BINAURAL FUSION TEST IN ENGLISH FOR CHILDREN

REG. NO: A0490010

MASTER'S DISSERTATION AS A PART FULFILLMENT OF FINAL YEAR M.SC (AUDIOLOGY),
SUBMITTED TO THE UNIVERSITY OF MYSORE
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MAY, 2006

అంకితం .....

My Dear KUTTU
(On U R 1st B'day)
&
Amma, Naanna

Dear Kuttu
On your birthday I wish you much pleasure and joy;
May each hour and minute be filled with delight,
And your birthday be perfect for you!

CERTIFICATE

This is to certify that this master's dissertation entitled **"Binaural Fusion Test in English for Children"** is the bonafide work done in part fulfillment of the degree of Master of Science (Audiology) of the student with **Reg. No.: A0490010.** 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.

Prof. M. Jayaram
Director,
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Mysore-570006.

Place: Mysore

May 2006

CERTIFICATE

This is to certify that this master's dissertation entitled **"Binaural Fusion Test in English for Children"** has been prepared under my supervision and guidance. It is also certified that this has not been submitted in any other university for the award of any diploma or degree.

Prof. Asha Yathiraj,

Guide,
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Place: Mysore

May 2006

DECLARATION

THIS IS TO CERTIFY THAT THIS MASTER'S DISSERTATION ENTITLED "**BINAURAL FUSION TEST IN ENGLISH FOR CHILDREN**" IS THE RESULT OF MY OWN STUDY AND HAS NOT BEEN SUBMITTED EARLIER AT ANY UNIVERSITY FOR ANY OTHER DIPLOMA OR DEGREE.

MYSORE

MAY, 2006 **REG. NO. A0490010**.

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INTRODUCTION

Hearing is a complex process. As sounds strike the eardrum, the acoustic signals are changed into neural signals which are then passed from the ear through complicated neural networks to various parts of the brain for additional analysis, and ultimately, recognized or comprehended. Central auditory processing is the ability of the brain (central nervous system) to process incoming auditory signals. The brain identifies sounds by analyzing the distinguishing physical characteristics: frequency, intensity, and temporal features that are perceived as pitch, loudness, and duration. After analyzing the physical characteristics, the brain constructs an "image" of the signal from the component parts for comparison with stored "images." If a match occurs, the person understands what is being said or recognizes sounds with important meanings (Hull & Dilka, 1984).

When a person is exposed to a sound, the listener will know the direction from which the sound comes, identify the type of sound, be able to separate the sound from background noise, and interpret the sound. The listener stores the memory of this sound stimulus and develops a mental sound library, which he uses to help him evaluate, interpret, and utilize new sound information that he experiences in the future (Chermak & Musiek, 1997).

Most people think hearing problems are the ears' inability to detect sound. Yet not all hearing is done in the ear. In fact, the ear merely brings in and delivers environmental sounds unsupported to the brain-stem above the spinal cord. As hearing nerves crisscross up several inches, the sorting out or processing begins. This processing includes: focusing attention away from other tasks (watching TV, taking test); separating out and inhibiting "non-speech-like" sounds (sending down neural messages to reduce nerve activity bringing up traffic or dishwasher noise); locating the voice to be heard (focusing on teacher, ignoring other children); conveying speech sounds (not yet words) without distortion to the brain cortex; organizing sounds into words and routing information to other centers of thought, action, and sight (Smoski, Brunt, & Tannahill, 1992). For this there must be enough nerve fibers to share the work and no cell loss from lack of oxygen at birth or failure of embryological development. The nerves must all transmit at normal speed and the brain must produce proper amounts of chemical neurotransmitters for the nerves to carry their messages (Chermak & Musiek, 1997).

Some children have normal hearing ability but have difficulty using information they hear in academic and social situations. These children may have a Central Auditory Processing Disorder. Children who have this difficulty are able to hear well, but have trouble paying attention to, remembering, and utilizing auditory information for academic and social purposes. Central Auditory Processing Disorders may have a very negative impact on their language acquisition, social skill development, and school performance (Musiek & Lamb, 1994).

When a child has a Central Auditory Processing Disorder he has an impaired ability to attend to, discriminate, remember, recognize, or comprehend auditory information. These processing difficulties become more pronounced in challenging listening situations, such as noisy backgrounds or poor acoustic environments, great distances from the speaker, speakers with fast speaking rates, or speakers with foreign accents.

Auditory Processing Disorders (APD) are deficits in information processing of audible stimuli but without hearing or intelligence deficits. It is the inability to attend to, discriminate, recognize or comprehend what is heard. Auditory processing deficits interfere directly with speech and language as well as all areas of learning, especially reading and spelling. Instruction in schools relay primarily on spoken language, so students with APD may have serious difficulty. APD often coexists with other disabilities, including speech and language disorders or delays, learning disabilities, dyslexia, attention deficit disorders, and social and/or emotional problems. APD are more pronounced when listening to distorted speech, or in poor acoustic environments such as listening in the presence of competing background noise (Bellis, 1996).

Central auditory processing has been described as "what we do with what we hear" by Katz, Stecker & Henderson (1992). Assigning a concrete definition to APD is a task that has been approached by many organizations. The American Speech-Language-Hearing Association's (ASHA) Committee on APD, devised the following description in the 1992: "Central auditory processing disorders are deficits in the information processing of audible signals not attributed to impaired peripheral hearing sensitivity or intellectual impairment. This information processing involves perceptual, cognitive, and linguistic functions that, with appropriate interaction, result in effective receptive communication of auditorily presented stimuli. Specifically, APD refers to limitations in the ongoing transmission, analysis, organization, transformation, elaboration, storage, retrieval, and use of information contained in audible signals" (ASHA, 1992).

Auditory processing can also be considered in terms of functional units or areas of the brain (Santucci, 2003). The arousal unit encompasses the subcortex area and the reticular formation, the mechanism which alters the brain to a novel stimulus within a stream of stimuli. This unit's operations include arousal, selective attention, divided attention, orienting reflex, localization, acoustic filtering, and registration. In contrast, the sensory reception unit is associated with the temporal, occipital, and parietal lobes of the brain. Its responsibilities involve detection, discrimination, short-term memory, recognition, acoustic analysis, perception, and consolidation. Finally, the output planning unit encompasses the frontal lobe. Operations such as concentration, comprehension, long-term memory, recall and retrieval, cognition, language, metalanguage, organization, input-output coordination, integration, and sequencing are performed by the output planning unit.

APD is assessed through the use of special tests designed to assess the various auditory functions of the brain. However, before this type of testing begins, it is important that each person being tested receives a routine hearing test (Chermak & Musiek, 1997). These special behavioural tests include:

- Dichotic Tests (Musiek & Pinheiro, 1985)
- Monaural Low-Redundancy Speech (Jerger & Jerger, 1971)
- Temporal Processing Tests (Pinheiro, 1977)
- Binaural Interaction Tests (Matzker, 1959)

Dichotic Tests:

Various dichotic speech listening tests are sensitive to central auditory nervous system dysfunction, and a wide range of tasks are included in this category (Musiek, Baran, & Pinheiro, 1994; Musiek & Pinheiro, 1985). Clinically, two main types of dichotic speech tasks have emerged: binaural separation and binaural integration. In binaural separation, the subject is directed to listen to a target stimulus within the dichotic task. While in the binaural integration task, both signals in the dichotic paradigm must be recognized. Competing sentences and synthetic sentence identification with contralateral competing message (SSI-CCM) are commonly used binaural separation tests (Musiek & Pinheiro, 1985). Dichotic digits, staggered spondaic words (SSW), dichotic consonant-vowels and dichotic sentence identification (DSI) are commonly used (binaural integration) dichotic tests (Bellis, 1996; Musiek & Pinheiro, 1985).

Monaural Low-Redundancy Speech (MLRS) Tests:

In this speech signals have been degraded or are presented in some type of acoustic competition. Filtered, compressed, expanded, interrupted, and reverberated speech signals have all been used as central tests (Musiek & Baran, 1987; Rintelmann, 1985). In addition, speech signals that are in competition with other speech signals, noise, or are altered in intensity have been used in central assessment. As a group, this category of test does not have a high sensitivity or specificity; however, they do test processes that are different from temporal and dichotic procedures (Musiek, Baran, & Pinheiro, 1994). Some common low-redundancy monaural speech tasks to consider when developing a test battery include low pass filtered speech test (Rintelmann, 1985), the synthetic sentence identification with ipsilateral competing message (Jerger & Jerger, 1974), the compressed speech with reverberation test (Bornstein & Musiek, 1992) and the pediatric speech intelligibility test (Jerger, Jerger, & Abrams, 1983).

Temporal Processing Tests:

Temporal processing tests measure the listener's ability to recognize the order or pattern of nonverbal auditory signals. Tones are presented to each ear using different time or pitch patterns, and the listener must either "hum" or verbally describe the pattern (Tallal, 1985). The frequency pattern test also requires temporal processing (Musiek & Pinheiro, 1987; Pinheiro, 1977). This test requires the subject to relate the pattern perceived from three brief (150 msec) tomes, which are combinations of 880 Hz or 1122 Hz sinusoids with a 200 msec interstimulus interval.

Binaural Interaction Tests:

This category includes a variety of tests. Their commonality is that the two ears (auditory systems) must interact (Chermak & Musiek, 1997). Binaural interaction tests includes Masking Level Difference (Schoeny & Talbott, 1994), Interaural Timing Tasks (Levine et al., 1993), Rapidly Alternating Speech Perception (Willeford, 1977) and Binaural Fusion Test (Matzker, 1959). Binaural interaction tests assess binaural fusion; the listener's ability to take incomplete information presented to each ear and fuses the information into an understandable signal. Two different parts of an acoustical signal are presented simultaneously to each ear and the listener must repeat the complete signal. Information presented to either ear alone is unrecognizable, and understanding depends on the brain's ability to integrate the information.

Tests of binaural interaction generally assess the ability of the central auditory nervous system to process disparate, but complementary, information presented to the two ears. Unlike dichotic listening task, the stimuli utilized in binaural interaction tasks typically are presented either in a nonsimultaneous, 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 (Bellis, 1996). A variety of binaural interaction tasks has been used clinically, including rapidly alternating speech perception, band-pass and CVC binaural fusion tasks, interaural difference limen tasks, and the masking level difference.

Need for the study:

Masking level difference is the only binaural interaction test available at present for the Indian population. Although the masking level difference test has been shown have a good sensitive to detect brain stem dysfunction (Bellis, 1996). Other experts have been shown the binaural fusion test to be more sensitive in identifying binaural interaction in children with processing problems (Singer, Hurley, & Preece, 1998; Roush & Tait, 1984; Welsh, Welsh, & Healy, 1980). Thus, there is a need to develop such test.

In literature, there are many studies demonstrating that children with learning disability may have auditory and/or visual processing problems (Kraus & McGee, 1994). Hence there need to be tests to detect their problems. In India it has been found that the percentage of children to have dyslexia ranges from 3% (Ramaa, 1985) to 7.5% Nishi Mary, 1988, cited in Ramaa, 2000). Most often than not these children go unidentified and drop out of school because of poor academic performance. Test developed in the west cannot be directly used in India due to variation in accent and vocabulary used. Hence, there is a need to develop a test appropriate for Indian context.

The average intelligibility scores of binaural fusion increases systematically as a function of age in normal children (Welsh et al.1980). This reflects the maturation of the central auditory processing mechanism. There is a need to see if similar findings are obtained with the material developed in the present study.

Aim of the Study:

The present study had the following aims:

- Developing a Binaural Fusion Test in English for children.
- Developing normative data for different age groups.
- Investigate if there is any difference in the results between males and females.
- Investigating if there is any difference across lists that are developed.

REVIEW OF LITERATURE

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, p. 41).

Individuals with auditory processing disorders experience difficulties comprehending spoken language in competing speech or noise backgrounds (Cherry, 1980; Jerger, Martin, & Jerger, 1987; Jerger, Johnson, & Loiselle, 1988). In addition, related performance deficits in understanding verbal directions, and auditory memory, as well as academic under-achievement and reading difficulties, demonstrate the complex linkages between central auditory processing and more global cognitive and linguistic functions (Butler, 1983; Chermak & Musiek, 1992; Willeford & Burleigh, 1985).

Diagnosis of Auditory Processing Disorders:

Diagnosis of APD is essential for the implementation of appropriate therapeutic and/or remedial strategies. Many auditory processes are involved in the appropriate perception of an acoustic event (Handel, 1989). Most of these processes are inter-dependent. So, a test battery is required to check all the processing abilities. Unfortunately, there is no “standard APD Battery.” Often, the clinic or the professionals create a test battery that best meets their needs, based on clinical and professional experience, and the needs of their patients and clients. APD batteries should include behavioural and electrophysiological tests to ensure the assessment of peripheral and central auditory processes and pathways (Chermak & Musiek, 1997).

Peripheral hearing tests verify if the child has a hearing loss and if so, the degree to which the loss is a factor in the child's learning problems. APD evaluation includes routine audiological evaluation and specific central auditory processing tests. Assessment of the central auditory system evaluates the child's ability to respond under different conditions of auditory signal distortion and competition. It is based on the assumption that a child with an intact auditory system can tolerate mild distortions of speech and still appreciate it, while a child with an APD will encounter difficulty when the auditory system is stressed by signal distortion and competing messages (Keith, 1995). The test results allow the audiologist to identify strengths and weaknesses in the child's auditory system that can be used to develop educational and remedial intervention strategies.

Recognizing the insensitivity of traditional auditory tests in assessing the central auditory nervous system, researchers developed behavioural tests composed of low redundancy material, such as filtered speech, compressed speech, interrupted speech and speech in noise to elucidate central auditory nervous system dysfunction (Bocca, 1958; Calearo & Lazzaroni 1957; Noffsinger, Olsen, Carhart, Hart, & Sahgal, 1972). Continuing efforts to develop tests sensitive to lesions of the central auditory nervous system led to measure that incorporated binaural interaction (Berlin, Lowe-

Bell, Jannetta, & Kline, 1972; Katz, 1962; Kimura, 1961a, 1961b; Matzker, 1959; Musiek, 1983).

The behavioural tests of APD are divided in to four sub-categories, including monaural low redundancy speech tests, dichotic speech tests, temporal patterning tests, and binaural interaction tests. It should be noted that children being assessed for APD would not necessarily be given a test from each of these categories. Rather, the audiologist will select a battery of tests for each child. The selection of tests will depend upon a number of factors including the age of the child, the specific auditory difficulties the child displays, the child’s native language and cognitive status, and so forth (Willeford & Burleigh, 1985).

In the following section a detailed review of a binaural interaction test is given. Due to the richness of the neural pathways in the human auditory system and the redundancy of acoustic information in spoken language, a normal listener is able to recognize speech even when parts of the signal area missing. However, this ability is often compromised in individuals with an APD. Binaural interaction tests represent a group of tests. These tests include, binaural fusion test, masking level difference, localization and lateralization and rapidly alternative speech perception test. The stimuli used in these tests have been modified by changing one or more of the following characteristics of the speech signal: frequency, temporal or intensity characteristics. Binaural fusion test is one such test, originally designed by Matzker in 1959 to evaluate binaural interaction.

Binaural Fusion Test as a Measure of APD:

History in the development of binaural fusion test:

The Binaural Fusion Test employs stimuli that have been filtered into two separate segments that are then presented simultaneously to the two ears of the subject. Generally, the filtering of the stimuli causes the stimuli to be unintelligible in one ear alone, but with the combined, filtered information from the other ear and assuming the auditory system is functioning correctly, the information is spectrally fused and recognition occurs. Binaural fusion task can be done in two ways: band pass binaural fusion and CVC binaural fusion (Wilson, Arcos & Jones, 1984).

The first binaural fusion test was developed by Matzker (1959). He applied the principle of binaural fusion to the study of central auditory processing in adults. He used bisyllabic, phonetically balanced word lists for assessing binaural resynthesis. In his test, the low-pass band (500 – 800 Hz) was presented to one ear while the high-pass band (1815 – 2500 Hz) was presented to the other ear. The 41-word list was presented three times: twice using filtered bands and once, during the second presentation, diotically so that fusion was not required. His results indicated that listeners with cortical lesions performed normally on the binaural fusion task whereas listeners with brainstem pathology had difficulty with the resynthesis of the auditory information. Matzker's binaural fusion test was modified by using the spondaic words and it was included in Willeford central test battery (Ivey, 1969, cited in Bellis, 1996).

Smith and Resnick (1972) maintained that the use of monosyllabic words would reduce the redundancy of the signal and thereby improve the sensitivity of the binaural fusion tasks. In their study, monosyllabic, CVC words were band-passed and presented using a variation of Matzker's resynthesis paradigm. The test results were interpreted by comparing the results of the diotic presentation of the stimuli with the two presentations requiring fusion. Diotic scores were significantly higher than resynthesis scores in the four cases of brainstem pathology that they studied.

Wilson, Arcos, and Jones (1984) developed a binaural fusion test where CVC words were segmented such that the consonantal information was delivered to one ear and the vowel information to the other ear in an alternating manner. They reported that the test was unaffected by peripheral hearing loss. In 1992 a CD version of the test was made available.

Several factors have been found to affect scores of a binaural fusion test. It is important that these factors be kept in mind while constructing such a test. The following section reviews studies related to factors that have been found to affect binaural fusion.

Factors Affecting the Performance of Binaural Fusion Test:

The factors that can influence the performance on a binaural fusion test can be classified as follows:

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

6. Pathologies/clinical conditions.

1. Affect of band pass filter width:

The original binaural fusion test, developed by Matzker (1959) made use of two narrow band-pass filters, a low one from 500 Hz to 800 Hz and a high one from 1815 Hz to 2500 Hz. Each band by itself was too narrow to allow recognition of the test words. However, when both bands were presented together, adequate recognition was possible. Matzker administered this test on more than 1700 patients. This test provided information on the functioning of the central auditory pathways. The test results not only indicated that a central lesion was present, but, within limits, pointed to the location of such lesions. He indicated that a high error score on binaural fusion test was indicative of a functional failure of the synaptic connections within the brain stem.

Smith and Resnick (1972) developed a binaural fusion test with monosyllables processed through two band-pass filters. They used a low band of 360 to 890 Hz and the high band was a one-third octave from 1,700 to 2,200 Hz with the centre frequency gain raised 10 dB with reference to that of the low band. The test consisted of three binaural conditions, in the first condition the high band was delivered to the left ear and low band to the right. The second condition had both high and low bands delivered to both ears. The third condition was the reverse of the first, so that the high band was in the right ear and the low band in the left ear. Results were obtained on 30 normal hearing individuals. The mean dichotic scores were 70.4% and 69.4% for first and third condition and 71.2% for second condition. Normal hearing subjects showed no significant differences among the three test conditions. Thus, it can be construed that any of the three filter conditions can be utilized.

Plakke, Orchik, and Beasley (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 cut-off frequencies and 1950 Hz and 2080 Hz for the high-frequency band-pass. The 300 Hz nominal band width had cut-off frequencies of 400 Hz and 700 Hz for the low-frequency band-pass and 1870 Hz and 2200 Hz for the high-frequency band-pass. The 600 Hz nominal band width had cutoff frequencies of 250 to 850 Hz and 1700 Hz to 2250 Hz for the low-frequency and high frequency band-passes, respectively. Their results indicated that there was no significant difference in scores of the 100 Hz band and 300 Hz band widths, whereas there was a significant difference in scores between the 100 Hz band width, 300 Hz band width and 600 Hz band width. It was also observed that as the band width increased from 300 Hz to 600 Hz, scores were also enhanced significantly.

Roush and Tait (1984) studied binaural fusion, masking level difference and auditory brain stem responses in children with language learning disabilities. They used a low-frequency pass-band of 420 to 570 Hz and a high-frequency pass band of 1950 to 2100 Hz for their binaural fusion test. This resulted in high and low pass-bands 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 (normal children) and experimental group (learning disability children). Means scores were 64.7 % and

50.9% for the control group and experimental group respectively for binaural fusion test. From these 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.

From the above studies it can be observed there is no standard band pass cut-off and band-width used in all the studies. It is also observed that as the band width of the signal is increased, perception also improves. Hence, when constructing a binaural fusion test the band-width should be such that it results in optimum difficulty. It should neither be too narrow or too wide to avoid making the test too difficult or too easy.

2. Effect of Presentation Level:

Plakke, Orchik, and Beasley (1981) studied the effect of presentation level for a binaural fusion test. They presented the band pass filtered signal at two different intensity levels i.e., at 30 dB sensation level and 40 dB sensation levels. It was observed that there was a considerable difference between the two presentation levels. As the presentation level increased from the 30 dB to 40 dB, scores also improved significantly.

Thus, there is general consensus that the scores of the binaural fusion test increases with increase in sensation levels. It reaches a plateau at 32 dBSL. Clinically, 40 dBSL has been found to be most appropriate.

3. Effect of Age:

It is essential to note that the human brain is not fully developed at birth. Although the production of neurons through cell division is completed by approximately 16 to 20 weeks after conception and no new neurons are produced after that time, the development of new and more efficient synaptic connections continues into adult hood (Kalil, 1989; Restak, 1986, cited in Bellis, 1996).

Windham, Parks, Mitchener-Colston (1986) studied the central auditory processing in urban black children. The subjects of this study were 40 black children who were intellectually, functionally, and behaviourally normal. Their ages ranged from 7 years 4 months to 11 years 4 months. The candidates were identified by classroom teachers, and then evaluated by specialists, using interviews, records, observation, and tests to identify hidden handicaps. Performance data were obtained on each of the age groups for the following CANS tests: time compressed speech; competing sentences; filtered speech; binaural fusion; alternating sentences; and staggered spondaic words. The results indicated that the performance is increased as the age increased and they also performed similar to normal white subjects, quantitatively and qualitatively.

Neijenhuis, Snik, Priester, van Kordenoordt, and van den Broek, (2002) studied the age effects and normative data 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: words-in noise, filtered speech, binaural fusion, dichotic digits, frequency and duration patterns, backward masking, categorical perception, digit span and a questionnaire. Data was obtained from 75 children from primary school (age 9-12 years) and 30 adolescents from secondary school (age 14-16 years) with normal hearing and normal intelligence. Age effects were present in most tests, within the group as well as when children and adolescents were compared to adults. This suggests that maturation of auditory processing abilities takes place even during adolescence. Relative measures regarding ear differences and binaural versus monaural scores did not appear to be age-related

Stollman, van Velzen, Simkens, Snik, and van den Broek (2004) studied the effect of age on auditory processing in children. A group of 20 children with normal cognitive and language development underwent several auditory tests at the ages of 6, 7, 8, 10 and 12 years. At the age of 10 years, three subjects were lost to follow-up, as was one more subject at the age of 12 years. The auditory performance of the children was compared to the performance of a group of 20 adults. The auditory test battery consisted of a speech-in-noise test, a filtered speech test, a binaural fusion test and two auditory sequencing tests. All auditory tests except the speech-in-noise test showed a clear effect of age on the performance of children. Results indicated that maturational effects play an important role in auditory processing (at least) up to an age of 12-13 years.

Studies have found that the discrimination ability of binaural fusion in children increases with age. The exact age up to which an increase in score is seen, is not clearly delineated in the studies but the scores reaches almost maximum level at the age of 12 to 13 years (Stollman et al. 2004).

4. Effect of Ear:

Smith and Resnick (1972) studied the ear effect in normal hearing individuals by presenting the signals in three different conditions. In the first condition, the high band was delivered to the left ear and low band to the right. In the second condition, both high and low bands were delivered to both ears. The third condition was the reverse of the first, so that the high band was in the right ear and the low band in the left ear. Results were obtained on 30 normal hearing individuals. The mean dichotic scores were 70.4% and 69.4% for first and third condition and 71.2% for second condition. Normal hearing subjects showed no significant differences among the three test conditions.

Plakke et al. (1981), in order to check a ear effect to, presented the signals in three modes each subject. 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 (both bands to both 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. It was found that there is no significant difference between BF1 and BF2 but scores improved in the diotic condition. This indicates there was no significant ear effect.

Roush and Tait (1984) conducted an experiment to evaluate the ear effect in a binaural fusion test in children with language learning disabilities. The binaural fusion test results were investigated in three listening conditions. In the first dichotic condition the low pass-band was delivered to the left ear and the high pass-band to the right ear. In second condition, which was a diotic task, both the low and high pass-bands were delivered simultaneously to each ear. A third condition, which was also a dichotic condition, was the reverse of the first dichotic task. Here the high pass band signal was sent to the left ear and the low pass to the right ear. Results suggested that there was no significant difference between the three test conditions in both the experimental and control groups.

From the above studies it is evident that there is no significance difference in between left ear and right ear scores. Thus, unlike other tests for APD, no ear advantage is obtained.

5. Effect of Language:

The performance of 16 South African English first and 16 South African English second language adult speakers on a series of auditory processing tests including binaural fusion test was carried out by Saleh, Campbell and Wilson (2003). The performances of the subjects were descriptively compared to previously published American normative data. Comparisons between the South American English first and second language speakers showed equivalent performances on the left ear performance on the two pair dichotic digits test, and the frequency patterns test, the duration patterns test, the low pass filtered speech test, the 45% time compressed speech test, the speech masking level difference test, and the consonant vowel consonant binaural fusion test. A poorer right ear performance by the second language speakers on the two pair dichotic digits test only. Comparisons between the South American English and the American normative data showed many 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.

6. *Effect of Binaural Fusion Test in the Clinical Population:*

The use of binaural fusion test as a part of the clinical test battery has grown out of the need to detect subtle neurological lesions that may go unnoticed by use of standard puretone and word discrimination measures of audition. These implications have been based upon the subtlety and bottleneck principle exposed by Jerger (1960, cited in Beasley & Freeman, 1977). He noted that, because of the complexity and neural redundancy of the central nervous system, measures of retro cochlear auditory dysfunctions required stimuli of a complex nature. Matzker (1959) recognized this problem and consequently employed binaural fusion test as a measure for evaluating lesions in the central auditory system. Binaural fusion test has been used on different clinical population for diagnostic purposes.

a. Peripheral hearing loss:

Miltenberger, Dawson, and Raica (1978) studied the effect of peripheral hearing loss on central auditory testing. The goal of the study was to examine the effect of peripheral hearing loss on auditory tasks that are used to assess dysfunction within the central auditory pathways. In this study seventy subjects with a sensorineural hearing loss participated. Each subject was evaluated with a central auditory processing (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 affected by certain degrees/configurations of sensorineural hearing loss.

Neijenhuis et al. (2004) evaluated the effect of a mild sensorineural hearing loss on auditory processing using Dutch auditory test battery. The test battery was administered on 24 subjects with a mild, relatively flat, symmetrical sensorineural hearing loss. The scores of the hearing-impaired subjects were significantly poorer than those of the subjects with normal hearing on five out of the six tests, even with the adjusted presentation level. Significant correlations were found between test scores and pure-tone average. All the tests were presented at equal sensation levels.

Schilder, Snik, Straatman, and van den Broek (1994) studied the effect of auditory perception in otitis media with effusion children. The relationship between otitis media with effusion at the preschool age and performance on five tests of auditory perception 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 to 4 year 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 there was no effect on other tests.

These studies indicate that in subjects with a sensorineural hearing loss, binaural fusion is effected whereas in subjects with a conductive hearing loss binaural fusion is not effected with adjusted presentation level. From the results of the above studies, it was concluded that while the central auditory processing test battery can be administered on certain persons with sensorineural hearing loss the results must be interpreted with caution and in view of the basic audiological assessment.

b. Dyslexia:

Welsh, Welsh, and Healy (1980) studied the central auditory processing in 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 the test medium and the results of the 77 dyslexic students were compared to the normative data. The test batter included 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's failed in two of the four tests, and each of the 77 failed 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 test and filtered speech test scores improved somewhat but rather moderately and never approach the normal range.

In another study Welsh, Welsh, Healy, and Cooper (1982) evaluated the effect of central auditory tests in dyslexic children. A group of dyslexic students was 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 tests 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 a binaural fusion speech test is useful in identifying processing problems in children with dyslexia. Abnormal binaural fusion performance has been seen in these children with dyslexia.

c. Auditory Processing Disorder:

Musiek and Geurkink (1980) evaluated the effect of central auditory tests on auditory processing in children. In this study they tested five children with auditory processing problems. These children had normal peripheral hearing and ENT findings, but were referred with a suspicion of hearing loss. An auditory perceptual test battery which included rapidly alternating speech, binaural fusion, low pass filtered speech, competing sentences, staggered spondaic words, dichotic digits and frequency patterns was employed. Though some of these tests did not show a perceptual deficit, the majority did depict specific types of auditory processing problems. Three children were 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 pretest 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 on auditory perceptual impairment among children.

d. *Brainstem Lesions:*

In 1972 Smith and Resnick carried out a study to check brain-stem integrity using the binaural fusion test in confirmed temporal lobe pathology and documented brain stem pathology. Results of this study indicated that, there was no significant difference between dichotic and diotic test results in temporal lobe lesions, whereas subjects with brain stem lesions, there was 18 to 34% diotic enhancement over at least one of the dichotic condition. This shows that, in subjects with a brain stem lesion, subjects the binaural fusion test results are affected.

Earlier Matzker (1959) administered binaural fusion test on more than 1700 patients. It was found that the test results do not only indicated that a central lesion was present, but within limits, indicated the location of the lesion. A high error score in the binaural fusion test was indicative of a functional failure of the synaptic connections within the brain stem.

e. Alcoholics:

Fitzpatrick and Eviatar (1980) studied the effect of alcohol on central auditory processing. Twelve subjects between the ages of 23 and 62 were tested for changes in hearing acuity and discrimination after ingestion of four ounces of vodka (80 U.S.

proof = 40 per cent ethyl alcohol). As compared with their own pre-alcohol ingestion test results, these subjects revealed, a decrease in discrimination of speech on CID W22 lists under difficult listening conditions, (in quite at 10 dB SL and in noise at a signal-to-noise ratio of -6); and a decrease in performance on a filtered speech test having a low-pass, or high-pass, and binaural fusion. The staggered spondaic word test was moderately affected only in one of the twelve subjects. Pure tone thresholds, speech reception thresholds, and speech discrimination at 40 dB SL were not influenced. It was concluded that alcohol ingestion in moderate amounts alters the central auditory processing under difficult listening conditions.

f. Misarticulation:

The auditory perceptual abilities in misarticulating children were studied by Riensche and Clauser (1982). Twelve children who recently had satisfactorily completed therapy for more than four phoneme errors, and normal controls, were given tasks of auditory perception consisting of repeating 5-word recorded sentences (0, 1st and 2nd order approximations) at 0 and at 60% time compression, and diotic and dichotic presentations at 40 dB SL 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 suggest that binaural interaction was not affected in children with misarticualtion.

g. Sickle cell anemia:

Wilimas, McHaney, Presbury, Dahl and Wang (1988) assessed the auditory acuity and central auditory processing in 22 patients with sickle cell anemia, 13 of whom were chronically transfused, and compared with a control black population. Pure tone air conduction thresholds were within normal limits for all patients, and mean Speech Reception Threshold for each ear was normal at 10 dB. All subjects exhibited type A tympanograms. Central auditory processing was assessed by the Competing Sentence Test and Binaural Fusion Test. No significant differences were found among transfused, nontransfused, and control patients. Thus, abnormal auditory function did not appear to be a common problem in patients with sickle cell disease.

h. Charcot-Marie-Tooth (CMT) disease type 1A:

Five genetically confirmed CMT1A cases with normal hearing underwent behavioural and objective tests. Pure tone audiometry, speech audiometry, and OAE assessment were followed-up by an auditory processing test battery comprising sentences-in-noise test, pattern recognition tests, words-in-noise test, dichotic digit test, filtered speech test, binaural fusion test, and categorical speech perception test. Subsequently, auditory brain-stem response and event related potential measurements were conducted. Results indicated that either the behavioural or objective test scores of four of the five CMT1A patients did not differ significantly from those with normal hearing. Significantly lower scores were obtained on one patient on the auditory processing tests and ABR measurements. The authors have 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 a peripheral hearing loss complicated the interpretation of auditory processing abilities (Neijenhuis , Beynon , Snik, van Engelen, & van den Broek, 2003).

i. Specific Language Impairment:

Stollman, van Velzen, Simkens, Snik, and van den Broek (2003) evaluated the auditory processing in 6-year-old language-impaired children. The performance of a group of twenty 6-year-old children with specific language impairment on several behavioural auditory tests was compared to that of a group of twenty age-matched control children. The auditory test battery used in this study consisted of the following tests: speech-in-noise test, filtered speech test, binaural fusion test, frequency pattern test, duration pattern test, temporal integration test, an auditory word discrimination test, an auditory synthesis test, an auditory closure test and a number recall test. Results show that the specific language impairment children obtained scores on almost all tests that were significantly lower than those of the control group. They also found that there was a significant correlation between the auditory processing test battery and receptive and language scores, suggesting a causal relationship between auditory processing and language proficiency.

Comparison of binaural fusion test with other auditory perceptual tests:

Singer et al. (1998) studied the individual test efficacy and test battery efficacy and to estimate the costs that are associated with the identification of a targeted sample. In this 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 to 13 years were given a battery of seven auditory processing tests. The test battery consisted of binaural fusion test, masking level difference, filtered speech test, time compressed speech test, dichotic digits test, staggered spondaic word test and pitch pattern test. Their results indicated that 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 or binaural fusion test and masking level difference represented the best battery approach when hit rate, false positive rate and cost factors were considered. These results indicated that binaural fusion test plays a major role in identifying auditory processing disorder children.

Roush, and Tait, (1984) studied the effect of binaural fusion, MLD and auditory brain stem responses in children with language-learning disabilities. Binaural fusion was measured for dichotically and diotically presented pass-bands of filtered speech in normal children and children with language-learning disabilities. Results indicated that lower overall scores for the experimental group on the diotic as well as dichotic conditions for the binaural fusion tasks, although both groups scored relatively higher in the diotic condition. Masking level differences and auditory brain stem responses were not significantly different for the two groups. These findings suggest that the use of binaural fusion test would be better to differentiate between normal and language learning disabled children.

Welsh et al. (1980) compared the sensitivity of several tests used to evaluate auditory processing. These tests included the Competing Sentence Test, Binaural Fusion Test, Rapidly Alternating Speech Perception test, and Filtered Speech Test.

These tests were administered on a group of pupils with dyslexia having normal end organ function. The results of the 77 dyslexic students were compared to normative data. They found that the binaural fusion test and filtered speech were more sensitive with less variation from the normal group.

The above studies indicate that the binaural fusion test was sensitive to identify auditory processing problems in children suspected to have an APD. It was found to be more sensitive than other APD tests.

The review of literature bring to light that there are several variables that influence the scores of binaural fusion test. It is essential that these variables be considered while developing and administering binaural fusions test. It is also evident from the literature that a binaural fusion test provides useful information regarding the presence of an auditory processing problem in various conditions such as brain damage, learning disability, specific language impairment, and peripheral hearing loss. In a view of the utility of the test, in diagnosing auditory processing problems, it is essential to develop the test in different languages.

METHOD

The main aim of this study was to develop and obtain normative data for a Binaural Fusion Test for children. The entire study was conducted in two stages. In the first stage material was developed. Following this normative data was collected in the second stage.

Subjects:

For developing the test, twenty children in the age range of 7 years to 7 years 11 months were taken to ensure that the test material was familiar to the children.

Fifty normal children in the age range of 7 years to 11 years 11 months were taken for collecting normative data. These children were grouped into five different age groups, each group consists of 10 children (5 males and 5 females). The age groups were:

7 years to 7 years 11 months

8 years to 8 years 11 months

9 years to 9 years 11 months

10 years to 10 years 11 months

11 years to 11 years 11 months

Subject selection criteria for both the stages:

Only those subjects who met the following criteria were considered for the study:

- Hearing sensitivity within normal limits i.e., air conduction thresholds were less than or equal to 15 dBHL in the frequency range of 250 to 8000 Hz in both the ears and the air bone gap was lesser than 10 dBHL at all frequencies.
- ‘A’ type tympanograms and reflexes were present in both the ears.
- Normal I.Q
- Studying in schools with English as medium of instruction at for two years.
- No past history of otological or neurological problems.
- Educational performance should be good/average as per the teachers’ report.
- No illness on the day of testing.
- Pass the Screening Checklist for Auditory Processing (SCAP) (Yathiraj & Mascarenhas, 2003), to rule out any auditory processing disorder.

Instrumentation:

The following instruments were used:

- A Pentium 4 computer with Creative Wave Studio and Sound Edit Pro (Version 2.1.126) software was used to record and to develop the material.
- A calibrated two channel diagnostic audiometer was used for subject selection and for running the Binaural Fusion Test.
- Immitence Audiometer was used to rule out the presence of a middle ear pathology.
- A CD (CD_R 700MB) player was used for playing the recorded material.

Test Environment:

Testing was done in a sound treated double room, with the ambient noise levels within permissible limits as recommended by ANSI (1989).

Procedure:

Stage I: *Development of test material:*

Initially 300 CVC words that are commonly used were selected from parents, teachers and age appropriate books. These words were presented to 20 children aged 7 years to 7 year 11 months to check the familiarity. Each subject was tested individually, where they were asked to describe words or show the picture representing the words. For developing the test material 100 words were selected which were familiar to all the twenty children. Using these familiar words, four lists were constructed with each having 25 words. These lists were phonetically balanced using frequencies of occurrence of English speech sounds in India by Ramakrishna et al. (1962).

Recording of Material:

Recording was done using a female speaker who spoke English fluently. Her fundamental frequency was within normal limits (212 Hz) which was measured by using the Vaghmi software. The words and sentences were recorded in a Pentium 4 computer by using the Sound Edit Pro software with a 24000 Hz sampling rate. Scaling of the words was done using the same software to ensure that the intensity of all words was brought to the same level. A five seconds inter-word interval was maintained. These words were band passed using the Sound Edit Pro (Version 2.1.126) 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. The band width for the high and low band passes were the same i.e., 200 Hz.

The four recorded lists were band-passed in the following manner:

- List one and two were filtered such that the low pass band was presented to the left ear and the high band-pass to the right ear.
- List three and four were filtered so that the high band pass was presented to the left ear and the low band pass to the right ear.

A 1 kHz calibrations tone was recorded prior to each list. The recorded material was burnt on a CD using, a CD burner, Nero Express.

Stage II: Obtaining normative data:

Initially, to check the equality of the four lists that were developed, the recorded unfiltered stimuli were presented to the 7 to 8 year old children who met the subject selection criteria. All four lists were presented to the 20 children at a comfortable listening level (approximately 40 dB SL). The stimulus was presented with the help of a CD player through the ear phones. The children were required to repeat the words heard. The responses were scores such that a correct response was given a score of one and a wrong response a score of zero. It was found that all the words were repeated in all four lists, showing that the four lists were of equal difficulty.

Following this normative data was obtained for the developed Binaural Fusion Test (BFT). The test was administered on a group of fifty normal hearing children who met the subject selection criteria. Prior to the administration of the test, all the children underwent pure-tone audiometry. Their speech recognition thresholds were obtained using the English pair-word list developed by Chandrashekar, (1972).

The recorded BFT material that was developed was played using a Philips CD (CD_R 700MB) player. The out put of the player was routed to the dual channel diagnostic audiometer Orbiter 922. The 1 kHz calibration tone was used to adjust the volume unit (VU) meter deflection of the audiometer to zero. The out put form the audiometer was played at 40 dBSL with reference to the subject's speech recognition threshold. The subjects heard the material through head phones (TDH 39 with MX-41/AR ear cushion). All the subjects heard all four lists. The order in which they heard the lists was randomized to avoid a list order effect. The subjects were instructed to repeat what they heard. Their oral responses was transcribed by the tester and later scored. A correct response was given a score of '1' and a wrong response a score of '0'.

The data obtained was subjected to statistical analysis using the SPSS version 10.0 software.

RESULTS & DISCUSSION

In this section, the results obtained from the present study are discussed. Statistical analysis was done to obtain information on the following using the SPSS (Version 10.0) software:

1. List effect
2. Gender effect
3. Age effect

Each of the above aspects were analyzed using repeated measures of ANOVA, two-way ANOVA, and one-way ANOVA respectively. In addition, age effect was analyzed using, Duncan's Post hoc test. The normative data for each age group was found out by calculating mean, standard deviation and confidence level.

List Effect:

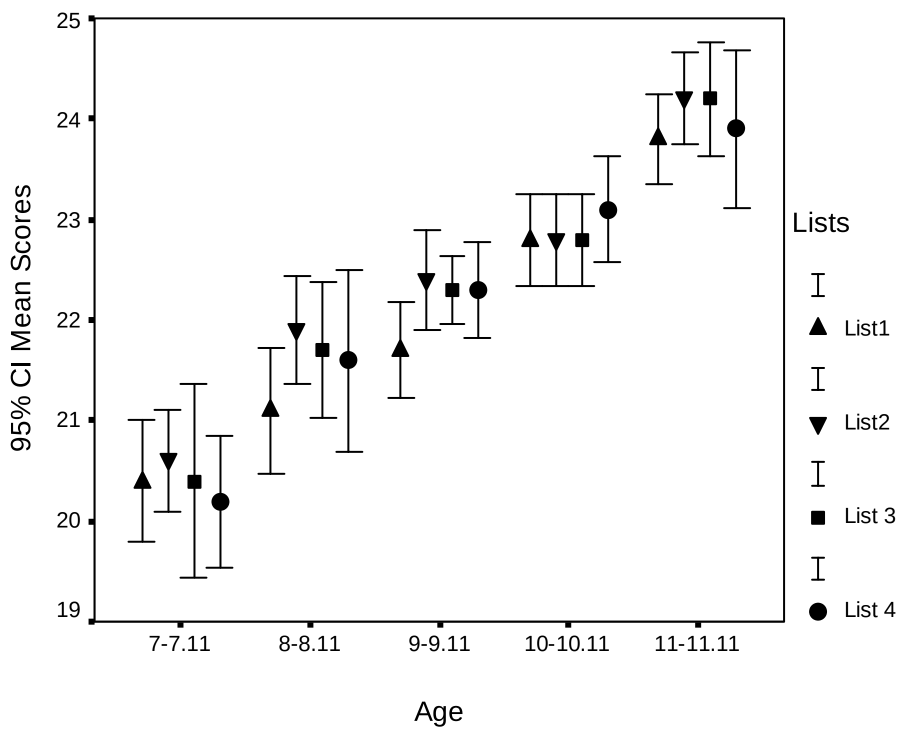
To check the perceptual equality of the four lists, prior to the filtering repeated measures of ANOVA was carried out. It was observed that there was no significant difference between the lists [$F(3, 79) = 0.357$, $p > 0.05$]. This indicated that the four phonetically balanced lists were equal in terms of perceptual difficulty. Hence, any one of them can be used for determining speech intelligibility.

Further to check the equality of the four lists developed to evaluate binaural fusion, the mean and standard deviation were obtained for the five different age groups (Table 1). A repeated measure of ANOVA was done in order to find out the effect of test lists. The results indicated that there was no significant difference between the four lists [$F (3, 135) = 2.255$, $p > 0.05$]. This was observed across the different age groups as well as between males and females.

Table 1: Mean and standard deviation (SD) for different lists across the age groups

	Age	Mean	SD
List 1	7 - 7.11	20.40	0.84
	8 - 8.11	21.10	0.88
	9 - 9.11	21.70	0.67
	10 - 10.11	22.80	0.63
	11 - 11.11	23.80	0.63
List 2	7 - 7.11	20.60	0.70
	8 - 8.11	21.90	0.74
	9 - 9.11	22.40	0.70
	10 - 10.11	22.80	0.63
	11 - 11.11	24.20	0.63
List 3	7 - 7.11	20.40	1.35
	8 - 8.11	21.70	0.95
	9 - 9.11	22.30	0.48
	10 - 10.11	22.80	0.63
	11 - 11.11	24.20	0.79
List 4	7 - 7.11	20.20	0.92
	8 - 8.11	21.60	1.26
	9 - 9.11	22.30	0.67
	10 - 10.11	23.10	0.74
	11 - 11.11	23.90	1.10

Figure 1: 95% confidence interval (CI) mean scores for different lists across the age groups



From Figure 1 it is clear that there is no significant difference between the lists within an age group. These results suggest that the lists were not significantly different from each other. This indicated that distorting the word lists by filtering them and then obtaining binaural fusion scores, does not alter the equality of the lists. Thus, immaterial whether a high pass signal is presented in the left ear and low pass signal in the right ear or vise versa there is no significant difference. Smith et al. (1972); Stollman et al. (2004) and Roush & Tait (1984) also found that there was no significant difference in presentation mode i.e., high pass signal is presented in the left ear and low pass signal in the right ear or vise versa in binaural fusion test.

Gender Effect:

The mean and standard deviation of the scores on the binaural fusion test was determined for males and females. Table 2 shows the scores obtained for list 1. Similar scores were obtained for lists 2, 3 and 4. Two-way ANOVA was done in order to find out the effect of gender on binaural fusion scores. The results indicated that there was no significant difference between males and females for all four lists [$F(1, 40) = 0.136$, $p > 0.05$]. This lack of gender difference was seen across the different age groups as well as for the four lists that were developed.

Table 2: Mean and standard deviation (SD) for males and females across the age groups for list 1.

Age	Gender	Mean	SD
7 - 7.11	Male	20.6000	0.5477
	Female	20.2000	1.0950
8 - 8.11	Male	21.2000	1.0954
	Female	21.0000	0.7071
9 - 9.11	Male	21.8000	0.8367
	Female	21.6000	0.5477
10 - 10.11	Male	22.8000	0.4472
	Female	22.8000	0.8367
11 - 11.11	Male	23.6000	0.5477
	Female	24.0000	0.7071

Studies have shown that young girls, aged 1 to 5 years, are more proficient in language skills, talk at an earlier age, produce longer utterances, and have larger vocabularies than do boys (Ruble & Martin, 1998, cited in Plotnik, 1999). Although there appear to be a gender difference in verbal abilities favoring women, this difference is relatively small and thus has little practical significance (Hyde, 1994, cited in Plotnik, 1999).

The result of the present study is also indicating that there exist no significant difference between the performance of males and females across age and across lists. Hence, it can be construed that boys and girls in the age range of 7 to 12 years develop in a similar manner, with respect to the way in which binaural interaction takes place.

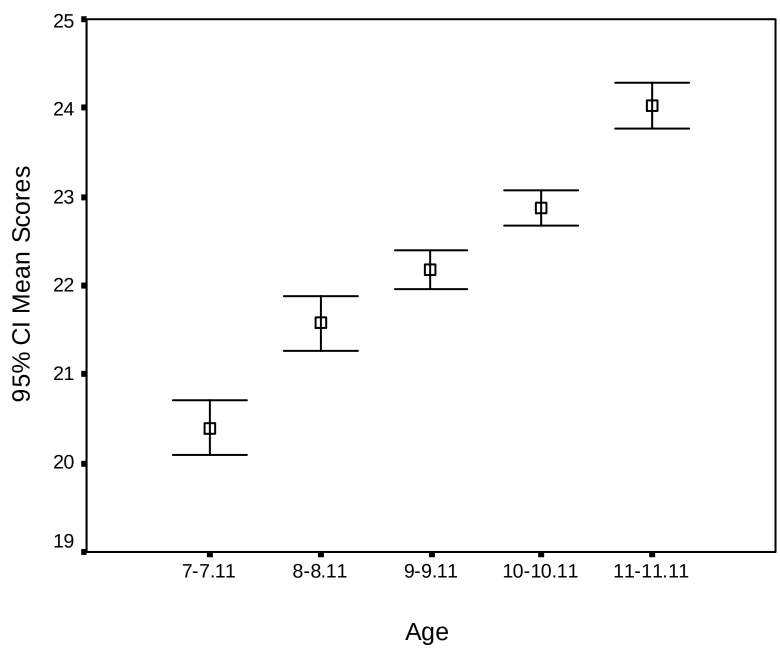
Age Effect:

As no significant difference was observed between males and females as well as between the lists, these scores were combined. Thus, for each age group there was one score which represented the average score of the male and females and the four lists. These scores, across the different ages are shown in table 3. ANOVA was carried out to check the significance of difference between means across the five age groups. The results indicated that there was a significant difference between age groups [$F(4, 199) = 109.156$, $p < 0.001$].

Table 3: Mean, standard deviation (SD) and confidence intervals for different age groups

Age	Mean	SD	95% Confidence interval for mean	
			Lower Bound	Upper Bound
7 - 7.11	20.4000	0.9554	20.0944	20.7056
8 - 8.11	21.5750	0.9842	21.2602	21.8898
9 - 9.11	22.1750	0.6751	21.9591	22.3909
10 - 10.11	22.8750	0.6480	22.6678	23.0822
11 - 11.11	24.0250	0.8002	23.7691	24.2809

Figure 2: Mean scores for different age groups.



From Table 3 and Figure 2 it is evident that as the age increases from 7 years to 12 years, auditory processing ability also increased. To further check the difference between the age groups, Duncan's post hoc analysis was carried out.

Table 4: Significance of difference in mean scores between the age groups based on Duncan's Post Hoc test.

Age	Subset of mean scores for alpha = 0.05				
	1	2	3	4	5
7 - 7.11	20.4000				
8 - 8.11		21.5750			
9 - 9.11			22.1750		
10 - 10.11				22.8750	
11 - 11.11					24.0250

The post hoc analysis (Table-4) shows that there was a significant age difference observed between all the groups. There was a steady increase in the scores with increase in age. Each age group differed significantly from the other. The youngest age group (7 – 7.11 years) performed the poorest and the oldest age group (11 – 11.11 years) performed the best. These results suggest that as the age increases from 7 years to 12 years auditory processing ability also increases.

Similar results have been reported in literature also. Stollman et al. (2004) studied the affect of age on central auditory processing using a test battery which included a binaural fusion. They found that as the age increased from 6 years to 12 years, auditory processing ability is also increased. These results indicated that maturation does occur in auditory processing abilities (at least) up to an age of 12 to 13 years.

Neijenhuis, Snik, Priester, van Kordenoordt, and van den Broek (2002) were also studied the age effects and normative data on a Dutch test battery which also include binaural fusion test for auditory processing disorders in 9 to 16 year old children. Their results suggest that age effects were present performance was increased as the age increases from 9 to 16 years. This suggests that maturation of auditory processing abilities takes place even during adolescence. Current research indicates that neuromaturation of some portions of the auditory system may not be complete until age 12 or later (Bellis, 2003).

The present study also confirms that as the age increases from 7 to 12 years, auditory processing ability also grows. This outcome indicated that neuromaturation of the auditory system occurs till age 12 years or later. Further, the results of the present study also suggest that when testing children using the binaural fusion test that has been developed, their scores should be checked against age appropriate norms.

In conclusions, analysis of the results obtained from the present study revealed that:

1. There existed no significant difference between the lists developed.

2. There existed no significant difference in the performance of males and females across ages and across lists.
3. There was a considerable difference in scores of binaural fusion test across the age groups. As the age increased from 7 years to 12 years the performance on binaural fusion task is also increased.
4. While using a binaural fusion test as a clinical tool, age appropriate norms should be referred to.

SUMMARY AND CONCLUSION

Binaural Fusion test is one of the most sensitive test in identifying auditory processing problems in children suspected to have an APD. It was found to be more sensitive than other APD tests (Roush et al. 1984; Singer et al. 1998; Welsh et al. 1980). Hence, the present study aimed to develop Binaural Fusion Test and to obtain normative data on a group of children.

This was done in two stages. In the first stage, four lists of CVC words were developed, each list consist of 25 words. All these words were familiar to children in the age range of 7 years to 7 year 11 months. The recoded unfiltered words were presented to a group of twenty children in age range 7 to 8 years to check whether there was any difference between the lists. It was found that all the lists were equal in difficulty. These words were filtered using a low band-pass of 500 to 700 Hz and a high band-pass of 1800 to 2000 Hz using the Sound Edit Pro software. Filtering was done such that list one and two the low pass band was presented to the left ear and the high band-pass to the right ear. List three and four were filtered so that the high band pass was presented to the left ear and the low band pass to the right ear.

In the second stage normative data was obtained for the developed Binaural Fusion Test (BFT). The test was administered on fifty normal hearing Indian children in the age range of 7 – 12 years. All the children had English as their medium of instruction for at least one year. None of the subjects had history of any neurological involvement and were initially tested to ensure normal auditory functioning prior to administering the binaural fusion test. All the subjects heard all four lists. The order in which they heard the lists was randomized to avoid a list order effect.

The responses were scored in terms of number of correct responses for different lists. The raw data was subjected to statistical analysis. The mean, standard deviation and confidence interval were also calculated for different lists across age. Repeated measures of ANOVA, two-way ANOVA, one-way ANOVA and Duncan's Post HOC test's were used to analyse the data.

The results revealed that:

1. There existed no significant effect of ear in binaural fusion test across the age ranges.
2. There existed no significant difference in the performance of males and females across age.
3. There was a significant difference between the scores across the age groups. As the age increased the performance on the binaural fusion test also increased significantly. This implied there were maturational changes till the age of 12 years.
4. While using a binaural fusion test as a clinical tool, age appropriate norms should be referred to.
5. It was also observed that there was no significant difference between the test lists. Hence, any of the test lists can be used to reduce the test time.

The results from the present study supported the findings of previous studies by Smith et al. (1972); Plakke et al. (1981); Roush et al. (1984); Windham et al. (1986); Neijenhuis et al. (2002); Stollman et al. (2004).

The developed Binaural Fusion Test has to administer on a clinical population to check its utility in these population.

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APPENDIX

BINAURAL FUSION TEST IN ENGLISH FOR CHILDREN

List I

1. Cage
2. Smile
3. Keep
4. Name
5. Will
6. Crow
7. Bird
8. Start
9. Root
10. Yes
11. Cup
12. Did
13. Give
14. Moon
15. Hole
16. Fan
17. Real
18. Teach
19. Coat
20. Shell
21. Gum
22. Soup
23. Ten
24. Match
25. Bowl

List II

1. Nine
2. Ride
3. Chair
4. Dress
5. Join
6. Fish
7. Voice
8. Him
9. Loud
10. Hunt
11. Pen
12. Raw
13. Save
14. Bath
15. Take
16. Dog
17. Wife
18. White
19. Frog
20. New
21. Rose
22. Long
23. Class
24. Hit
25. Rest

APPENDIX

BINAURAL FUSION TEST IN ENGLISH FOR CHILDREN

List III

1. Van
2. Guess
3. Sell
4. Please
5. Note
6. Tell
7. Nice
8. Road
9. Pig
10. Jar
11. Neck
12. Live
13. Dish
14. Smooth
15. Comb
16. Choice
17. Make
18. Talk
19. Well
20. Cap
21. Done
22. Home
23. Box
24. Bat
25. Rat

List IV

1. Wire
2. Gun
3. Shout
4. Thin
5. Youth
6. Fix
7. Close
8. Ring
9. Wheat
10. Case
11. Key
12. Rain
13. Team
14. Fat
15. Bad
16. Drop
17. Front
18. Hurt
19. Love
20. Chain
21. Neat
22. Duck
23. Shirt
24. Star
25. Had