheiro, 1971). This test consists of 120 pattern sequences wherein every sequence is made up of three tone bursts, two of one frequency and one of another. Thirty items are presented to each ear and the listener is instructed to repeat verbally each pattern heard. The Frequency Pattern Test has been found to be useful in detection of disorders of the cerebral hemispheres (Musiek & Pinheiro, 1987, Pinheiro, 1976; Pinheiro & Musiek, 1985)

A related test of temporal ordering is the Duration Pattern Test (Pinheiro & Musiek, 1985) this test is similar to the Frequency pattern Test except that the frequency of the two tones is held constant at 1000 Hz and duration is the factor to be discriminated. Here short (250 msec) and long (500 msec) tone bursts are presented in sequences of three tone patterns and the listener is required to describe verbally the pattern heard. The Duration Pattern Test appears to be sensitive to cerebral lesions while remaining unaffected by peripheral hearing loss as long as the stimuli are presented at a frequency and intensity that can be perceived by the listener (Musiek, Baran, & Pinheiro, 1990).

An additional test of auditory pattern perception that is also a dichotic nonspeech task is the Psychoacoustic Pattern Discrimination Test (Blaettener et al., 1989). This test assesses discrimination of temporal changes through the use of dichotically presented sequences of noise bursts or click trains. The Psychoacoustic Pattern Discrimination Test is found to be sensitive to lesions of the cerebral hemispheres, including the auditory association areas.

Monaural low-redundancy speech tests-

These tests involve reducing the redundancy of the speech signal in order to assess central auditory function using the method of – low pass filtering, time compression, and addition of reverberation. The earliest assessment of the integrity of Central auditory nervous system using Low Pass Filtered Speech was carried out by Bocca et al. (1954). They developed a filtered speech test that they administered to patients with confirmed temporal lobe lesions. They results showed that though routine peripheral auditory tests failed to demonstrate any auditory deficits in these patients, a sensitized low pass filtered speech test revealed contralateral ear deficits.

Two of standardized filtered speech tests that are in widely used for clinical purpose are – the Ivey filtered speech test of the Willeford Central Test Battery and the low pass filtered versions of the Northwestern University No. 6 (NU-6) word lists. The Ivey filtered speech test consists of two- fifty item lists of the Michigan consonant-nucleus- consonant (CNC) words with a 500 Hz cut-off and 18 dB/octave filter. The low pass filtered versions of the NU-6 lists have been made with different cut-off frequencies of 500, 700, 1000 and 1500 Hz.

The low pass filtered speech procedures have been found to be sensitive to a variety of central disorders, including brainstem and cortical dysfunction (Bellis, 2003).

Another way of reducing the redundancy of speech is through time compression. Here the temporal characteristics of the signal are altered by electronically reducing the duration of the speech signal without affecting the frequency characteristics (Fairbanks, Everitt, & Jaeger, 1954, cited in Bellis, 2003). The time compressed speech tasks have been found to be sensitive to diffuse pathology involving the primary auditory cortex (Baran et al., 1985; Kurdziel et al., 1976; Mueller et al., 1987).

The third method of reducing the redundancy of speech is by embedding the speech signal in a background of noise. In such tests, the speech signal, typically monosyllabic words are presented with different types of noise such as- white noise, speech spectrum noise, or speech babble at different speech to noise ratios.

One such test is the Synthetic Sentence Identification Test with Ipsilateral Competing Message (Jerger & Jerger, 1974) where sentences are presented along with ipsilateral continuous discourse. This test has been found to be sensitive in the identification of lesions of the low brainstem. (Jerger & Jerger, 1974, 1975).

A test of speech in noise designed specifically for children is the Paediatric Speech Intelligibility Test (Jerger, Jerger & Abrams, 1983) where stimuli are presented at various S/N ratios and the child is required to point to the picture representing the target message. Another related test is the Selective Auditory Attention Test (Cherry, 1980) where the listeners are required to identify a target embedded in competing signals.

Binaural interaction tests-

Binaural processing is assessed through two principal behavioural procedures. Tests of binaural integration/separation require the listener to integrate/separate different auditory stimuli presented to each ear simultaneously (Bamiou, 1997). There are several tests that have been designed to assess binaural interaction. These include-

1. Masking level difference
2. Rapidly alternating Speech perception
3. Interaural just noticeable differences
4. Binaural fusion test.

Masking level difference test- Masking level difference refers to the improvement in intelligibility (effective signal to noise ratio) under noise conditions when a tone is presented out of phase rather than in phase (Medwetsky, 2002). The improvement in intelligibility is greatest when the target stimuli are 180^0 out of phase with the competing noise. Masking Level Differences may be obtained to tonal or speech stimuli, and have been shown to be sensitive to brainstem dysfunction. (Bellis, 2003). Lower brainstem lesions have been found to greatly reduce the magnitude of the masking level difference (Olsen & Noffsinger, 1976; Lynn et al., 1981) whereas upper brainstem lesions (Noffsinger et al., 1984) or cortical lesions (Noffsinger & Kurdzeiel, 1979; Lynn et al., 1981).

Rapidly alternating speech perception test- This test involves the rapid switching of sentence material between the ears at periodic intervals, resulting in the alternating presentation of unintelligible sequential bursts of information. In normal listeners, this rapidly alternating presentation of a speech message is easily understood (Bellis, 2003), some listeners with brainstem lesion, however, demonstrate difficulty with the task (Lynn & Gilroy, 1975). The Rapidly alternating speech perception has been reported to be only sensitive to grossly abnormal brainstem pathology (Lynn & Gilroy, 1975; Musiek, 1983c;

Willeford & Burleigh, 1994). Hence the clinical utility of Rapidly alternating speech perception procedures in central assessment is questionable (Bellis, 2003).

Interaural just noticeable differences- Pinheiro & Tobin (1969, 1971) utilized an interaural intensity difference (IID) paradigm in which the degree of intensity difference between ears needed for lateralization of a signal was evaluated. They reported greater IID's in the ear ipsilateral to the lesion in subjects with central involvement.

Levine et al. (1993 a, b) developed an interaural just noticeable difference task in which tonal stimuli were either low pass or high pass filtered and presented in pairs to both ears simultaneously. Either the onset time (time just noticeable difference) or intensity (level just noticeable difference) of one half of the stimulus pair was altered in one ear. The listener was required to indicate when the signal lateralized to one ear or the other. The results of the high pass time just noticeable difference evaluation was found to be closely related with ABR results and thus, appeared to be a good behavioural measure of brainstem integrity. However, because of the difficulty in obtaining greater acoustic control of the stimulus than is possible with standard audiometric equipment, the clinical utility of these test paradigms is questionable (Bellis, 2003).

Binaural fusion test- the binaural fusion test involves presentation of different segments of band- pass filtered speech to the two ears with a low band pass filtered speech stimulus presented to one ear and a high band pas filtered speech to the other ear the patient should be able to fuse the information from each channel to report the word. (Bamiou, 1997).

APD tests in Indian languages

In the Indian scenario, a limited number of tests have been developed for assessing auditory processing disorders. These are- Dichotic CV Test- Revised Normal data for Adults (Choudhury, 2002), Speech- In- Noise Test (Peter, 2003), Time Compressed speech Test in English for Children (Sujitha, 2005), Time Compressed Speech test in Kannada for Children (Prawin, 2006), Duration Pattern Test (Gauri, 2003), Pitch Pattern Sequence Test (Shivani, 2003), Auditory Memory Test in English (Yathiraj & Mascarenhas, 2003), Auditory Memory Test in Kannada (Yathiraj & Vijayalakshmi, 2005). Shivaprasad (2006) developed a binaural fusion test in English for children in the age range of 7 – 12 years using high band pass and low band pass CVC words.

Development of Binaural Fusion Test

Matzker (1959) used bisyllabic, phonetically balanced word lists for assessing binaural resynthesis. In his test, the low band pass(500-800) Hz was presented to one ear while the high band pass (1815- 2500)Hz was presented to the other ear. The forty one word list was presented three times- 1) low band pass segment being presented to one ear, 2) high band pass being presented to one ear. 3) simultaneous presentation of low band pass to one ear and high band pass to the other ear. His results indicated that listeners with cortical lesion performed normally on the binaural fusion task whereas the ones with brainstem pathology had difficulty with the resynthesis of auditory information.

Wilson et al. (1984) developed a binaural fusion test where consonant vowel consonant (CVC) words were used as stimuli for the test. The consonant segment was presented to one ear and the vowel segment presented to the other ear. They reported that the test was unaffected by monaural hearing loss.

Neijenhuis et al. (2001) used 22 monosyllabic words low –pass filtered with a cut off frequency of 500 Hz and high pass filtered with a cut-off frequency of 3000 Hz, both with a slope of 60 dB per octave. They reported good test retest reliability for their test.

Factors affecting binaural fusion test

There are several factors that may affect a subject's performance on a binaural fusion test. These include the effect of-

1. Presentation Level
2. Age
3. Band pass filter width
4. Ear
5. Language

1. Effect of Presentation Level-

Presentation level affects the low band pass in a different manner relative to the high band pass for the monaural condition, with a rapid rise in intelligibility of the high band pass and a shallower slope for the low band pass segment with increasing intensity. (Katz & Ivey, 1994). A presentation level of 25 to 30 dB SL results in low intelligibility for the bandpass segments in the monaural condition but high intelligibility for the binaural condition. (Katz & Ivey, 1994).

Plakke et al. (1981) studied the effect of presentation level on a binaural fusion test. They presented band pass filtered signal at two different levels- 30 db and 40 dB SL . It was reported that there was a significant improvement in the scores as the presentation level increased from 30 to 40 dB SL.

Wilson (1994) conducted a study using a CVC binaural fusion test on 120 adults with normal hearing sensitivity at various presentation levels. He reported that with the monaural vowel segments, there was a minor improvement of 8 % when the presentation level was increased from 20 to 40 dB HL. Recognition performance improved substantially for the consonant segments in the monaural condition when the presentation level increased from 40 to 60 dBHL.

On the whole, an increase in the presentation level does bring about an improvement in the scores on a binaural fusion test.

2. Effect of age-

There have been several studies to find the effect of age on the performance on a binaural fusion test. Plakke et al. (1981) studied the effect of age on 108 children (4, 6 and 8 year olds) on measures of binaural fusion. The results indicated that the performance of the subjects increase with an increase in age.

Neijenhuis et al. (2002) studied the effect of age on a Dutch test battery for auditory processing disorders. A test battery compiled to diagnose auditory processing disorders in an adult population was used on a population of 9-16 year old children. The battery consisted of eight tests- word- in noise, filtered speech, dichotic digit test, frequency pattern test, duration pattern test, backward masking, categorical perception, digit span, binaural fusion test and a questionnaire. Subjects were 75 children from primary school in the age range of 9 – 12 years and 30 adolescents from secondary school in the age range of 14 – 16 years, who had normal hearing and normal intelligence. Age effect was found to be present in most of the tests within the group as well as when children and adolescents were compared to adults.

Stollman et al. (2004) studied age effects on auditory processing in children. The subjects were a group of 20 children with normal cognitive and language development. They were administered several auditory tests at the ages of 6, 7, 8, 10 and 12 years. The auditory performance of the children was compared to the performance of a group of 20 adults. The test battery consisted of- speech in noise test, filtered speech test, auditory sequencing tests and binaural fusion test. Age effect on the performance of the children was seen on all tests except speech in noise test. Their results show that age and maturational effects play an important role in auditory processing, at least, up to an age of 12- 13 years.

An increase in the performance of children on a binaural fusion task is thus, clearly linked to an increase in age. The scores have been reported to reach almost maximum level by 12- 13 years of age. (Stollman et al, 2004).

3. Effect of band pass filter width-

There have been several studies on binaural fusion test using different band pass filters. In the binaural fusion test developed by Matzker (1959), two narrow band pass filters were used, the low band pass filter (500- 800) Hz and a high band pass filter (1815- 2500) Hz. Here each band was on its own, too narrow to allow for recognition of the words, however when both the bands were presented together, adequate recognition was possible.

Smith and Resnick (1972) developed a binaural fusion test where monosyllables were used as stimuli. These were band passed using a low band pas of 360- 890 Hz and a high band pass of 1700- 2200 Hz, with the centre frequency gain raised 10 dB with reference to that of the low band. The test consisted of three binaural conditions- 1) high band pass was presented to left ear and low band pass to the right ear. 2) both high and low band pass were presented to both the ears. 3) high band pass presented to the right ear and low band pass presented to the left ear. The mean dichotic scores for a group of 30 subjects with normal hearing sensitivity were 70.4 % and 69.4% for the first and third condition and 71.2% for the second condition. No significant difference was found among the three test conditions.

Plakke et al. (1981) studied the performance of children on a binaural fusion task. They used three different band widths to see the effect of band width on the binaural fusion test. The nominal 100 Hz band width had cut off frequencies of 500 Hz and 580 Hz for the low frequency band pass and 1950 and 2080 Hz cut off frequencies for the high frequency band pass. The 300 Hz nominal band width had cut off frequencies of 400- 700 Hz for the low frequency band pas and 1870 and 2200 Hz for the high frequency band pass. The 600 Hz nominal band width had cut off frequencies of 250 – 850 Hz and 1700 – 2250 Hz for the low frequency and high frequency band passes respectively. Their results indicated that there was no significant difference in scores between the 100 Hz band width and 300 Hz band width there was however a significant difference in scores between the 100 Hz band width, 300 Hz band width and 600 Hz band width. A significant improvement in the scores was seen with an increase in the band width from 300 Hz to 600 Hz.

Roush and Tait (1984) studied binaural fusion, masking level difference and auditory brainstem responses in children with language learning disabilities. They used a low frequency band pass of 420- 570 Hz and a high frequency band pass of 1950- 2100 Hz. This resulted in high and low band pass approximately 150 Hz wide, with a filter rejection rate of approximately 60 dB/ octave of the high band and 52 dB / octave for the low band. Their result suggested that there was a significant difference between the control group and the learning disability children. Mean scores were 64.7% and 50.9 % for the control group and learning disability group respectively for the binaural fusion test. From the results it can be inferred that the band pass used by them was useful in differentiating children with a processing problem from those who had no problem.

Thus it can be inferred from these studies that there is no standard band pas cut off and band pass width for binaural fusion test. As the band width of the signal increases, there is an increase in perception. Hence, an appropriate band width should be used while constructing a binaural fusion test, such that neither the sensitivity nor the specificity should be compromised.

4. Effect of ear-

Smith and Resnick (1972) studied ear effect in normal hearing individuals by presenting the signals in three different conditions. 1) high band pass was presented to the left ear and low band pass to the right ear. 2) both high and low bands were delivered to both the ears. 3) the high band pass was presented to the right ear and low band pass to the left ear. 30 normal hearing subjects were used as subjects. The mean dichotic scores were 70.4 % and 69.4% for the first and the third condition and 71.2 % for the second condition. This indicates no significant ear effect and no significant difference across all the three conditions.

Plakke et al (1981) studied the ear effect on scores for binaural fusion test by presenting the signal in three different conditions. The first presentation was a binaural fusion condition (BF1) where the low frequency band was presented to the left ear and the high frequency band was presented to the right ear. This was followed by a diotic condition where both the bands were presented to both the ears and finally a second binaural fusion condition (BF2) where the low frequency band was presented to the right ear and the high frequency band was presented to the left ear. No significant difference was found in both the binaural fusion conditions but scores improved in the diotic condition. This indicates that there was no significant ear effect.

Roush and Tait (1984) conducted an experiment to evaluate the ear effect in a binaural fusion test for children with language learning disabilities. The binaural fusion test was administered in three conditions- 1) low band pass was delivered to the left ear and high band pass to the right ear. 2) both low and high band pass were delivered simultaneously to each ear. 3) this was a reverse of the first dichotic condition, here the high band pass was delivered to the left ear and low band pass to the right ear. No significant difference was reported between the three test conditions in both the control group and experimental group.

Hence there appears to be no effect of ear on performance on a binaural fusion test.

5. Effect of language-

Saleh, et al. (2003) compared the performance of South African English first and South African English second language speakers on a series of auditory processing tests including binaural fusion test. The performances of the subjects were compared to previously published American normative data. Comparisons between the South African English first and second language speakers showed equivalent left ear performances on all the tests including consonant vowel consonant binaural fusion test. A poorer right ear performance by the second language speakers was seen on the two pair dichotic digit test only. Comparisons between the South African English and the American normative data showed large differences, with the South American English speakers performing both better and worse depending on the test involved. This study indicates that language does affect scores on an APD test.

Comparison of the test results of binaural fusion test with other tests

Singer et al. (1998) studied the individual test efficacy and test battery efficacy and estimate of the costs that are associated with the identification of a target sample. In their study they took ninety children with normal learning abilities and 147 children with a classroom learning disability and presumed auditory processing disorders. These children in the age range of 7-13 years underwent a battery of auditory processing tests- binaural fusion test, masking level difference test, filtered speech test, time compressed speech test, dichotic digit test, staggered spondaic word test and pitch pattern test. Their results indicated that the binaural fusion test separated the two samples most effectively and that the filtered speech test was the next most effective. A test protocol with binaural fusion test and filtered speech test/masking level difference test represented the best battery approach when hit rate, false positive rate and cost factor were considered. Their results indicated that binaural fusion test plays a major role in identifying auditory processing disorders.

Roush and Tait (1984) studied the effects of binaural fusion, masking level difference and auditory brainstem responses in children with language learning disabilities. They reported that the use of binaural fusion test would be better to differentiate between normal and language learning disabled children.

Welsh et al. (1980) administered a battery of tests used to evaluate auditory processing on a group of dyslexic children. The results of the dyslexic children were compared to normative values. They reported that binaural fusion test and filtered speech test were more sensitive with less variation from the normal group.

Bamiou (1997) reported that Rapidly alternating speech perception (RASP) has not received much clinical acceptance because of the low sensitivity of this test in identifying patients with central auditory processing deficits, as well as in differentiating between different sites of brainstem pathology. Also, the clinical utility of Rapidly alternating speech perception (RASP) and Interaural just noticeable differences has been reported to be questionable Bellis (2003).

From the above studies, the Binaural fusion test emerges out to be a sensitive tool in the assessment of central auditory processing disorders and more effective in identifying central auditory dysfunction as compared to other binaural interaction tests like Rapidly alternating speech perception (RASP) and Interaural just noticeable differences. Hence, the need to develop such a test in the Indian context arises.

Binaural Fusion Test in clinical population

1. Peripheral hearing loss-

Miltenberger et al. (1978) studied the effect of peripheral hearing loss on central auditory testing. The study examined the effects of peripheral hearing loss on auditory tasks that are used to assess dysfunction within the central auditory pathways. In their study, they took seventy sensorineural hearing loss subjects. Each subject was evaluated with a CAP test battery that consisted of –dichotic sentence listening task, monosyllabic filtered word task, spondaic word binaural fusion task, and rapidly alternating speech task. All of these tasks were found to be affected by certain degrees/configurations of SN hearing loss.

Neijenhuis et al (2004) conducted a study to check for the effect of mild SN hearing loss on auditory processing. They used a Dutch test battery and administered it on 24 subjects with a mild, relatively flat, symmetrical Sensorineural hearing loss. They reported that the scores of the hearing impaired listeners were significantly poorer than those of normal hearing listeners on five out of six tests, even with the adjusted presentation level. They found a significant correlation between test scores and pure tone average.

Schilder et al. (1994) evaluated the effect of auditory perception in children with otitis media with effusion. The relationship between otitis media with effusion at the preschool age and performance on five auditory perception tests was studied in 89 school age children who had a history of otitis media with effusion histories well documented from participation in serial screening for otitis media with effusion at 2-4 years of age. The tests used at 7.5- 8 year of age were- speech in noise, filtered speech, binaural fusion, dichotic speech, and auditory memory. A significant effect of otitis media with effusion was found on the speech in noise test but not on the other tests.

Thus, these studies show that sensorineural hearing loss does seem to have an effect on binaural fusion. However, in case of conductive hearing loss, there seems to be no effect on binaural fusion. In other words, the scores of a person with sensorineural hearing loss on binaural fusion test can be affected because of peripheral hearing loss in addition to a deficit in the central auditory processing pathway.

2.Alcoholics-

Fitzpatrick and Eviatar (1980) conducted a study to see the effect of consumption of alcohol on central auditory processing. The subjects were aged between 23 and 62 and were tested for changes in hearing acuity and discrimination after ingestion of four ounces of vodka (80 U.S proof = 40 percent ethyl alcohol). As compared with their own pre ingestion test results, these subjects showed, a reduction in the discrimination of speech on Cid W22 lists under difficult listening conditions (in quiet at 10 dBSL and in noise at a signal to noise ratio of -6 dB), and a decrease in performance on a filtered speech test having a low pass or a high pass and binaural fusion. The staggered spondaic word test was mildly affected only in one out the twelve subjects who were tested. Pure tone thresholds, speech reception thresholds and speech discrimination threshold at 40 dBSL were not affected. They concluded that alcohol ingestion in moderate amounts alters the auditory processing under difficult listening conditions.

3. Misarticulation-

Riensche and Clauser (1982) studied the auditory perception abilities in twelve children with misraticulation. These children were given tasks of auditory perception consisting of repeating 5 word recorded sentences (0, 1st and 2nd order approximations) at 0 and 60% time compression, and diotic and dichotic presentations at 40 dBSL of the WIPI test split into two bandwidths (500-580 and 1950- 2080 Hz) results showed that the performance of the experimental group was significantly poorer than that of age matched controls on time compressed speech but not on the binaural fusion task. These results show that binaural fusion was not affected in children with misarticulation.

4.Dyslexia-

Welsh et al. (1980) studied the central auditory processing in a group of children with dyslexia. A group of dyslexic pupils with normal end organ function was studied by a central auditory battery to determine whether a hearing disability existed. The central battery of Willeford was selected as a test medium and the results of the 77 dyslexic students were compared to normative data. The test battery consisted of competing sentence test, binaural fusion, rapidly alternating speech perception and filtered speech test. The authors identified a high rate of failure in this investigation. Over 50% of the dyslexic failed in two of the four tests, and each of the 77 children failed in at least one component. The most sensitive tests were binaural fusion and filtered speech with less variation from the norm in the remaining two components. The effect of maturation in central audition was measured in each of the four tests. The data suggested that the scores were lower in the early ages in each test; that rapidly alternating speech and competing sentences approach the normal range albeit somewhat delayed; and binaural fusion and filtered speech test scores improved somewhat but rather moderately and never approach the normal range.

In another study, Welsh et al. (1982) evaluated the effect of central auditory tests in dyslexic children. A group of dyslexic students were examined by a central auditory test battery including competing sentences, binaural fusion, filtered speech, and compressed speech. Auditory evoked brainstem responses were also measured in conjunction with the central auditory test data. The auditory test indicated a high degree of failure in those areas requiring sophisticated interaction, coordination, and identification of the modified speech stimuli in dyslexic children whereas the auditory evoked brainstem responses did not identify a significant abnormality.

From the literature it is evident that binaural fusion test is useful in identifying auditory processing problems in children with dyslexia.

5. Sickle cell anaemia-

Wilimas et al. (1988) assessed the auditory acuity and central auditory processing in 22 patients with sickle cell anaemia, 13 of who were chronically transfused and compared with a control black population. Pure tone air conduction thresholds were within normal limits for all the patients, and mean speech reception threshold was normal at 10 dB for each ear. All subjects exhibited A type tympanograms. Central auditory processing was checked by 2 tests- competing sentence test and binaural fusion test. Results revealed that there were no significant differences in scores of transfused, non transfused and control patients for the binaural fusion test.

6. Charcot-Marie-Tooth disease type 1A (CMT1A)-

Neijenhuis et al. (2003) investigated auditory processing abilities in five CMT1A patients with normal hearing. These genetically confirmed CMT1A cases with normal hearing were made to undergo a battery of behavioural and objective tests. These consisted of pure tone audiometry, speech audiometry and OAE assessment, followed by an auditory processing test battery comprising of speech in noise test, pattern recognition test, words in noise test, dichotic digit test, filtered speech test, binaural fusion test and categorical speech perception test. Subsequently, auditory brainstem response and event related potential measurements were conducted. Results indicated that either the behavioural or objective test scores did not vary from those of the normal hearing subjects for four out of five CMT1A cases. However, significantly lower scores were obtained on one patient on the auditory processing tests and ABR measurements. Hence, the authors concluded that CMT1A patients, with normal peripheral hearing have auditory processing abilities that were not indicative for an auditory processing disorder. Furthermore the presence of peripheral hearing loss complicated the interpretation of auditory processing abilities.

7.Specific language impairment-

Stollman et al. (2003) compared the performance of a group of twenty 6-year-old children with specific language impairment (SLI) on several behavioral auditory tests to that of a group of twenty age-matched control children. The auditory test battery used in this study consisted of the following tests: a speech-in-noise test, a filtered speech test, a binaural fusion test, a frequency pattern test, a duration pattern test, a temporal integration test, an auditory word discrimination test, an auditory synthesis test, an auditory closure test and a number recall test. Results showed that the SLI children obtained scores on almost all tests that were significantly lower than those of the control group. Many of the basic auditory processing measures in the test battery correlated significantly with receptive and language scores, suggesting a (causal) relationship between auditory processing and language proficiency.

8. Auditory processing disorder-

Musiek and Geurnik (1980) evaluated the effect of central auditory tests in processing in children. In their study, they tested five children with auditory processing problems. They took five children who had normal peripheral hearing and otological findings but were referred with a suspicion of hearing loss. An auditory perceptual test battery consisting of rapidly alternating speech, binaural fusion, low pass filtered speech, competing sentences, staggered spondaic words, dichotic digits and frequency patterns was used. Though some of these tests did not show a perceptual deficit, the majority did depict specific types of auditory processing problems. Three children got lesser scores in the binaural fusion test.

Ferre and Wilbur (1986) examined the performance of normal children and learning disabled children on an experimental battery of central auditory processing tasks. This battery included low pass filtered speech, binaural fusion, time compressed speech and dichotic monosyllable tests. The learning disabled subjects were classified as having normal or significantly impaired auditory perceptual skills on the basis of a pre-test battery of auditory language tests. The normal subjects tended to perform alike across measures, while the auditorily impaired subjects tended to perform significantly poorer than their normal age mates. The results emphasized the heterogeneity of the learning disabled population. The results also suggested a potentially useful "at risk" criterion when a CAP test battery which includes binaural fusion test was used in the assessment of auditory perceptual impairment in children.

8. Brainstem lesions-

Matzker(1959) used bisyllabic, phonetically balanced word lists for assessing binaural resynthesis in subjects with cortical lesion and brainstem pathology. In his test, the low band pass (500-800) Hz was presented to one ear while the high band pass (1815-2500) Hz was presented to the other ear. His results indicated that listeners with cortical lesion performed normally on the binaural fusion task whereas the ones with brainstem pathology had difficulty with the resynthesis of auditory information.

Development of Binaural Fusion Test in Indian languages

In India, only one Binaural fusion test has been developed so far, by Shivaprasad (2006) in English where he used consonant- vowel- consonant (CVC) words. These were low pass filtered using a pass band of 500- 700 Hz and high pass filtered using a pass band of 1800 -2000 Hz.

Thus, it can be seen from the review of literature that there is an apparent lack of tests for assessing auditory processing disorder in children, in the Indian context. Hence, there is a need to develop it in various Indian languages and obtain age appropriate norms. Therefore, the present study aims to develop a binaural fusion test in Kannada and obtain age appropriate norms for 7+ to 12 year old children.

Chapter III

METHOD

The study was conducted with an aim of developing a binaural fusion test for children in Kannada language. This was done in two stages. Stage one involved development of the test material and in the stage two, normative data were collected for the same.

Subject selection criteria-

For both the stages, the subjects had to meet the following criteria to be considered for the study –

1. Hearing sensitivity within normal limits. The air conduction thresholds should be less than or equal to 15 dBHL at all frequencies from 250 – 8 KHz for both the ears.
2. 'A' type tympanograms with normal acoustic reflex thresholds for both the ears.
3. Mother tongue as Kannada as well as the language spoken at home should be Kannada.
4. No history or presence of otological problems like ear pain or ear discharge.
5. Academic performance should be good or average as per the teacher's report.
6. Should not have auditory processing disorder as indicated by the screening checklist for auditory processing (SCAP) (Yathiraj & Mascarenhas,2003)

Stage one- This involved development of the test material, checking the test items for their familiarity and recording of the material.

Development and familiarity checking of test material-

A Corpora of 360 CVCV Kannada words that are commonly used were selected from Kannada dictionary, English to kannada translation book and a story book entitled- Sri Krishnadevaraya and Appaji's stories. These 360 words were selected by 5 native Kannada speakers with the criteria that they are familiar and whether they are picturizable or not.

Evaluation of familiarity of test items-

20 children in the age range of 7+ to 8 years, who met the subject selection criteria, participated in this evaluation. These children, participating in the familiarity check of the test items, were instructed to classify the words on a three point scale as – "Highly familiar', "Familiar', or 'Not familiar'. Based on their rating, the degree of familiarity was classified as follows: 'Highly familiar', 'Familiar' and 'Not familiar'.

The words that were considered 'highly familiar' or 'familiar' by 90% of the subjects were utilized for the final construction of the test

50 words which were rated as 'Highly familiar' and 'familiar' by all the twenty children were finalised for developing the test material. These words were grouped into 2 lists consisting of 25 words. List I consisted of picturizable words and list II consisted of non picturizable words. It was ensured that both the lists were phonetically balanced as per the frequency of occurrence of Kannada speech sounds. (Ramakrishna et al. 1962). These lists have been provided in **Appendix A**.

For List I, four pictures were presented for every target word and the children had to point to the target picture. Out of the four pictures, one was that of the target, one picture was that of a similar sounding word (Homophone), one of another word from the same lexical category and the last was a picture selected at random. The order of occurrence of the target word's picture was varied randomly throughout the list. A sample of the test picture plate has been provided in **Appendix B**.

Recording of the test material-

Recording was done using an adult female speaker whose mother tongue was Kannada. To ensure that the two lists are of equal difficulty, the recorded stimuli before filtering was presented to the twenty children in the age range of 7+ to 8 years who participated in the familiarity check of the test items. Once it was found out that the lists were of equal difficulty, the filtering of the lists was carried out.

The test items were recorded using Adobe Audition version 3.0 software and band passed using Goldwave digital audio editor software. A low pass band of 500 to 700 Hz and a high band pass of 1800 to 2000 Hz were used to filter the words.

A 1 KHz calibration tone was recorded preceding each list and a six seconds inter stimulus interval was maintained.

Stage two- This involved administration of the test to obtain normative data**.**

Subjects- One hundred normal hearing children who met the subject selection criteria and who were in the age range of 7+ to 12 years were taken for the collection of normative data. These children were grouped into 5 age groups-

Group I – 7+ to 8 years

Group II- 8+ to 9 years

Group III- 9+ to 10 years

Group IV- 10+ to 11 years

Group V -11+ to 12 years

Each group consisted of 20 children; out of which 10 were boys and 10 were girls.

Instrumentation-

The following instruments were used-

- A Pentium 4 computer with Adobe Audition version 3.0 software was used to record the speech stimuli and Goldwave editing software for filtering the stimuli.
- A calibrated dual channel diagnostic audiometer (Orbiter 922) with TDH-39 headphones housed in MX-4/AR cushion was used for running the test material. The calibration standards were as recommended by ANSI(S3.6 1996).
- Calibrated GSI- tympstar middle ear analyzer was used to rule out the presence of any middle ear pathology.
- A CD (CD_R 700MB) player was used for playing the recorded test material.

Test environment-

Testing was done in a sound treated double room. The ambient noise levels were within permissible limits as recommended by ANSI (S3.1 1991)

Procedure-

1. Pure tone audiometry was done for all the children. Air conduction thresholds were checked for frequencies between 250 Hz– 8 KHz. Bone conduction thresholds were checked for frequencies between 250 Hz – 4KHz.

2. Tympanometry was carried out on all the children using 226 Hz probe tone and acoustic reflexes thresholds were recorded at frequencies of 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.

3. SCAP was administered for all the children.

The binaural fusion list was administered at 40 dBSL with reference to pure tone average and the children were asked to point to the target word's picture for list I and repeat the words for list II. Each correct response was given a score of one and a wrong response a score of zero.

Reliability check- 10 percent of the children were subjected to retesting after a time gap of at least 2 days. Test- retest reliability was checked using this data.

Statistical analysis- appropriate statistical analyses were carried out to analyse the age effect and gender effect.

Chapter IV

RESULTS AND DISCUSSION

The present study was conducted with an aim of developing a Binaural fusion test in Kannada language and establishing the normative data for the test across the 5 age groups of 7+ to 8 years, 8+ to 9years, 9+ to 10 years, 10+ to 11 years and 11+ to 12 years.

The data obtained was analyzed using Statistical Package for the Social Sciences (SPSS) version15 software.

The following statistical tools were used for analyzing the data-

- Descriptive statistics to calculate the mean and standard deviation for the scores obtained on list I and list II across all age groups.
- Mixed ANOVA (repeated measure ANOVA) to find out if there is any statistical significant difference across age, gender and list.
- Duncan's Post- Hoc test to find out the pair wise comparison of all age groups.
- Independent t-test for comparison of scores across gender in each age group.
- Paired t-test for comparison of lists within each age group.

I. Comparison of Lists, Age & Gender

The mean and standard deviations for all the five age groups across gender are given in table 1. The results are given for the two lists which were developed for establishing the normative data for the five age groups.

Table 1.

Mean and Standard deviation (S.D) of Binaural fusion test scores for List I & II for males and females across all age groups.

Age (years)	**Gender**	**List I Max. score:25**		**List II Max. score:25**	
		Mean	**SD**	**Mean**	**SD**
7+ to 8	Male	17.70	1.76	18.40	1.07
	Female	18.40	1.42	18.30	1.49
8+ to 9	Male	19.20	1.03	20.10	1.59
	Female	20.20	1.54	19.90	1.44
9+ to 10	Male	20.90	0.73	20.30	0.82
	Female	20.80	1.22	20.50	1.43
10+ to 11	Male	21.40	0.51	21.80	0.42
	Female	21.60	0.51	21.40	0.96
11+ to 12	Male	22.30	0.67	21.80	0.63
	Female	22.70	1.05	22.10	0.56

Table 1 shows the mean scores for list I and II. It may be noted that the mean scores increase from the younger age group to the higher age groups. It may also be noted that for list I there is a slight difference in mean scores obtained for the two genders. The scores are more for the females compared to the males for 7+ to 8years and 8+ to 9 years age groups. However, for rest of the age groups and for list II the mean scores of males and females are comparable. Figure1 shows the graphical depiction of the mean scores of both the genders for List I which increase with age .

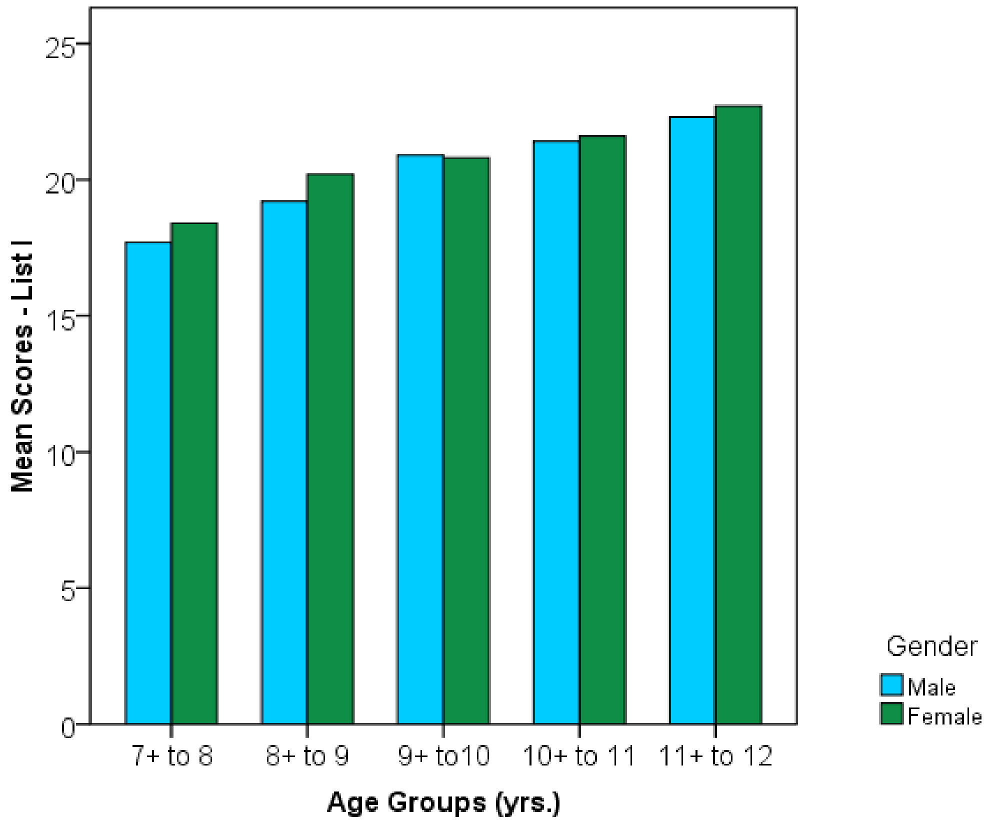

Figure 1. Comparison of mean scores for List I across the gender for each age group.

Even for list II it can be seen from Figure 2 that the mean scores increase as the age increases. However there is an overlap of mean scores for the two genders.

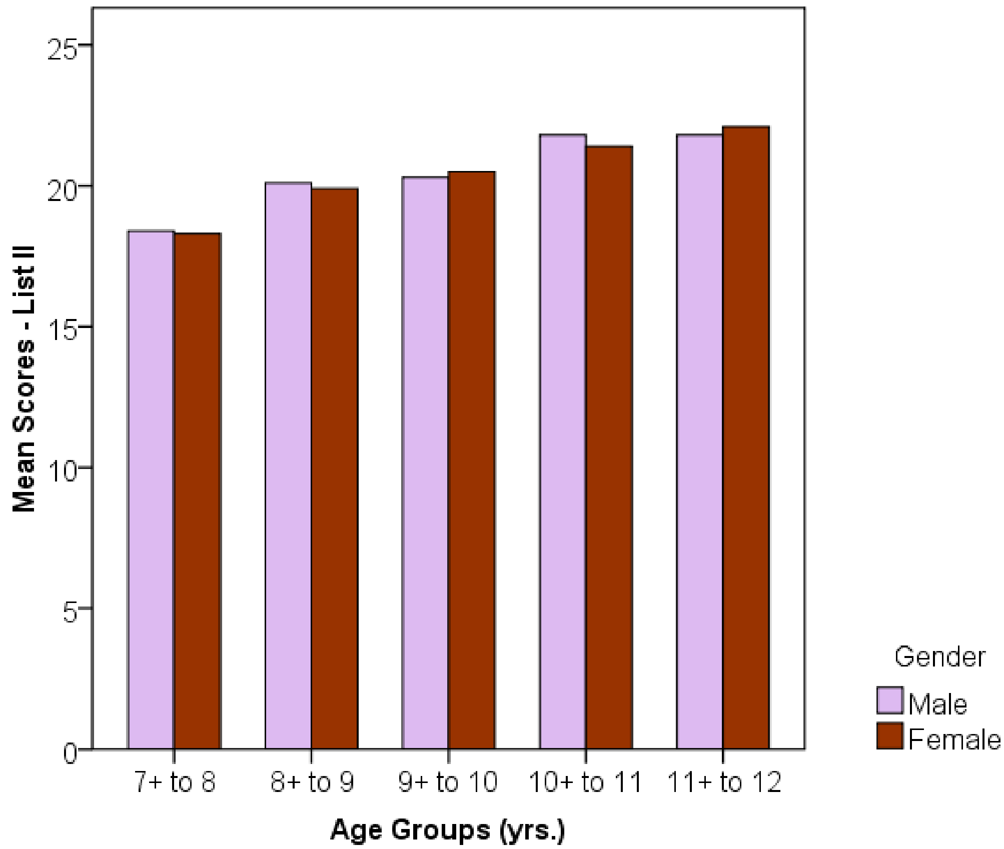

Figure 2. Comparison of mean scores for List II across the gender for each age group**.**

Figure 3 shows the comparison of the mean scores obtained on the two lists for each age group (both the genders put together). From Figure 3, one can see that there is an improvement in scores as the age increases. It is also clear from Figure 3 that the scores for the two lists are comparable for all the age groups.

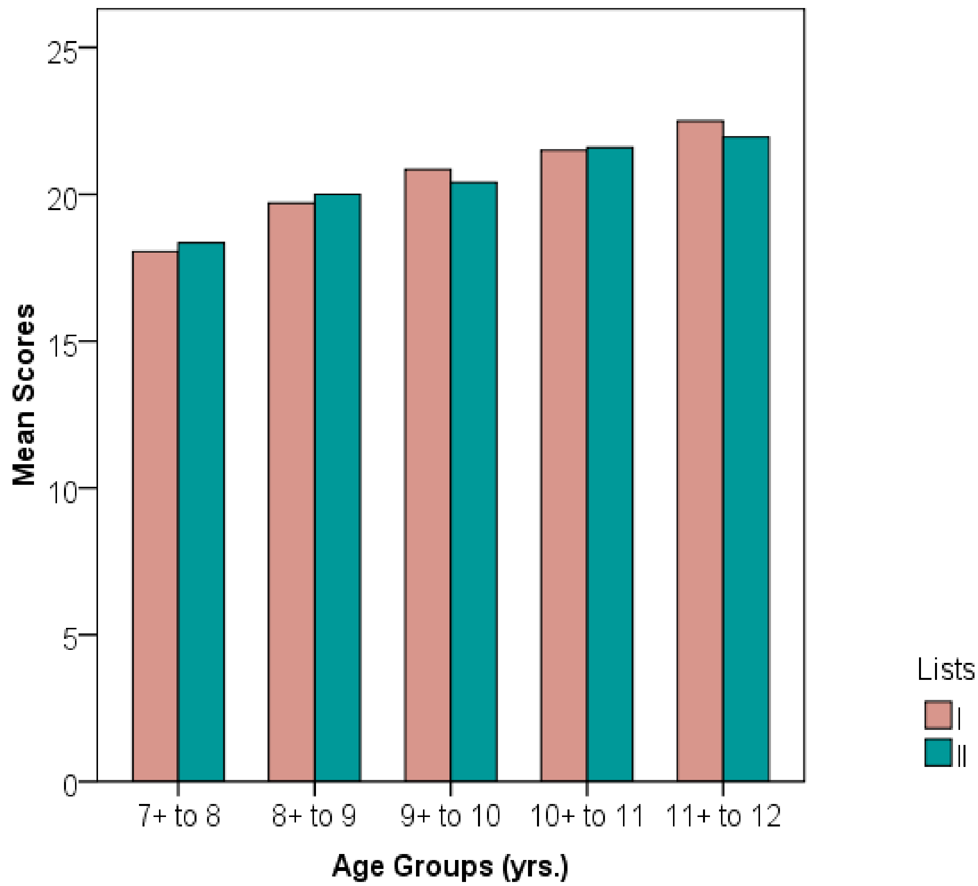

Figure 3. Comparison of mean scores across age group for the two lists.

Mixed analysis of Variance (ANOVA) was done to see if there is any statistical difference between the lists, between the age groups and between the genders. The results of Mixed ANOVA are as follows-

Table 2.

The results of Mixed ANOVA comparing the lists, age groups and genders

Measure	F value	Significance
List	F(1, 90) = 0.28, p>0.05	No significant difference
Age	F(4, 90) = 53.196, p<0.001	**Significant difference**
Gender	F(1,90)= 1.085, p> 0.05	No significant difference
Age and Gender	F (4, 90) = 0.251, p>0.05	No significant interaction
Age and List	F (4,90)= 2.429, p>0.05	No significant interaction
Age, Gender and List	F(4, 90) =1.245, p>0.05	No significant interaction

Duncan's Post Hoc test was done to see which of the age groups were significantly different from each other. Results of Duncan's Post Hoc test revealed that all age groups were significantly different from one another at 5% level of significance.

The results of the present study are concurrent with the findings of Plakke, et al. (1981) who reported of a systematic improvement in binaural fusion scores with increasing age in normal hearing children of 4, 6 and 8 years of age. Also, Neijenhuis et al. (2002) found an age effect within their group of 9-12 year old children as well as when children and adolescents were compared to adults on a variety of APD tests including Binaural fusion test. Binaural interaction has been found to reach adult values by ages 6-8 (Whitelaw and Yuskow, 2006). However, the results of the present study show that the increase in scores with increase in age is seen up to 12 years and hence gives an indication of maturation of auditory processing taking place even during adolescence.

Similarly Stollman et al. (2004) also reported of an effect of age in 6-12 year old children on a battery of APD tests including Binaural Fusion test. In the Indian context, Shivaprasad (2006) reported similar findings on binaural fusion task indicating an age effect up to 12 years. The results of the present study also showed age and maturational effects till 12 years, indicating maturation of auditory processing, at least, up to an age of 12- 13 years which is in good agreement on development of auditory processing abilities and electrophysiological studies of the maturation of the cortical auditory function (Cunningham et al., 2000; Johnstone et al., 1996; Ponton et al., 1996; Sharma et al. 1997).

The present findings thus suggest the importance of having age appropriate norms while assessing children using the developed binaural fusion test.

II. Comparison of Gender in each Age group.

Independent t- test was done to see if there was any significant difference between list I and list II scores for both the genders across ages. Results of the Independent t-test revealed that there was no significant difference between gender scores for all the age groups.

Table 3.

The results of Independent t-test comparing the Gender effect in each age group

Age Group (years)	't' value	Significance
7+ to 8	List 1- t(18)= 0.974, p>0.05 List2 -t(18)= 0.172, p>0.05	No significant difference
8+ to 9	List 1- t(18)=1.698, p>0.05 List2 - t(18)= 0.293, p>0.05	No significant difference
9+ to 10	List 1 - t(18)= 0.221, p>0.05 List2 - t(18)= 0.383, p>0.05	No significant difference
10+ to 11	List 1 - t(18)= 0.866, p>0.05 List2 - t(18)= 1.2, p>0.05	No significant difference
11+ to 12	List 1- t(18)= 1.007, p>0.05 List2 - t(18)=1.116,p>0.05	No significant difference

The present findings support the results of Stollman et al. (2004) who also did not find any significant difference between the scores of males and females on a variety of APD tests including binaural fusion test. Shivaprasad (2006) also did not report any significant difference in the performance of males and females in the age range of 7-11.11 years on a measure of binaural fusion test.

Earlier studies have shown that young girls in the age range of 1-5 years are more proficient in language skills, learn to talk at an early age, produce longer utterances and have longer vocabularies than that of boys (Ruble and Martin, 1998, cited in Plotnik

1999). However, even though there appears to be a gender difference in verbal abilities favouring females, this difference is relatively small (Hyde, 1994, cited in Plotnik 1999).

III. Comparison of Lists within each Age group

Paired t-test was done to see if there was any significance difference between list I and list II scores across ages. The results of the Paired t-test showed that there was no significant difference between lists for age groups 7+ to 8 years- [$t(19) = 0.900$, $p>0.05$], 8+ to 9 years –[$t(19) = 0.860$, $p>0.05$], 10+ to 11 years- [$t(19) = 0.490$, $p>0.05$]. However, there was a significant difference between the lists for age groups 9+ to 10 years- [$t(19) = 2.131$, $p<0.05$] and 11+ to 12 years- [$t(19) = 2.604$, $p<0.05$]

The significant difference between the lists for age groups 9+ to 10 years and 11+ to 12 years could be attributed to any chance factor.

IV. Test –Retest reliability

To find out the Test- Retest reliability, Reliability coefficient α was calculated for both the lists. Reliability coefficient was 0.86 for list I and 0.85 for list II.

Chapter V

SUMMARY AND CONCLUSION

The present study aimed at developing a Binaural fusion test in Kannada language and establishing the normative data for the test across the 5 age groups of 7-7.11 years, 8-8.11 years, 9-9.11 years, 10-10.11 years and 11- 11.11 years.

The test material was developed using a corpora of 360 CVCV words which were taken from age appropriate Kannada textbooks and 50 words which were familiar to all the children. They were then randomly grouped into 2 phonetically balanced lists, containing 25 words each. List I was picturizable and list II was non picturizable.

The lists were then filtered using a low pass band of 500 to 700 Hz and a high band pass of 1800 to 2000 Hz with the help of Goldwave digital audio editor software and presented at 40 dBSL (with reference to pure tone average) to one hundred children who participated in the study and normative data was collected.

The data obtained was analysed for the presence of age and gender effect. The results showed that there was an improvement in the scores for both List I and List II with an increase in age. These findings are supported by earlier investigations by Plakke, et al. (1981); Neijenhuis et al. (2002); Stollman et al. (2004) and Shivaprasad (2006) who also found an age effect in the scores on Binaural fusion test in children. This increase in age has been attributed to the neuromaturation that takes place in central auditory nervous system till the age of 11-12 years.

The scores for males and females were comparable for both List I and List II, which reflected that there was no gender effect. This was supported by the findings of Stollman et al. (2004) and Shivaprasad (2006) who also reported the absence of any gender effect in the scores on Binaural fusion test for children aged 6- 12 years.

Thus, the Binaural fusion test in Kannada developed in the study can be used to assess children from 7-12 years of age for the presence of any auditory processing disorder. It can be used clinically as an assessment tool for auditory processing disorder in Kannada speaking children.

Limitations-

Only two lists for Binaural fusion test were developed in the present study. Additional lists would have helped in finding out if there was any apparent ear effect on the scores.

Future implications-

The Binaural fusion test developed in the study can be administered on children with known auditory processing disorder to find out the sensitivity and specificity of the developed test. Also, further research can be done to develop the test in other Indian languages for assessment of auditory processing disorder.

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APPENDIX A

LIST I	LIST II
UÉÆÃqÉ	vÀUÉÆÃ
¸ÀgÀ	PÉÆÃ¥À
VqÀ	¢£À
zÉÆÃ¸É	PÀÄr
PÀÄj	vÀr
£ÀÆgÀÄ	gÀ¸À
PÉÆÃw	eÁuÉ
dqÉ	zÀÆgÀ
mÉÆÃ¦	PÉgÉ
gÁd	UÀÆ¨É
vÀÄn	vÀÆPÀ
ºÀ¸ÀÄ	¤Ã£ÀÄ
ªÉÄÃPÉ	¸ÀÆf
©½	²ÃvÀ
ZÁPÀÄ	ºÀt
ªÀÄÆgÀÄ	ªÀÄgÀ
ªÀÄÆUÀÄ	ªÀiÁvÀÄ
d£À	ºÁqÀÄ
¥Á¥ÀÄ	§r
«ÄÃ£ÀÄ	©¹
¸ÉÃ§Ä	£ÉÆÃqÀÄ
¤ÃgÀÄ	¸ÁgÀÄ
gÀeÉ	ZÁPÀÄ
ªÀÄj	£Á£ÀÄ
¸ÉÆ¼Éî	PÁ¸ÀÄ

APPENDIX B

A SAMPLE OF THE TEST PICTURE PLATE

Rhyming word-

Random word-

Target word-

Word from the same lexical category-