# A DICHOTIC CV TEST : NORMATIVE DATA ON CHILDREN

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**DISSERTATION SUBMITTED AS PART FULFILLMENT OF FINALYEAR M.Sc. (SPEECH AND HEARING) TO THE UNIVERSITY OF MYSORE, MYSORE**

**ALL INDIA INSTITUTE OF SPEECH AND HEARING**
**MYSORE 570 006**
**MAY 1996**

# MA AND BAPI

## Bhai and Mitu

# CERTIFICATE

This is to certify that that this Dissertation entitled

A DICHOTIC CV TEST: NORMATIVE DATA ON CHILDREN,

is the bonafide work in part fulfillment for the

Final Year M.Sc, (Speech and Hearing) of the student with

Registration No.M9411.

Dr(Miss)S.Nikam
Director
All India Institute of
Speech and Hearing
Mysore 570 006

Mysore
May 1996

# CERTIFICATE

This is tocertify that that this Dissertation entitled

A DICHOTIC CV TEST : NORMATIVE DATA ON CHILDREN,

has been prepared under my supervision and guidance.

Asha Yathiraj.

**Dr. Asha Yathiraj**
**Reader in Audiology**
**Department of Audiology**
**All India Institute of**
**Speech and Hearing**
**Mysore 570 006**

**Mysore**
**May 1996**

# DECLARATION

I hereby declare that this Dissertation entitled

**A DICHOTIC CV TEST : NORMATIVE DATA ON CHILDREN,**

is the result of my own study under the guidance of

Dr. Asha Yathiraj, Reader in Audiology,

All India Institute of Speech and Hearing. Mysore

and has not been submitted earlier at any University for any other Diploma or Degree.

**Reg.No.M9411**

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# INTRODUCTION

Speech is a complex process. The ability to attend to spoken conversation, to comprehend, remember, and respond appropriately involves a series of intricate process that occur automatically in most individuals. Rarely does one consider the complex succession of events that is involved in the integration of information in our brain during conversation. For effective communication to occur, the brain, through the central nervous system network, must receive, transmit, decode, sort and organize all auditory information before comprehension is achieved. This int.egration must take place in a rapid and precise manner even when background noise and other alterations of the auditory signal create interference. The anatomical network and redundancies of the auditory neural pathways work as an intricate mechanism to perform these functions (DeConde, 1984).

Central auditory processing (CAP) is the label ascribed to this neurologic phenomenon. This term is used interchangeably with other terminology such as central auditory ability, central auditory perception and central auditory function. Central auditory processing dysfunction, auditory perceptual disorder, non-sensory deficit, auditory language disorder or auditory processing problem are names used to describe the problem that some individuals experience as a result of deficiency in the above mentioned aspects (DeConde, 1984).

Central auditory processing disorder (CAPD) may be broadly defined as an impaired ability to discriminate, identify or otherwise process auditory information that cannot be attributed to impaired hearing sensitivity or impaired intellectual function (Keith and Jerge, 1990).

During the 20th century, an exponential growth in knowledge and technology has placed significant stress on each child's sensory and learning abilities. The child now needs to listen for long periods in noisy, large classrooms, remember more complex information at an earlier age and memorize not only for short durations but for long durations. As a result, reports of children with central auditory processing problems have also increased exponentially.

The assessment of central auditory processing must, thus begin with careful observation of the child, with particular attention to the auditory behaviour patterns.

When possible, an in depth history from the child's parent or guardians should be taken. Hearing evaluation to rule out peripheral hearing loss is also essential.

There are two very different approaches to test central auditory abilities. The first approach used primarily by speech-language pathologists and reading and learning disability teachers involves assessing auditory abilities, assumed by them, to be pre-requisites to language acquisition or reading skills. The tests assess the-auditory attention, auditory figure - ground, auditory discrimination, auditory memory etc. (Willeford and Burleigh, 1985).

A second and very different approach to assess auditory perceptual abilities is used by audiologists. This approach evaluates the child's ability to respond under different conditions of signal distortion and competition. The principle of the approach assumes that a normal listener can tolerate mild distortions of speech and still understand it. A listener with an auditory processing deficit will encounter difficulties with the distorted stimulus due to added internal distortion (Willieford and Burleigh, 1985). Auditory tests used in accessing developmental integrity or maturation of the auditory nervous system include Masking

Level Difference (MLD), (Hirsch, 1948), Staggered Spondaic Words (SSW), (Katz, 1962), Consonant-Vowel Identification Test, (Berlin, 1973) and many others.

Dichotic tests have been developed using both verbal (Dichotic CV Test by Berlin, 1973; Dichotic Digits Test, by Kimura, 1981) and non-verbal. The Dichotic Consonant-Vowel (CV) Test, has been reported to be an effective tool for the assessment of central auditory function and for differential diagnosis of central auditory lesion. Results of testing cortical lesion patients using CV syllables show decreased performance, contralateral to the lesion (Berlin et al. 1973;, Olsen, 1983; Speaks, 1975). The test has also been used extensively to investigate the lateralized language abilities localized in the left temporal lobe and to assess the development of central auditory processes (Hynd, Cohen and Obrzut, 1983, Oslen, 1983).

Dichotic CV tests have the added advantage of being least influenced by memory and linguistic factors (Keith, Tawfik, Katbamma, 1984). This is in contrast to the use of staggered spondaic words which may have memory factors operating, similar to the Dichotic Digit recall task. Similarly, the Dichotic Sentence task suggested by Willeford

(1978), seem to have obvious limitations in groups who characteristically have difficulties with memory for sentences and related language processing problems.

Research with paediatric tests of central auditory function accelerated in the 1980"s. Several tests have been developed for children to help identify whether the auditory system is functioning normally (Keith and Jerger, 1990) . These tests provide information on whether there is a neurologic basis for a language learning disorder as shown by reserved cerebral dominance, depressed overall performance, immature auditory receptive abilities or failure of interhemispheric transfer of information. More commonly, central auditory testing in children is used to determine the functional auditory ability. They describe a child's ability to process speech under various difficult listening conditions.

The present study aims at establishing normative data using dichotically presented CV syllables on a group of normal children. The CV syllables developed by Yathiraj (1994) was utilized. The stimuli were presented at simultaneity and different lag times.

## Purpose of the study

The tests of central auditory dysfunction must be carefully interpreted according to normative data. The Dichotic Consonant-Vowel (CV) Test, is one such test used for CAD evaluation. Norms for this test have been reported by Berlin et al. (1973) and Bryden and Allard (1973) for the Western population. No such study has been done using the Dichotic Consonant vowel (CV) syllables in the Indian population. Therefore, the present study has been taken up to establish normative data in the Indian children. This will help in the diagnosis of children with auditory perceptual problems, whose scores on the Dichotic CV Test can be compared with the norms available.

When stimuli in the Dichotic CV Test are presented to the two ears at onset asynchronies of 30-90 ms, the lagging signal of the pair is received more accurately than the stimulus presented first (Studdert-Kennedy, 1970). Because of this lagging effect, the right ear advantage is overcome when the lagging syllable is presented to the left ear (Studdert-Kennedy, 1970). The present study also aims verify if perception of CV's improve with increase in lag time from 0-90 msec, in the Indian children.

Auditory capacity, as measured by the dichotic CV test, has been found to increase systematically as a function of age in normal children (Berlin et al. 1973; Mirable et al. 1978; and Rosen, et al. 1983). This reflects the maturation of the central auditory processing mechanism. The present study, thus, focuses on any systematic increase in auditory capacity in the two groups of normal children (8-12 years and 13-17 years).

In a multilinguistic country like India, a test that could be used with individuals from various linguistic backgrounds is required. As the dichotic CV test has the least influence of linguistic factors it can be used to test children from varying linguistic background.

# REVIEW OF LITERATURE

## Introduction

Interference in the central auditory nervous system (CANS), from the cochlear nuclei to the auditory cortex in the temporal lobe, including interhemispheric pathways may result in central auditory dysfunctions. The interference can result from a lesion directly or indirectly affecting the CANS. Such lesions may be space occupying, neoplasm, degenerative disease, infections, vascular disorders, congenital neurologic deficits or acquired neurologic deficits such as that resulting from head trauma. Central auditory dysfunction can also result from minimal lesions of the CANS which cannot be detected by sophisticated radiologic and neurologic techniques.

Central auditory testing has been employed to (Silman and Silverman, 1994).

a) detect and localize the site of a central auditory lesion,

b) to identify children with central auditory processing disorders who demonstrate learning and communication problems,

c) to quantify and describe the deficit of central auditory processing in order to determine the nature of remediation,

d) to assess the benefits of educational and medical, including surgical remediation on central auditory function,

e) to determine ear dominance and hemispheric specialization for various types of auditory stimuli,

f) to examine the effects of maturation on central auditory processing.

**Principles of central auditory testing**

A majority of speech measures that assess CANS are based on the principle of redundancy expressed by Bocca et al. (1954). The acoustic properties of speech are redundant since there is normally a broader range of frequencies, greater amplitude, longer duration, better speech to noise (S/N ratio), syntactic, semantic and phonological rules of the language than is minimally required for understanding speech. Similarly, following the principle of physiologic safety (Teatini, 1970), the intrinsic or neuroanatomic pathways are normally redundant based on multiplicity of neural pathways, centers and decussations and bilateral representation of auditory system.

There are two important principles that are helpful when considering central hearing tests (Jerger, 1960).

(i) Subtlety principle
(ii) Bottle neck principle

The subtlety principle states that subtlety of the auditory manifestation increases as the site of lesion progresses from peripheral to central. At the peripheral level the presence of a lesion may be demonstrated with relatively simple tests such as pure-tone threshold measures. At more central sites, the presence of a lesion can be demonstrated only by means of considerably more subtle auditory tasks such as sensitized speech tests where the redundancy of speech is reduced by a number of means including filtering, interrupting, compression of message and so on.

The Bottle Neck Principle states that a complex auditory stimulus such as speech encounters a point of neural congestion at the eighth nerve and brain stem. While lesions at those sites markedly reduce the ability to understand speech, lesions more peripheral or central have relatively less effect on speech discrimination ability.

Table No. 1 : Diagnostic principles of intrinsic and extrinsic redundancy, (Keith, 1982).

| Extrinsic Redundancy in message | Intrinsic Redundancy of subject | Intelligibility |
|---|---|---|
| a) NORMAL | NORMAL | GOOD |
| b) REDUCED | NORMAL | RATHER GOOD |
| c) REDUCED | REDUCED | POOR |

The table No.1 shows that when extrinsic redundancy is normal but intrinsic redundancy of the subject is reduced, speech intelligibility is good. The implication is that non-distorted speech is unable to detect lesions of the CANS. Therefore, sensitized speech tests are useful for diagnostic testing.

**Assessment of Central Auditory Function**

The clinical focus of central auditory testing in adults and children have taken very different approaches. While studies of adults proceeded from the identification of central auditory lesions to functional auditory processing, studies of children developed for the identification of auditory perceptual disorders, with little documentation of the presence or locus of known central lesions.

This chapter will summarize the research on testing for lesions of the central auditory pathways of adults and on children. The various tests that have been discussed are listed and are described thereafter.

## CENTRAL AUDITORY PROCESSING TESTS

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**Hearing Evaluation to CAD Testing**

Assessment of peripheral auditory function is essential in the Central Auditory Processing Disorder (CAPD) evaluation. Pure tone - air and bone conduction thresholds, immittance testing should be carried out to rule out any peripheral hearing deficit.

There have been some evidence to suggest that persons with CAPD have an abnormal audiometric contour. The thresholds are often within defined normal limits of hearing sensitivity, yet they display a rising audiogram. Jerger et al. (1988) compared three groups of children those with auditory brain lesions, with known non-auditory brain lesions and those with suspected CAPD Average thresholds were within normal limits (better than 20 dB HL) bilaterally for all groups. Children with confirmed auditory brain lesions and suspected CAPD had thresholds significantly poorer in the low frequencies relative to those in the non-auditory brain lesion group.

The connection between the peripheral and central auditory systems is not fully understood, nor is the role of periphery in auditory perception. Typically, persons are referred for auditory assessment because they have difficulty in hearing or listening. As the complaints of those with CAPD are often similarities to those with peripheral hearing loss, many speech and non-speech tests have been adapted for the use in the evaluation of CAPD. These tests include adult tests for site of lesion and have adjusted norms for children with suspected CAPD (Jerger et al. 1988).

## A) NON-SPEECH PROCEDURES IN TESTING CENTRAL AUDITORY DISORDERS

The following provides a review of the non-speech pure tone based tests that have been used for a evaluation of the central auditory mechanism.

For the non-verbal stimuli, the data are assumed to be encoded in the cochlea and transmitted through the VIII nerve to the ipsilateral lower brain stem where it continues to the cerebral hemisphere contralateral to the ear initially receiving the data.

### (i) Pitch Pattern Sequence Test (PPST)

This test was first reported by Pinheiro in 1977 to assess pattern perception and temporal sequencing skills.

The stimuli include low (880 Hz) and high (1,430 Hz) tones of 500 ms. duration, with a 300 ms. interval between tones. The tones are presented in groups of three with six possible sequences monotically. Thirty such stimuli are presented to each ear at comfortable listening level at about 50dB at 1 KHz threshold. Three response modes are used - hummed, verbal or point. Patients with lesions in auditory cortex in either hemisphere or patients with inter hemispheric dysfunction are detected. However, they do not localize the lesion.

**PPST in children**

The children's version of the test is similar but the duration of both the stimulus and the interval are longer, (Pinheiro, 1977).

Normal listeners can respond well in all three modes (Musiek, et al. 1982). He reported that learning disabled children could hum the correct response but did poorly on verbal and pointing tasks.

This test can be used with all ages, but there is a wide scatter in performance for children younger than age seven (Pinheiro, 1978). He found a significant difference both normal and dyslexic group using the PPST.

### (ii) **Duration pattern Test (DPT)**

This test was reported by Baran and co-authors in 1987. The design of this test was similar to the PPST except that it used short (250 ms) and long (500 ms) stimuli. The subjects were required to give verbal and pointing responses. A 70% correct score was suggested as normal performance cut off score. Patients with lesions in the auditory cortex in either hemispheres or inter hemispheric lesions showed poor scores.

In 1990, Musiek et al. reported a study evaluating learning disabled college students on several central auditory processing measures and found that 'Duration Pattern Test (DPT)' to be one of the most sensitive test for this age group.

In 1991, Jerger et al. used the DPT as one of the many central auditory processing measures to evaluate an eighteen year old college student with suspected CAPD. Although the student scored within normal limits on all other tests, she had an abnormally low score on the short-long-short sequence in the left ear.

Therefore, careful examination of each pattern may provide useful information regarding the processing skills of an individual.

(iii) **Wichita Auditory Fusion Test (WAFT)**

McCrosky (1984) devised this test to evaluate temporal functioning. The test uses pairs of tonal stimuli that are gradually separated in time by milli seconds intervals, called interpulse intervals. The response required was to report if one or two tones were heard. A screening version and an expanded version of the test has been developed. Auditory fusion threshold is calculated for each ear at each frequency.

There is an age effect but no frequency effect. The younger subjects require longer time to hear the two tones.

(iv) **Psychoacoustic Pitch Discrimination Test (PPDT)**

This is a recently developed test that overcomes some of the problems of using speech material. it was developed by Blaettner et al. (1989). This test was developed to provide a measure that -

a) was not confounded by perceptual deficits inherent in the use of speech materials.

b) would detect unilateral telencephalic hearing disorders

c) would be relatively in sensitive to peripheral hearing loss

The procedure uses noise burst to assess discrimination changes in intensity and click trains to test discrimination of changes in temporal structure. The major finding was that the most prominent abnormality consisted of greater missed discrimination in the ear opposite to the telencephalic lesion. Patient group not having telencephalic auditory structure lesions performed the same as normals. An interesting observation of this study was the relation between performance on the PPDT and the particular vascular involvement. Clear differences were obtained depending on the branch of the cerebral artery involved.

Blaettner et al. (1989) showed the auditory evoked potentials (AEPs) revealed abnormal middle and/or late potentials in all cases with abnormal PPDT without the reverse being true.

### (v) Masking Level Difference (MLD)

The MLD test has been useful as a clinical tool to assess lower brain stem function (Hirsh, 1948; Willeford (1977). It evaluates the ability of the auditory system to process subtle interaural time and amplitude difference.

The stimulus most often used is a 500 Hz pure tone. The masker is a narrow band noise centered around 500 Hz. When the noise is presented to one ear and the tone to the other the listener finds the tone clearly audible. However, when the same tone is added with the noise in the second ear, the tone becomes inaudible in either ear. If the polarity of the tone to one ear is reversed, the tone again becomes clearly audible. The stimulus and the masker are thus presented binaurally for two conditions - in the first condition, the stimulus and the masker are both in phase between the earphones. In the second condition, the stimulus is out of phase and the noise in phase.

A number of listening conditions have been used to investigate MLDs. The parameters that have been manipulated have included variations of interaural phase, interaural time delay, interaural intensity ratio, interaural noise corelation and combinations of monaural and binaural listening (Schoeny and Talbott, 1994).

Specifically, the MLD is the difference in decibels between the signal level in the reference and out of phase conditions. It has been seen as a stable aspect of auditory behaviour and can be reliably measured in the clinic (Schoeny, 1968). The MLDs are greater at lower frequencies, particularly in the region of 200-500 Hz. The size of MLDs increase with the level of masking up to an effective masking level of about 40-50 dB. The MLD is greatest in the antiphasic listening condition followed by S M (signal is presented in phase at one ear relative to the other and the masker is reversed in phase one ear relative to the other). At intermediate values of phase shift from 180 to 0, the function shows a gradual decrease in the size. The effect of time delay on MLD is essentially the same as that for phase shift (Schoeny and Tatboli, 1994).

Studies by a number of investigators like Sahoeny and Carhart in 1971 have shown that certain peripheral hearing losses can have a profound effect on the size of the MLD. Conductive hearing loss can reduce MLD effect.

Quaranta, Cassano and Cervellara (1978) studied the tonal MLD in different groups of patients suffering from either hearing loss or from central nervous system disorders with normal hearing. They concluded that tonal MLD may be used as a test for the diagnosis of CAD only in the presence of normal peripheral hearing. In subjects with sensorineural hearing loss the MLD loses its diagnostic meaning.

**MLD's in the Assessment of Central Auditory Function**

Brain stem lesions have been shown to reduce or eliminate the MLD (Olsen and Noffsinger, 1976). Cortical lesions on the other hand rarely affect MLDs (Cullen and Thompson, 1976).

Olsen and Noffsinger (1976) found that high frequency and noise induced hearing loss does not affect MLD for 500 Hz Scores were decreased for Meniere's disease group. The group of patients having CNS disorders attributed to multiple sclerosis, inflammatory lesions of brain stem, cerebro vascular accidents had normal hearing according to conventional pure tone and speech testing, but attained smaller than normal MLD for 500 Hz. Therefore, MLD tests have unique value in the detection of subtle lesions of the central auditory nervous system.

## MLD in Children

**MLD can** be easily and quickly administered to children and Sweetow and Rede11 (1978) felt that it holds promise when used as a part of a test battery.

Hall and Grose (1990) found that MLD for children below 5-6 years of age was smaller than that found in adults. This was attributed not only to peripheral factors alone but was attributed to developmental differences probably related to central auditory processing.

MLDs have also been used in assessing children with learning disability. Sweetow and Reddell (1978) found reduced MLD in children suspected to have auditory perceptual problems.

Therefore, MLD with behavioural assessment will provide the clinician with a powerful approach to assess auditory function.

Concluding, the tonal tests or non-speech tests can be an important addition to a central auditory test battery. Overall, the tests show improved performance with increasing age. There appears to be no ear effect for normal subjects on these tests. Considerable variability is generally found at each age level but severely depressed scores can be considered abnormal and ear asymmetries can provide useful information (Stecker, 1992) .

**B) SPEECH TESTS**

**(1) MONOSYLLABIC PROCEDURES IN CENTRAL TESTING**

Monosyllables are commonly used for CANS testing since monosyllables represent the linguistic unit with the least extrinsic redundancy, distorting the stimulus by filtering, time compression or introducing background voice can easily affect patient performance. For dichotic tests, monosyllables are frequently chosen because of the relative ease of obtaining precise temporal alignment of the stimuli presented to each ear. As a result, a dichotic CANS test using monosyllables, presents a more difficult task than when bisyllable or sentences are employed for dichotic testing.

**a) MONAURAL CANS TESTS**

**(i) Filtered Speech**

The natural intelligibility of speech is degraded by limiting its frequency content. Such stimuli are perceived with difficulty by listeners with temporal lobe lesions.

As early as 1954, Bocca et al. developed a low pass filtered speech test to reduce the redundancy of the material. While various low pass filtered conditions have been used the low pass filtered speech test by Willeford's (1976) a cut off frequency of 500 Hz and a rejection rate of approximately 18 dB/Octave has been used most often for diagnostic purposes, some authors such as Lynn and Gilroy (1972) use a fixed sensation level of presentation. They presented the signal at 60 dB SL. However, others appear to prefer to run a performance intensity function using the filtered speech.

**Filtered Speech Test in Children**

Fancer and Keith (1984) observed that cut off frequency altered children's recognition of low pass filtered speech. They demonstrated that the use of either 750 or 1000 Hz cut off was more effective in discrimination between groups of normals and learning disabled than a 500 Hz or 1000 Hz cut off frequency.

Lynn and Gilroy (1977) reported a 74% sensitivity rating for the low pass filtered speech test (NU-6 word lists) for detecting temporal lobe lesions.

Willeford (1978) studied children from age five through ten years and adults. The most notable feature of the data was an observable age progression, which suggests that task performance improves with maturation of the central auditory nervous system. It was also noted that performance was comparable in left and right ears and that a fairly wide range of scores were obtained at all age levels, particularly for younger children.

Farrer and Keith (1981) observed that there was little overlap between the group of normal children and the group of auditory-learning disabled children on the low pass filtered PB-Kindergarten word test when the out of frequency was 1000 Hz; clear separation between the groups was not obtained at cut off frequencies of 500 or 750 hz.

Willeford and Billger (1978) reported that only 57% of their 150 learning disabled children obtained abnormal filtered speech test scores.

Ferre and Wilber (1986) reported that abnormal performance on the low-pass filtered NU-CHIPS test was obtained in approximately 92% of the 13 learning disabled children with presumed auditory impairment and approximately 24% of the 13 learning disabled children with presumed normal auditory skills.

Thus, it is evident that studies on filter speech show varying sensitivity to identifying auditory processing problems in children with learning disabilities. A difference in the methodology could account for some of this variability. Each study tends to use a different cut-off frequency and different test material. The difference in finding could also be an indication that there is considerable variability in the auditory perception of learning disabled children.

Therefore, the essential finding in filtered speech tests is that the speech intelligibility score is reduced in the ear contralateral to a temporal lobe lesion. The difference between ears should be greater than 20% to be significant (Calearo and Antonelli, 1963).

**(ii) Time Altered Speech**

Another way to reduce the redundancy of a speech signal is to alter the temporal characteristics of the signal. Speech can be temporally altered in a variety of ways. The speaker can simply talk fast, or recorded material can be played at a high speed. These are called 'accelerated speech[1]. Bocca (1958), and Calearo and Lazzaroni (1957) were the first to use recorded accelerated speech to evaluate patients with lesions of the auditory cortex. Currently, electronic time compression is used to reduce the duration of a speech signal without altering the frequency characteristics. Time reduction is usually described in terms of the percentage of temporal reduction, i.e. 30% of compressed speech refers to speech in which 30% of the signal has been removed in small units.

Beasley et al. (1972) found the recognition of monosyllables decreased gradually from normal listeners as time compression increased from 30% - 60% and that recognition was drastically reduced.

Time compressed speech has also been used to assess patients with cortical lesions. Kurdziel et al. (1976) reported reduced performance for the contralateral ears of patients with diffuse temporal lobe lesions. However, patients with discrete lesions showed normal overall performance bilaterally.

**Tine Altered Speech in Children**

Test of time compressed speech show much less conclusive results with children. They could possibly reflect methodological differences.

Freeman and Beasley (1976) presented a time compressed variation of WIPI test, in both closed and open set response format, to children with and without reading difficulties. The children with reading difficulties performed less well than the control group on at least one test condition.

Manning, Johnston and Beasley (1977) observed that chidren suspected of having central processing dysfunction performed similarly as normal children on a time compressed speech test at a 30% compression ratio. However, the scores in the former group was poorer than normal at 0 and 60% compression ratio.

Willeford (1978), studied a group of children with central auditory dysfunction using the compressed WIPI tests and Willeford Battery. He observed no apparent pattern to the test on which the failure occurs. They thus stted that children with central auditory dysfunction form a diverse group of individuals who can only be evaluated properly by a comprehensive series of tasks.

Watson and Rastatter (1985), using 50% time compression rate on learning disabled children, with normal intelligence found that they exhibited auditory processing capacity equivalent to a younger age group.

In conclusion, it has been found that central auditory lesions are best identified at 60% time compression (Kurdziel, Noffsinger and Olsen,1976). Kurdziel and co-workers (1976) found that in some brain lesions, time compressed speech discrimination scores were poorer in the ear contralateral to the lesion, whereas in other cases scores remained normal in both ears. Children studies however, showed less conclusive results.

**(iii) Speech-in-Noise**

One of the most common complaints of individuals with CAPD is the inability to process speech in a background of noise. The ability to process speech in a background of noise is tested in a variety of ways.

Baran and Musiek (1990) reported that the most common speech in noise tests use monosyllables presented at 40 dB SL with a background of white or speech noise at a 0 to +10 signal to noise ratio.

There is no one way of conducting speech-in-noise test and several variables such as speech stimuli, noise, S/N ratio and presentation types need to be standardized before using the test clinically. There are however, some commercially available speech-in-noise tests - "Test of auditory discrimination by Goldman, Fristoe and Woodcock (1974).

Abnormal scores on speech in noise tests was found to be associated with VIII cranial nerve lesion (Dayal et al. 1966; Olsen, et al. 1975) extra-axial (Dayal et al. 1966) and intra axial brain stem lesions (Morales-Gasccia and

Poole, 1972; Noffsinger, 1972) temporal lobe lesions (Olsen et al. 1975) as well as in split brain patients (Musiek et al. 1979) patients with multiple sclerosis (Fowler and Noffsinger, 1984) and learning disability (Chermak et al. 1989).

Difference scores for each group was calculated by comparing scores obtained in quiet with scores obtained in noise. A difference of 40% or more between the two conditions was considered significant (Olsen et al. 1975).

Chermak et al. (1989) in their study used eight learning disabled and eight control adults. NU-6 word list was presented along with speech spectrum noise and three different linguistic maskers. Grammatic linguistic strings, semantic anamolous strings and agrammatic strings. These maskers were chosen to evaluate the strength of the linguistic context of the noise A +12.5 dB S/N ratio was used. The results showed that the learning disabled group performed significantly poorer on all measures when compared to the control group. Both groups scored worst with speech noise masker.

**Speech-in-Noise in Children**

Conflicting reports concerning clinical application of speech in noise testing has led to poor understanding of normal performance.

Cohen (1980) in a study reported that nine year old children with PBK - in noise score (S/N = 0 dB) at or near 60% have auditory perceptual deficits. In contrast, Rupp (1983) reported that the mean PBK - in noise score (S/N = 0 dB) for normal nine year old children was 39%. Therefore, Bess (1983) noted that the reliability of speech in noise testing is a concern. Difference in scores between the ears was also noted. These could be attributed to test variability.

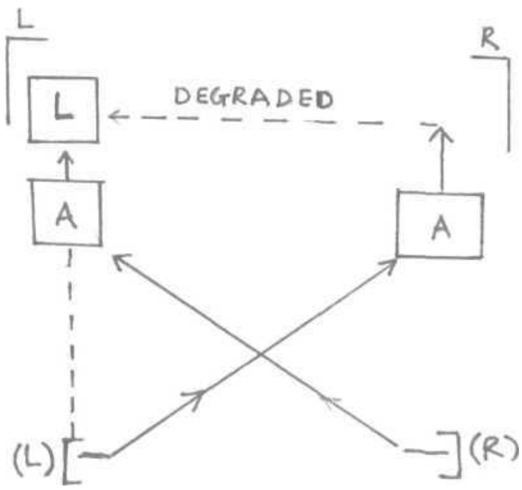
In summary, the above mentioned sensitized speech tests do not show a dominance effect in adults. Also normal individuals have equivalent scores for both ears. When a lesion of the auditory cortex is present, sensitized speech tests yield mild to moderately reduced intelligibility scores in the ear contralateral to the lesion. Brain stem lesions affect the sensitized speech scores to a greater extent than cortical lesions.

**b) Dichotic Tests**

The term dichotic refers to the simultaneous competing presentation of two different speech signals to opposite ears. Subjects are asked to repeat back what is heard in one or both ears.

Generally, when speech is presented dichotically to normal listeners, higher scores are obtained in the right than in the left. This has been referred to as right ear advantage and is believed to reflect the left hemisphere dominance for speech and language (Studdert-Kennedy and Shankweiler, 1970) .

Speaks (1975) proposed a model to account for the contralateral and ipsilateral ear effects. The model is based on the premise that the contralateral pathways are more numerous or stronger than the ipsilateral pathways. During monotic listening, either contralateral and/or ipsilateral pathways enable recognition of the stimuli. The model assumes that during dichotic listening, the ipsilateral pathways are suppressed so only the contralateral pathways contribute to recognition.




Key:

L-Left temporal lobe auditory areas.
R-Right temporal lobe association areas
(L) - Left ear
(R) - Right ear
A - Association primary

Fig:l - Ipsilateral and decussating auditory pathways to the temporal lobe and across the corpus callosum) (Speaks, 1975).

Fig.l shows the mechanism underlying the ear effect obtained in a normal hearing, non-brain damaged person for a dichotic speech test. The left ear is routed cotralaterally to the right temporal lobe where acoustic analysis and possibly pre-linguistic analysis of the speech signal occurs. The signal is then routed from the right (R) to left (L) hemisphere for further linguistic analysis As the signal is routed between hemisphere it undergoes slight degradation, so the left scores are slightly reduced.

Efron (1985) contended that the use of the hemispheric specialization model to account for the dichotic speech test results is weakened by the fact that although nearly all right handed people are left hemisphere dominant, only about 50% of normal subjects actually show right ear advantage on dichotic speech tests. Efron (1985) also commented that the hemispheric specialization model is further weakened by the fact that ear effects can be elicited with non-speech as well as speech stimuli. Some of the ear effects may result from efferent pathways from the cortex to subcortical structures rather than from degradation of the signal during interhemispheric transmission from the non-dominant to the dominant hemisphere, but this needs to be clarified by further research (Efron, 1985).

## DICHOTIC SPEECH TESTS

Kimura (1961) is credited with the introduction of dichotic speech tests into the field of central auditory assessment. Since then, several variations of the dichotic digit test, as well as several other dichotic speech tests, have been introduced. These tests have been shown to be particularly sensitive to cortical pathology, though abnormal results also have been reported for subjects with brain stem involvement.

### (i) DICHOTIC DIGIT TEST (DDT)

Kimura (1961) was the first one to use dichotic digits to study subjects with brain damage. She used three digits presented to each ear of the subject simultaneously. After the six digits were presented, the subject was asked to report all the numbers heard in any order.

Musiek (1983) reported that the dichotic digits test is highly sensitive for detecting both brain stem and hemispheric pathology. In a study of nine subjects with brain pathology and twelve subjects with hemispheric lesions, Musiek (1983) reported that eighteen showed abnormal results at least in one ear. Due to the tests apparent sensitivity, as well as the fact that it is relatively unaffected by peripheral hearing loss, the dichotic digits test has been recommended by Musiek and his colleagues as a quick and easy screening test for central auditory nervous system (CNS) dysfunction.

Shivshankar and Harlekar (1991), administered the Dichotic digits test to six subjects with confirmed intracranial lesions. Three had hemispheric lesions, one had subcortical and the remaining had brain stem lesions. The results indicated significantly abnormal performance of these subjects on the task. The test thus, seems to have clinical valve in detecting brain stem or cortical dysfunction but does not appear to differentiate the anatomical sites.

**DDT In Children**

Ling in 1971 studied ear asymmetry for dichotic digits in an attempt to estimate speech laterality in nineteen children with learning disability and nineteen normal hearing children. The normal hearing group was significantly superior to the hearing-impaired in the recall of both monaural and dichotic digits. No ear advantage was observed for either group on the monaural test. Right ear dichotic scores were significantly superior for the normal hearing group but intersubject variability resulted in a non-significant right ear trend for the hearing-impaired group, with individuals showing marked right or left ear advantage. It was concluded that speech lateralization could not safely be inferred from dichotic digit scores of hearing-impaired children.

Pettit and Helms (1979) explored language dominance by administering the Dichotic Digit Test to ten language disordered, ten articulatory disordered and ten normal children. A significant right ear preference was found for the control and articulatory disordered groups, but no significant ear preference was found for the language disordered group.

Musiek (1983) developed a modified version of this dichotic digits test, here, two instead of three pairs of digits were delivered to the two ears simultaneously. Forty such pairs were delivered. The presentation level was 50 dB SL relative to the SRT. Musiek (1983) reported that the dichotic digits test was highly sensitive for detecting both brain stem and hemispheric pathology. Subjects with normal hearing typically score above 90% and subjects with peripheral hearing loss 80% and above. Scores below 80% suggested that further CANS testing was indicated.

Morton and Siegel in 1991 studied twenty reading comprehension disabled (CD) and twenty reading comprehension and word recognition Disabled (CWRD). These subjects were matched with twenty normal achieving age matched controls. When tested on dichotic listening tasks using digits, both reading disabled groups showed lower left ear scores in digits when compared to the normals.

(ii) **Dichotic Consonant-Vowel (CV) Test**

The dichotic consonant-vowel (CV) test was developed by Berlin (1972). It is considered a more difficult task as compared to the dichotic digit test (Niccum et al. 1981).

Dichotically presented CVs have an apparent advantage over digits, in that, alignment of acoustic energy is relatively simple because of the high degree of similarity among the syllables. This allows a more simultaneous presentation than is possible for digits, reduces linguistic value of the CV task and maximizes the acoustic and phonetic competition (Berlin and McNeil, 1976). The dichotic CV task also relies less heavily on short term memory than the digit test in which as many as six digits must be remembered. It is likely that these two dichotic tests measure slightly different perceptual processes (Mueller and Bright, 1994).

The material consists of six stop consonant-vowel syllables (pa, ta, ka, ba, da, ga). They may be presented simultaneously to both ears such that the onset of the vowels to one ear lags behind the onset of the consonant-vowels to the other ear by 0, 15, 30, 60 or 90 ms.

Berlin et al. (1973) and Olsen (1983) have reported that normal subjects show an, impairment in scores with lag time of 30 to 90 msec, when compared to the scores obtained for simultaneous presentation. Similar improvements in scores have not been seen in patients with temporal lobectomies.

Olsen (1983), administered the dichotic CV test on patients with anterior portion of either the left or right temporal lobe removed. He reported a wide range of performance for normal listeners and over 40% of the temporal lobe patients obtained scores that fell within normal limits.

**Dichotic CV test in Children**

Auditory capacity on dichotic CV test has been found to increase systematically as a function of are in normal children in a study by Berlin et al. (1973). Rosen et al. (1983) studied thirty two normal children with mean age 6.6 years (5-8 years) once each year for 4 years. They used dichotic CV syllables at different temporal offsets. Results showed no significant change in ear laterality over the 4 years. However, there was a significant age related increase in auditory capacity. None of the subject groups showed a significant lag effect. With respect to right ear advantage, Bryden (1970) and Thompson (1976) suggested that children with learning disability have diminished or non-existent right ear advantage. However, Tobey et al. (1979) found significant right ear advantage for two groups of learning disabled children with severe auditory perceptual problems. Auditory capacity studied by Dermody (1976) and Tobey et al. (1979) has shown that this measure is significantly reduced in LD subjects. This difference could be attributed to procedural variations and also the analysis of the data.

Dermody (1976) studied LD children on the dichotic CV test. He concluded that the LD children perform less efficiently on the dichotic task than do normals. On the single response the performance of the LD group is quantitatively and qualitatively similar to the performance of the normals. He also reported a difference in terms of voiced - voice less distinction between the two groups.

Hynd, Cohen and Obrzut (1983), suggested that lateralized language capabilities exist in normal children from age 6-12. Significantly it seems as though these lateralized language asymmetries do not develop after age six.

Dermody, Mackie and Katsch (1983) studied the dichotic listening performance using CV pairs in a group of 30 children, 15 good readers and 15 poor readers. The results indicate similar laterality and phonetic processing effects in both good and poor readers. There was however a significant difference in their ability to identify both items on a dichotic trial correctly. However, when the same stimuli were presented monotically, there was no difference in the performance of the two groups.

Morton and Siegel (1991) studied reading comprehension disabled (CD), reading and word recognition disabled (CWRD) matched with normal achieving age controls. They concluded that on the consonant-vowel test, the CD group showed a high left ear report but only when there was no priming precursors such as direction to attend to right first. The children in the study did show an attentional priming effect on the consonant-vowels. The right ear response was lower for subjects directed to report what was heard at the left ear first . Presumably, this was due to the difficulty in shifting to the right ear in those directed to the left fist.

Therefore, concluding, when a temporal lobe lesion is present, there is a severe loss of dichotic speech information in the ear contralateral to the lesion. The normal advantage of lagging message is also lost.

(iii) **Dichotic Rhyme Test**

The dichotic rhyme task was introduced by Wexler and Halmes (1983) and identified by Musiek et al. (1989). it is composed of rhyming pairs of consonant - vowel - consonant (CVC) words that begin with one of the stop consonants (p, t, k, b, d, g). Each pair of words differ by the initial consonant (e.g. bill-pill, ten-pen etc.).

Musiek et al. (1989) have collected normative data for the dichotic rhyme test as well as preliminary data for split brain patients. They found the left ear scores in the split brain patients were significantly lower than normals and the right ear scores were enhanced.

Dichotic rhyme test may be uniquely suited to assess split brain patients or hemispherectomy patients because of the relatively low scores obtained by normals on this test (near 50%).

**OTHER MONOSYLLABIC TEST FOR CHILDREN**

**(i) SCREENING TEST FOR AUDITORY PROCESSING DISORDERS (SCANS):**

SCANS, was developed by Keith in 1986, is a screening test of central auditory nervous system dysfunction for children aged 3-11 years. The purpose of SCANS was to provide preliminary information about a child's maturation and auditory processing abilities, to identify children at risk for auditory processing problems and to identify children who might benefit from intervention to improve auditory learning abilities.

SCANS is a taped test that consists of 3 subtests - (a) low pass filtered words, (b) auditory figure - ground, (c) competing words. Both filtered word and figure ground subtests were included to identify problems that might occur due to poor listening environments. The competing words subtests was included to provide information about the maturation of a child's auditory system.

In a study comparing SCANS to several other CANS and language tests, results from the competing words subtests of the SCANS co-related highly with the Staggered spondaic Word (SSW) and the competing sentences subtests (Keith, 1989).

C) **SPONDAIC WORD TESTS IN CENTRAL TESTING**

Some audiological tests of the central function make use of spondaic words. Two well known tests are the -

(i) Binaural Fusion (BF) procedure
(ii) Staggered Spondaic Word (SSW)

Spondees are two syllable words of equal stress on each syllable (e.g. base ball, cowboy). Spondees rise rapidly **in** intelligibility with small increase in intensity, therefore they are ideal for the measurement of speech thresholds. Beyond 10 dB SL the percent of words that are correctly identified remains fairly constant.

(i) **Binaural Fusion Test- (BF) Test**

The BF test was developed by Matzker (1959). The listener was required to combine the high frequency band portion of the message that was presented to one ear with the low frequency band portion that was directed to the other ear. Matzker indicated that the BF test evaluated the brain stem fusion mechanism.

Miltenberger et al. (1978) concluded from their study that the BF test could be administered on persons with sensori-neural hearing loss as long as the audiometric results were considered.

Researchers such as Matzker (1959), Liden (1969) and others in their study with adults showed that the test to be sensitive to CNS lesions.

**BF test in children**

Ivey (1969), as a part of the Willeford Battery for Children, presented spondee words such that a low frequency band width segment (500-700 Hz) was presented to one ear and simultaneously a high frequency band segment (1900-2100 Hz) of the same word to the opposite ear. Inability to resynthesize was indicative of upper brain stem dysfunction, performance between ears should be equal by nine years.

Nalsh et al. (1980) was the first to apply BF test to children having difficulty in school. He found that 79% of the LD children failed the BF test in one or both ears. Ivey (1986) found that 49% of the children failed the BF in one or both ears. Poor scores may be due to a failure **of** the binaural mechanism of the brain stem or to the difficulty discriminating words having reduced redundancy which may be due to a left hemisphere deficit (Dempsey, 1977).

**(ii) The Staggered Spondaic Word Test (SSW)**

Staggered Spondaic Word Test (SSW) was developed and standardized by Katz (1962, 1963, 1968) and described further by Arnst (1982). It has been used for localizing the site of dysfunction in cases with suspected brain or brain stem lesion (Katz (1962) .

The SSW is a dichotic listening test of central auditory function. It uses as an acoustic stimulus, familiar spondee words that are partially overlapped to provide both non-competing and competing words to each ear. The first spondee is presented to one ear while the second spondee is presented to the second ear with sufficient delay to overlap competing portions of the words. In this way individual scores are obtained for the four conditions : right ear competing (RL), right non-competing (RNC), left competing (LC) and (L) non-competing (LNC). Two quantitative measures are obtained : the raw SSW score and the corrected SSW score. The raw score is the percentage error for any one of the four test conditions (RNC, RC, LC, RNC). The corrected SSW (C-SSW) is obtained by subtracting the percentage error that a subject obtains on a standard speech discrimination test from the respective R-SSW score. Additional information is obtained from the SSW response biases. These are order effect, ear effect, reversals and they signify idiosyncracies in the manner of response.

The features that make SSW test especially useful, includes -

(a) its resistance to the influence of peripheral hearing distortion (Katz, 1968; Cafarelli, et al. 1977; Arnst, 1980),

(b) its simplicity which makes it applicable to a wide variety of age (Brunt, 1965; Ammerman and Parnell, 1980) and disordered population,

(c) coherent normative data to evaluate individuals from 5-70 years of age,

(d) evidence of strong reliability and validity (Katz and Arndt, 1982 and others).

## SSW In Children

Myrick (1965) assessed the performance of normally functioning children aged 7-11 years and an adult control group on the SSW test. It was found that the errors decreased with increasing age. In addition she found that the scores approximated adult scores by 11 years of age. The data also showed superiority of right ear performance over left ear performance from age 7-11 years the discrepancy decreasing with increasing age.

Stubblefield and Young (1975) compared the SSW performance of normally achieving with children having learning difficulties. They found significant difference in performance between the groups.

Johnson et al. (1981) found that the number of errors decreased with age for both normals and learning disabled children.

In conclusion, the SSW test has been predominantly used with adults in the investigation of cortical lesions (Katz, 1962; Katz et al. 1963). The test is also being used frequently with children. In general, children show a superior performance to the stimuli presented to the right ear. Katz also describes a maturation effect. Children improve at the task between six and eleven years, and the test variability reduce with increasing subject age.

D) **SENTENCE PROCEDURES IN CENTRAL TESTING**

Sentence type materials have been used clinically for the purpose of identifying site of lesion in adult patients who have sustained damage to the brain. Sentence tests have also been used to confirm the presence and determine the nature of central auditory processing difficulties primarily involving children.

### (i) **Synthetic Sentence Identification Test (SSI)**

Sentences were systematically altered from the standard rules of grammar and syntax and were developed into a test to serve as an adjunct to standard speech audiometry (Speaks and Jerger, 1965) . The rationale for using this technique was to benefit from the sentence structure, a rapidly changing acoustic pattern with time. Both the limited meaningfulness of the sentences and the use of a closed message set response mode reduced the dependence on linguistic and memory skills. Thus, in this procedure, one would need only identify which of the ten sentences was present (Speaks, et al. 1968). When the sentences and the competition were directed to opposite ears it was referred to as contralateral competing message (CCM) and when both the sentences and the competition were presented to the same ear, it was termed ipsilateral competing message (ICM).

Jerger and Jerger (1974) used SSI test with patients with intra-axial brain-stem lesion cases. In contrast to the poor performance on the ICM procedure, on the CCM the brain stem patients had relatively little difficulty.

Jerger and Jerger (1975) showed that in temporal lobe lesions, subjects failed in both the ICM and CCM conditions.

In general, brain stem cases have relatively more difficulty on the ICM task than on the CCM whereas the opposite is true for the temporal lobe.

Normal performance on SSI-CCM was found to be 100%. For SSI-ICM, the scores ranged from 100% to about 20% with increasing competition (Jerger, 1975).

**SSI in Children**

Jerger, Speaks and Trammel (1968), gave the SSI as a part of the Willeford Battery for Children. Here, linguistically constructed non-sense sentences interspersed periodically as the primary message and a continuous speech discourse (Barry Crockett Story) as the competing message. The stimuli were presented at 0, -10 and -20 dB message to competition ratios. When presented contralaterally, it assessed cortical function, ipsilateral presentation assessed brain stem function scoring was based on the average of three message to competition ratios. Performance between the ears was equalled by ten years.

SSI appears to be sensitive to maturation effect (Orchik and Bergess, 1977). Deckes and Nelson (1981) tested six groups of six subjects each (8-25 years) with the SSI-ICM. Test scores improved in successive age groups. Therefore they recommended that normative data he established in make SSI-ICM a useful test for children.

The limitation of the SSI is that it the SSI makes use of a visual as well as auditory tasks. This might penalize adults who have reading impairments, or those who have visual handicaps. Its use would also be precluded for younger children with under-developed reading skills.

To remediate these problems a number of modifications to the SSI have been proposed by a number of researchers. Speaks (1975) suggested that the subject repeat the stimulus. This makes scoring much more difficult. Martin and Mussell (1979) observed that the Davy Crockett story that serves as competition for the synthetic sentences contain pauses which enables sentence identification because of unopposed word (s). They used a speech noise to fill the pauses. Blattie and Cark (1982) replaced the Davy Crockett story with four talker babble.

### ii) **Paediatric Speech Intelligibility Test for Children**

PSI was developed by Jerger and Jerger (1984) specifically for children is a modification of SSI. The PSI consists of monosyllabic word and sentence materials composed by normal children between three and six years old. Testing is carried out by presenting a sentence or word target and requiring the child to point to the picture corresponding to the sentence or word that was heard. The basic procedure of PSI test are performance intensity functions and message to competition ratio (MCR) function.

Jerger (1987), Jerger and Zeller (1989) and Jerger et al. (1988), on studying ten children with lesions in areas of the brain anatomically remote from auditory nuclei and pathways indicated that the MCR component of the PSI test accurately distinguished between children with central auditory versus non-auditory central nervous system lesions. All children with CNS lesions in the areas of the brain, important for auditory perceptual function (cochlea nucleus, superior olivary complex, lateral lemniscus, inferior-colliculus, median geniculate body, temporal lobe or corpus callosum) had abnormal PSI results. Children with non-auditory CNS lesions consistently had normal PSI performance. It was also found that abnormal findings were obtained for the PSI-CCM (SPI-contralateral competing message) but not for PSI-ICM (PSI-Ipsilateral competing message). The investigators suggested that the central auditory processing disorder was auditory rather than linguistic in nature.

Therefore, the preliminary reports of the results for children with confirmed or suspected central lesions suggest that the PSI is able to distinguish between children with central auditory lesions and those with non-auditory central lesions (Jerger, et al. 1988) .

(iii) **Competing Sentence Test**

Willeford (1968) developed the competing sentence test (CST) to evaluate central auditory function. The test was first described by Ivey (1969) . It was developed to avoid dependence on the identification of highly transient single word, particularly monosyllabic words. Another reason was to simulate language constructions that might occur in daily life. An effort was made to select a level of language that did not penalize children, persons with low intelligence or patients with reduced physical well-being.

The CST items consists of paired sentences, concerning time, weather or other common themes. The two sentences are presented simultaneously one to each ear. The primary message is at 35 dB SL and the competing at 50 dB SL (Ref. PTA).

Ivey (1969) standardized 25 pairs of CST sentences using normal hearing adults. The 'signal' message was to be reported and the "competing' message ignored. The original test was subsequently shortened to two tests of 10 competing sentence pairs. This was based on the findings with clinical patients that only ten items were needed to identify adult patients. Five more items were used to assess the patient's ability to repeat both messages. Lynn and Gilray (1977) found that normal hearing adults scored 100% in each ear.

CST has been used widely with adults and children with neurologic lesions. Lynn and Gilroy (1975) tested patients with tremors in the posterior region of the temporal lobe. Scores were seen to be slightly poorer in the ear contralateral to the brain lesion for both dichotically and monotically degraded speech procedures.

**CST in Children**

Willeford and Billger (1982) developed the Ipsilateral-Contralateral Competing Sentence Test (I-C/CST) as a part of the Willeford Battery. They simultaneously presented sentences of similar content in contralateral mode (-15 dB message to competition ratio), ipsilateral mode (equal or -5 dB message to competition ratio) and binaural mode (equal message to competition ratio) utilizing male vs. female voice. Contralateral mode assess cortical function, ipsilateral mode - the brain stem function.

Children's norms reflect quite a different pattern of results. Subjects 5-10 years old generally score 100% on one ear, usually the right ear. The other ear may score any where from 0-100%. Thus normal children show a strong ear and weak ear. However, the scores in the weak ear improve progressively with increasing age until 8-10 years. When disparity between the ears is not achieved by that age or when strong ear score is less than 90%, the results are considered clinically significant (Lynn and Gilroy, 1976-1978).

(iv) Rapid Alternating Speech Perception (RASP)

This test developed by Bocca and Calearo (1963) is not commonly used. It makes use of sentence material which are switched at periodic intervals between the two ears, each ear receiving atlernate bursts of unintelligible spoken messages in a sequential manner.

Lynn and Gilroy in (1977) reported low scores in low pons lesion but patients with lesions of the 8th nerve, upper brainstem and unilateral cerebral areas had little difficulty.

Willeford and Billger (1978), using a 30 dB SL presentation level, have found abnormal results on this test in only a small percentage of the children with central auditory processing disorder whom they evaluated. The test is easily administered to children and is a generally enjoyable task for them, but in its present form it is not one of the more sensitive test for children with CAPD.

In summary, the tests discussed above and other behavioural and physiologic tests can be used in an audiologic test battery to aid identification of lesions of the CANS. It is difficult to say as to which of the tests are most sensitive.

Lynn and Gilroy (1977) compared the results of undistorted speech tests, low pass filtered tests, SSW and competing sentence tests on patients with temporal and parietal lobe lesions. They reported that the competing conditions of the SSW and low pass filtered tests appear to be the most sensitive for identifying temporal lobe lesions.

Musiek (1983) compared three dichotic tests competing sentences, staggered spondaic words and dichotic digits. The Dichotic Digits Test appeared most sensitive, followed by SSW test and competing sentences. All three tests demonstrated greater ipsilateral ear deficits for subjects with brain stem lesions, however for hemispheric lesions all tests showed poorer contralateral to the lesions.

Therefore, a test battery approach (Willeford Central Auditory Processing Battery) is recommended, as it assesses the overall integrity of the central auditory system. In the battery of tests, the child's or adult's ability to perform auditorily under different conditions of signal distortion or competition is assessed (Keith, 1981). Due to the complexity and redundancy of the central auditory system, the tests assess both brain stem and cortical functioning within the brain. The results must be carefully interpreted according to normative data and if this is not available interpretation is difficult (Lass, 1982).

## METHODOLOGY

### SUBJECTS:

The subjects for the study were a group of 50 normal children- 25 boys and 25 girls in the age range of 8-17 years (Table-2).

Table-2: Age and sex breakup of the subjects

| | Age (years) | No.of subjects | Males | Females |
|---|---|---|---|---|
| Group - 1 | 8-12 | 25 | 12 | 13 |
| Group - 2 | 13-17 | 25 | 13 | 12 |

To be selected as subjects, they were required to fulfill the following criteria :

(a) Should be right handed
(b) Should have normal IQ
(c) Should have no history of ear infection, head trauma or known neurological disorders.
(d) Should have pure tone thresholds of less than 15 dB for frequencies 250 Hz through 8 KHz and 250 KHz to 4 KHz for air conduction and bone conduction respectively.

(e) Speech reception thresholds were required to co-relate with pure tone average. This was established using either, the W-22 word list in English (Hirsh, 1964) or the Kannada version developed by Rajshekhar (1976). Depending on the language the subjects were familiar with they were administered either the Kannada or the English SRT test.

(f) On the PB-max (Mayadevi, 1974), the subjects were required to have a score of 90% and above.

(g) On a monaural presentation of the CV syllables (single track of the dichotic CV test) a score of 80% and above was taken as a criteria for selection. This score had to be obtained in both ears. This was done to confirm absence of any peripheral hearing loss.

A teacher's report of no reading or writing difficulties was also taken as a criteria for selection of the subjects.

**TEST MATERIAL** :

Consonant-vowel (CV) syllables (pa, ta, ka, ba, da and ga) was recorded by Yathiraj, (1994)* on two tracks using a

*Yathiraj, A. (1994), Developed the Dichotic CV test at CID St.Louis, USA.

**INSTRUMENTATION :**

The preliminary tests were done using a clinical audiometer Madsen OB 822 which was coupled to a TDH-39 earphones housed in MX-41/AR ear cushions, for air conduction. Bone conduction testings were done using RADIO EAR B-71 BC vibrator.

For the dichotic test, an audio cassette tape was played on the tape recorder (PHILIPS AW 606) the output of which was fed to the tape input of a clinical audiometer (Madsen OB 822). The output of the audiometer was given through the TDH-39 ear phones housed in MX-41/AR ear cushions (Fig.1)

The audiometer was calibrated to conform to ISO standards [ISO 1983] . Frequency and intensity calibration for air conduction and bone conduction measurements were carried out.

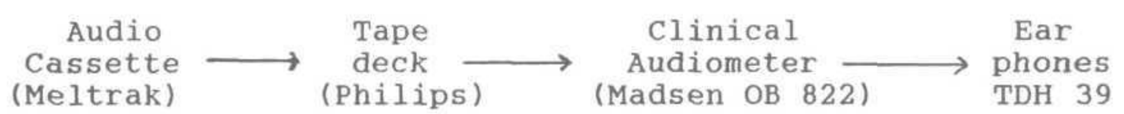



Fig. 1:Block diagram of instruments used for the dichotic CV test.

computer software program "Sound Ed. Pro.", at CID, St. Louis.

The recording contained 30 dichotic presentations in all combinations of CV syllables, in each of the five different onset asynchronies i.e. -

a) At 0 ms (Simultaneous presentation of stimuli to both the ears).

b) At 30 ms (R) lag (Stimulus to the right ear presented 30 ms. after the presentation of stimulus to the left ear).

c) At 90 ms. (R) lag (Stimulus to the right ear presented 90 ms. after the presentation of stimulus to the left ear)

d) At 30 ms (L) lag (Stimulus to the left ear presented 30 ms. after the presentation of stimulus to the right ear).

e) At 90 ms. (L) lag (Stimulus to the left ear presented 90 ms. after the presentation of stimulus to the right ear).

A 1 KHz calibration tone was recorded before each list for the VU meter calibration. The output of the computer was recorded on to an audio cassette. The five lists were randomized using a statistical random Table (Maharajn, 1990) to form two sets. These two sets were recorded separately on an audio cassette (MELTRAK) using a tape deck (SONY FH 411 R). Each set contained all the five lists.

## PROCEDURE :

Testing was performed in a two room, sound treated suite. Those subjects who passed the subject selection criteria were administered for the dichotic CV test. The dichotic test was administered at 70 dB HL. The two sets were administered on the subjects randomly, such that, twenty-five subjects were tested using set-I and twenty-five subjects using set-II. The subjects were asked to report both the syllables that had been presented on each dichotic trial. The responses were marked on a multiple choice score sheet (Appendix-A).

## SCORING :

The responses were scored in terms of single and double correct responses. The single correct response refers to a correct response in any one ear (left ear or right ear), and the double correct response refers to a correct response in both ears.

The scores were statistically analyzed using mean (M), standard deviation (SD) and the t-test.

# RESULTS AND DISCUSSION

The results obtained from the present study have been reported in this chapter and these results have thereafter been discussed. The statistical methods used to obtain the results were mean, standard deviation and range. The t-test was also used to find out whether the difference between the different parameters analyzed, was significant or not. Analysis was done to obtain -

1) **SINGLE CORRECT SCORES**

Single correct score refers to a correct response in either left or right ear. This was done at -

a) simultaneity (0 ms)
b) different lag times (30 ms. and 90 ms.) for each ear

2) **DOUBLE CORRECT SCORES**

Double correct score refers to a correct response of a subject to both the right and left ear for each stimulus presentation. This was also evaluated at :

a) At simultaneity ( 0 ms.)
b) At different lag times (30 ms. and 90 ms.) for each ear.

3) **AGE RELATED CHANGES**

The effect of age on the performance of the two groups (8-12 years and 13-17 years) was compared.

## SINGLE CORRECT SCORES

### i) **AT SIMULTANEITY**

Table-I : Mean, Percent Correct Scores Range and Standard Deviation and t-scores at simultaneity (0 ms. Lag).

| 0 ms. lag | Right | Left |
|---|---|---|
| Mean | 17.56 | 14.50 |
| % correct | 58.53 | 48.33 |
| Range | 9-27 | 8-21 |
| Standard Deviation | 3.72 | 3.77 |
| Average Correct % | 53.43 | |
| t-Score | 4.13 | |
| Significance | 0.01 | |

Max. Score - 30

Table-I represents the mean, percent correct scores, range, standard deviation and t-scores with level of significance at simultaneity (0 ms. Lag).

As seen in Table I scores at simultaneity for the right and left ear, for the normal children, was found to be 17.56 (58.53%) and 14.50 (48.33%) respectively. The score that was arrived by averaging the single correct responses for right and left ear was 16.03 (53.44%). The range of scores in the normal children was also calculated (Table-I) and was found to be 9-27 (30% - 90%) for the right ear and 8-21 (26.6% - 70%) for the left ear.

The results of the single correct responses at simultaneity reveals that there is a distinct right ear advantage. The right ear advantage was found to be statistically significant at the 0.01 level, on the t-test (Table-I).

The percent correct score at simultaneity is similar in magnitude to other studies who also used dichotic CV syllables. Bryden and Allard (1973) found the average correct for kinder garten and second grade children to be 50%. Berlin et al. (1973) found the average percent score for children between 5-13 years to be between 55-60%.

The agreement in scores in the Indian population when compared to the western norms, throws light on the universality of the test and that it can be used with children from different linguistic background.

The results obtained in the present study showing a distinct right ear advantage at simultaneity, correlates with studies quoted in literature (Studdert-Kennedy and

Shankweiler, 1900; Berlin et al. 1973 (Olsen, 1983)). The right ear advantage at simultaneity reflects the prepotency of the crossed neural pathways from the right ear to the language dominant left hemisphere (Kimura, 1961). Since the auditory system has a strong contralateral pathway (Rosenzweig and Rosenblith, 1953) and since most people are left brained for language, independent of their handedness (Penfield and Roberts, 1959), we would expect that most people would show a right ear dominance in simultaneous listening tasks. When normal hearing listeners attend to dichotic simultaneous speech, both ears are suppressed relative to their one channel, monaural performance. The right ear may simply perform better during competition and its pathways may suppress competition more effectively than those from the left ear.

In the present study, the right ear was found to obtain an average of 10% higher score than the left ear. This right ear advantage has been supported by many investigators. Berlin et al. (1973) reported a right ear advantage of about 14%. Studdert-Kennedy and Shankweiler (1970) also reported a right ear advantage of a similar magnitude. In a study by Olsen (1983), normal subjects yielded a right ear advantage of 10% difference between ears. Children tested using directed ear instructions yielded a right ear advantage (REA) whether listening with right ear or left ear (Hynd, et al. 1983). Dermody et al. (1983), also supported the view of right ear advantage in both groups of good and poor readers.

The findings in the present study is thus comparable with findings of individuals from different linguistic and cultural backgrounds.

Dichotic competition always does not reveal a right ear advantage in all subjects. In the present study five (10%) out of the fifty subjects selected for the study exhibited a left ear advantage at simultaneity. However, the left ear scores were not found to be significantly higher when compared to the right. Studdert-Kennedy and Shankweiler (1970), also reported that four out of twenty-four subjects who showed a left ear advantage at simultaneity.

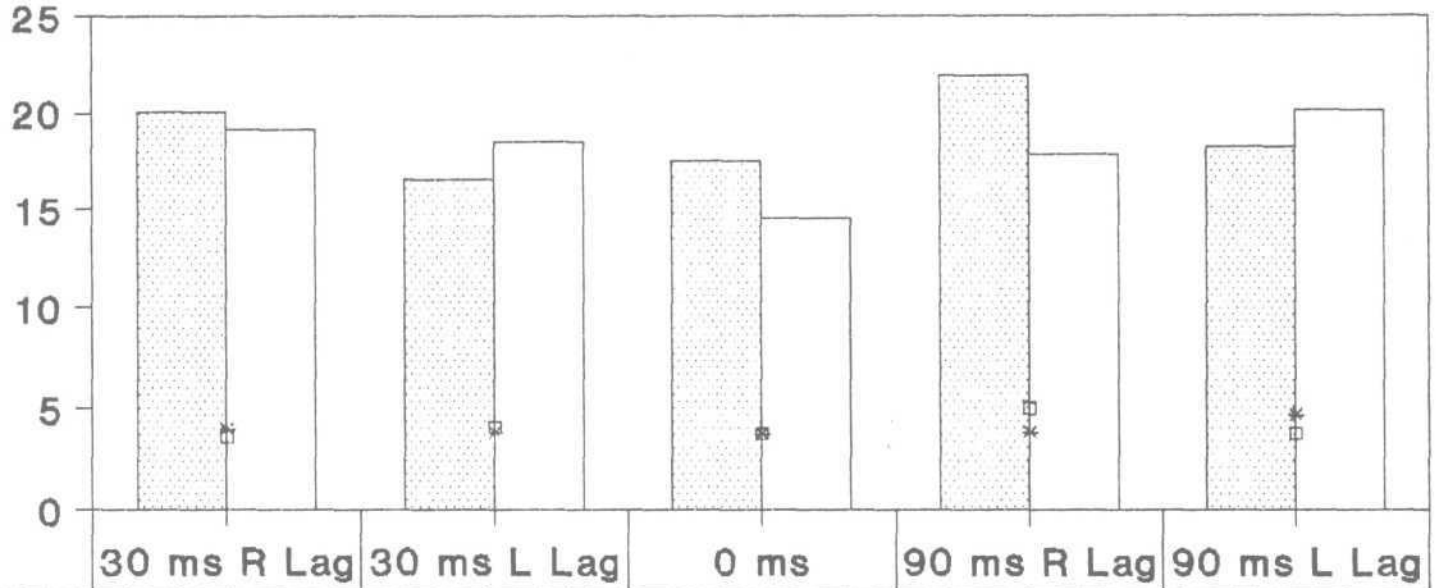
Therefore, in the normal Indian children in the age range of 8-17 years, on the dichotic CV test, an average score of 53.43% and a range of 28% to 71% can be considered as norms. In addition with the exception of a few right handed individuals with LEA, a right ear advantage seen in the normals on the dichotic listening task is a reflection of the left hemisphere's dominance for speech perception and related functions (Studdert-Kennedy and Shankweiler (1970), Kimura (1961). This is because the left anterior lobe is closer than the right temporal lobe, to the left primary speech areas, therefore transmission loss is less on the basis of proximity (Berlin et al. 1973).

**SINGLE CORRECT SCORES AT DIFFERENT LAG TIMES**

Table-II : Mean, Percent correct, Standard Deviation, and t-scores at different lag times.

| | | Mean | | S.D. | Range | t-scores | Significance |
|---|---|---|---|---|---|---|---|
| 30 ms. R Lag | R | 20.04 | (66.80%) | 3.98 | 19-27 | 9.32 | 0.01 |
| | L | 19.14 | (43.80%) | 3.54 | 5-20 | | |
| 30 ms L Lag | R | 16.60 | (54.33%) | 3.85 | 10-26 | 2.48 | 0.01 |
| | L | 18.54 | (61.8%) | 4.07 | 11-25 | | |
| 90 ms. R Lag | R | 21.88 | (72.93%) | 3.81 | 13-29 | 4.64 | 0.01 |
| | L | 17.84 | (54.46%) | 4.93 | 9-29 | | |
| 90 ms. L Lag | R | 18.28 | (60.93%) | 4.64 | 7-27 | 2.21 | 0.05 |
| | L | 20.14 | (67.13%) | 3.78 | 13-29 | | |

Max. score possible = 30
R - RIGHT EAR SCORE
L - LEFT EAR SCORE



| | 30 ms R Lag | 30 ms L Lag | 0 ms | 90 ms R Lag | 90 ms L Lag |
|---|---|---|---|---|---|
| R Lag | 20.04 | 16.6 | 17.56 | 21.88 | 18.28 |
| L Lag | 19.14 | 18.54 | 14.5 | 17.84 | 20.14 |
| Rt SD | 3.98 | 3.85 | 3.72 | 3.81 | 4.64 |
| Lt SD | 3.54 | 4.07 | 3.77 | 4.93 | 3.78 |

Graph-I : Mean and Standard Deviation at different onset asynchronies for single correct responses.

The Table-II represents the mean, percent correct scores, standard deviation and range at the different onset asynchronies for the single correct responses. The t-scores have also been depicted for the right and left ear along with their levels of significance.

1: is a graphical representation of the mean and standard deviation at simultaneity and at different lag times for the single correct response.

On analyzing the data using mean, standard-deviation and the t-test, it was found that maximum scores were obtained when the stimuli were presented simultaneously to the two ears (0 ms.). Scores were seen to improve with increase in lag time from 30 ms. lag to 90 ms lag. Maximum scores were obtained at 90 ms. lag. It was also found that the scores in the lagging ear was significantly better than the leading ear.

**RIGHT EAR LAG**

Table-II depicts the left ear and right ear scores at different onset asynchronies, when the lag is given to the right ear. A statistically significant difference between the right and left ear scores was seen at 30 ms. R lag and

90ms. R lag, the difference being significant at 0.01 level of significant.

Table-III : Percent score and t-scores comparing right ear Lag scores.

| Right ear Lag | % scores | t-scores | Significance |
|---|---|---|---|
| 0 ms. R Lag vs. 30 ms. R Lag | 58.53% 66.80% | 3.26 | 0.01 |
| 0 ms. R Lag vs. 90 ms. R Lag | 58.53% 72.93% | 5.83 | 0.01 |
| 30 ms. R Lag vs. 90 ms. R Lag | 66.80% 72.93% | 2.38 | 0.05 |

Table-III shows the performance of the right ear at different onset asynchronies. On computing the percent score and the t-scores, it was found that the performance of the lagging ear (30 ms. and 90 ms.) was significantly better than the other ear or the leading ear. The difference was significant at the .01 level of significance. On comparing the lagging ear performance at 30 ms. R lag and 90 ms. R lag significantly better scores were obtained for 90 ms. R lag condition when compared to the 30ms. R lag condition. The difference was significant at .05 level of significance.

**LEFT EAR LAG**

Table II depict a significant difference in scores between the right and left ear when the lag was given to the left ear. The difference was significant at .01 level for the 30 ms. L lag condition and at .05 level for the 90 ms. L lag condition.

Table-IV: Percent scores and t-scores comparing left ear Lag scores.

| Left ear Lag | % scores | t-scores | Significance |
|---|---|---|---|
| 0 ms. L Lag<br>vs.<br>30 ms. L Lag | 48.33%<br><br>61.80% | 5.10 | 0.01 |
| 0 ms. L Lag<br>vs.<br>90 ms. L Lag | 48.33%<br><br>67.13% | 7.62 | 0.01 |
| 30 ms. L Lag<br>vs.<br>90 ms. L Lag | 61.80%<br><br>67.13% | 2.05 | 0.01 |

Table-IV depicts the performance of the left ear at different lag times. Similar to the right ear a significant higher score was obtained in the lagging ear. In other words, higher scores were obtained in the left ear when compared to the right, when the left ear was lagged by 30 ms. or 90 ms. was significant at .01 level of significance. On comparing the left ear's performance at 30 ms. and 90 ms.

lag conditions, better scores were obtained for the 90 ms condition, the difference being significant at .01 level of significance.

**Average scores at different lag times:**

As depicted in Table II, percent average scores obtained at different lag times were -

- 55.3% at 30 ms. R lag
- 58.06% at 30 ms L lag
- 63.69% at 90 ms R lag
- 64.03% at 90 ms L lag conditions.

A number of studies reported in literature support the above results. Lowe et al. (1970) varied the onset time between natural speech CV's upto 90 ms - 500 ms. from 30 ms. the results show a trail or lag effect in the 30 - 90 ms. range. Similar findings have also been reported by Studdert-Kennedy, Shankweiler and Shulman (1970). They found better identification of the trailing syllable than the leading syllable in dichotic conditions. Berlin et al. (1973) in two experiments on normals presented non-sense CV syllables both dichotically and monotically, with onsets of syllables separated by 0, 15, 30, 60 and 90 ms. (first experiment) and 0, 90,180, 250 and 500ms. (Second experiment). It was found that when the CV's trailed the other by 30 - 60 msec, the trailing CV became more intelligible than when it was given simultaneously. The leading syllables intelligibility dropped from its simultaneity level when leading by 15 - 30 msec. Olsen (1983), Gelfand et al. (1980), Loovis and Thompson (1972) and Berlin (1972) , also reported that the trailing CV became more intelligible than when it was given simultaneously.

This lag effect seen is due to a single left hemisphere speech processor being entered from two channels. This hypothetical processor requires a finite-time of 30 - 90 ms. to handle a CV accurately, provided it were not interrupted by different information arriving from another channel (Berlin et al. 1973). Physiological support for the importance of 30ms. separation between the signals come from studies by Hazemann, Oliver and Dupont (1969) and Happel (1972). They suggest that short latency (< 30ms.) responses recorded from cortex ipsilateral to the side of stimulation arrive by way of the corpus callosum in the somatosensory pathway. Thus, a lag of 30 ms. or more to the left ar might take both its ipsilateral information and contralateral information. The lag to the right ear would also be expected to improve its scores by virtue of freeing it from suppressive effect of the left ear.

Concluding, a significant lag effect is seen with performance improving with increase in lag time. Cancellation of the right ear advantage by an appropriate left ear lag suggest that the laterality and lag effects are independent phenomenon (Berlin, 1973).

**DOUBLE CORRECT SCORES**

a) AT SIMULTANEITY (0 msec) AND AT DIFFERENT LAG TIMES

Table-V : Mean, percent correct scores, standard deviation and range at different onset asynchronies for double correct responses.

| | Mean | S.D. | Range |
|---|---|---|---|
| 0 ms. | 6.9 (23.00%) | 2.00 | 1-17 |
| 30 ms. R lag | 7.66 (25.53%) | 3.97 | 2-17 |
| 30 ms. L Lag | 8.17 (27.23%) | 3.07 | 0-21 |
| 90 ms. R Lag | 12.34 (41.13%) | 5.50 | 3-25 |
| 90 ms. L Lag | 11.17 (37.23%) | 4.74 | 4-72 |

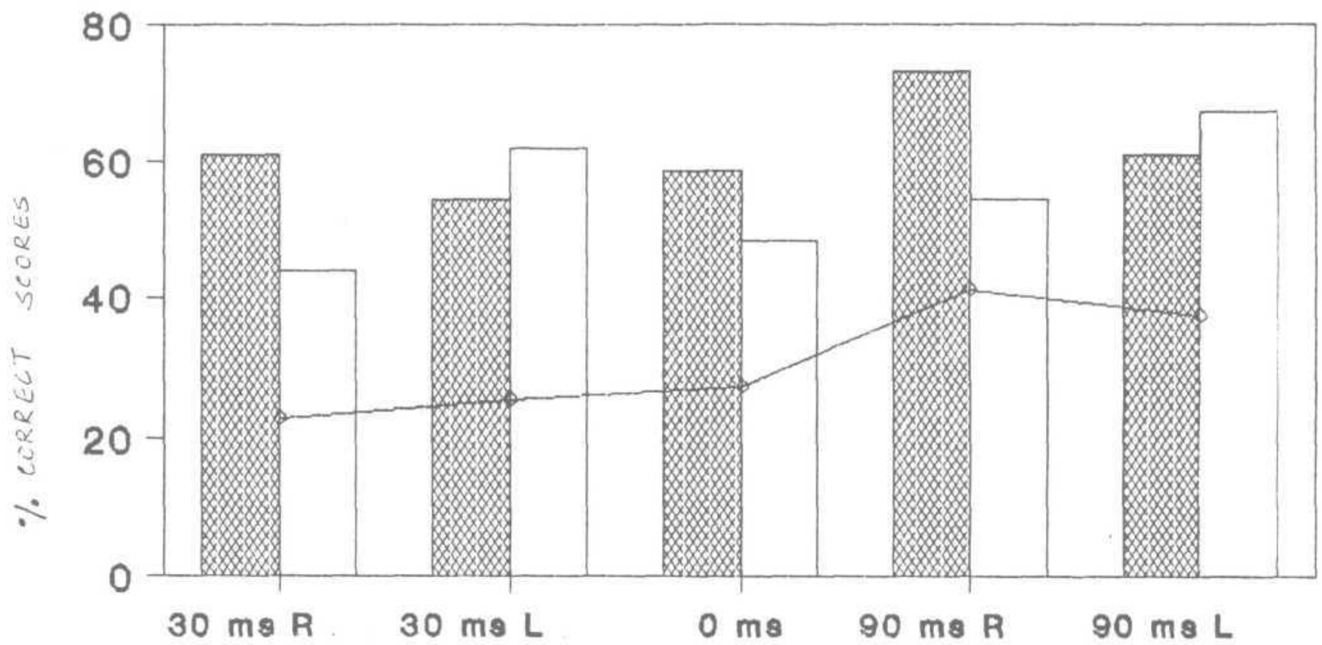
Max. Score Possible = 30

Double correct score refers a condition where the subject responds correctly to stimuli presented to both ears. As with the single correct scores, the double correct scores also varied across the different lag times in both ears. However, the double correct scores were found to be significantly lower than the single correct scores. The range of scores were also calculated at simultaneity and different lag times.

The data generated for the double correct scores at simultaneity and at different lag times is as given in Table-V.

Table-V depicts the mean, percent correct scores, standard deviation (SD) and range at simultaneity and at different lag times, for the double correct scores. The mean scores in the double correct responses were considerable lower than the single correct responses. It is evident from the range that the double correct responses (Table V) had a lot more variability when compared to the single correct responses (Tables I and II). This was true for the scores obtained at simultaneity and at different lag times. Due to the lesser variability seen when the single correct responses, it is recommended that this measure be used while calculating dichotic scores.

The mean scores in the double correct responses were considerable lower than the single correct responses, as evident in Graph II.




| | 30 ms R | 30 ms L | 0 ms | 90 ms R | 90 ms L |
|---|---|---|---|---|---|
| Right | 60.8 | 54.33 | 58.53 | 72.93 | 60.93 |
| Left | 43.8 | 61.8 | 48.33 | 54.46 | 67.13 |
| Double correct | 23 | 25.53 | 27.23 | 41.13 | 37.23 |

Right   Left   Double correct

Graph-II : Percent correct for single and double correct responses at 0 ms. and different lag times.

**EFFECT OF AGE ON DICHOTIC EAR ADVANTAGE**

Variations of age and dichotic listening will indicate "the effect of development on dichotic listening. This indicates the age at which the dichotic tasks show a hemispheric dominance for speech and language and how changes occur in dichotic listening with developmental changes and difference between the age groups.

Table-VI: Comparing Mean and SD of the er syllables for the two age groups at different lag times.

| | Age (years) | N | Right Ear Mean | Right Ear SD | Left Ear Mean | Left Ear SD |
|---|---|---|---|---|---|---|
| 0 ms. | 8-12 | 25 | 16.46 | 2.45 | 13.52 | 3.39 |
| | 13-17 | 25 | 18 | 5.41 | 15.48 | 3.33 |
| 30 ms. (R) | 8-12 | 25 | 18.92 | 4.4 | 11.84 | 5.2 |
| | 13-17 | 25 | 21.16 | 3.83 | 14.44 | 2.87 |
| 30 ms. (L) | 8-12 | 25 | 16.48 | 3.06 | 17.40 | 4.13 |
| | 13-17 | 25 | 16.72 | 4.67 | 19.68 | 3.76 |
| 90 ms. (R) | 8-12 | 25 | 20.72 | 3.85 | 16.56 | 3.84 |
| | 13-17 | 25 | 23.04 | 5.41 | 19.12 | 5.49 |
| 90 ms. (L) | 8-12 | 25 | 18.44 | 4.02 | 20.40 | 2.79 |
| | 13-17 | 25 | 18.12 | 5.98 | 19.88 | 4.09 |

Table-VI Compares the performance of the two groups of children (8-12 years vs. 13-17 years) on the dichotic CV test, using mean correct and standard deviation at different onset asynchronies.

Using mean, standard deviation and t-test a significant right ear advantage (REA) was found in both groups of subjects (8-12 years and 13-17 years) at simultaneity. This difference between right and left ear scores was found to be statistically significant at the .01 level. The significant right ear advantage seen in both the groups indicates that a left hemisphere dominance or lateralized language capabilities exists in normal children from the age of 8 years 17 years. It is possible that these hemispheric asymmetries develop before the age of 8.

In the present study findings support the previous studies on dichotic listening by Ingram (1975) who reported that a right ear superiority was indicated on dichotic listening tasks at as early as three years of age, suggestive of a left hemispheric dominance for speech functions. Knox and Kimura (1970) suggested that non-verbal environmental sounds were more correctly identified than the verbal. However, a number of verbal tasks demonstrate a REA. They attributed this to the established efficiency of the crossed pathways from the ear to the brain. They demonstrated that the right and left hemisphere functional differentiation had begun by age 5. Horning (1972) reported that children acquire functional differences by the age of five and behave in the same manner as the adults. Berlin and McNeil (1976) reported that the language skills, as the children develop from the age of 5-13 years can be reflected in the presence of REA suggesting the left hemisphere dominance. Hynd, Cohen and Obrzut (1983) suggested that lateralized language capabilities exist in normal children from the age 6 through 12.

It can be thus stated that the findings of the present study are incoordinance with the Western studies.

The Table-VI also shows that the older group (13-17 years) performs better than the younger age group (8-12 years) not just at simultaneity but also at the different lag times. This difference was calculated using t-test. The poorer performance of the young age group when compared to the older though not statistically significant can be attributed to the progressive maturation of the auditory system and therefore an age related increase in auditory capacity. In addition, the shorter attention span in the younger group, difficulty in following of instructions and the rapid rate of presentation of stimuli could be other contributing factors that could have resulted in the overall poorer scores in the younger age group. Rosen et al. (1983), who studied the dichotic presentation of CV syllables at different temporal offsets reported of no significant changes in ear laterality after the age of 4 years. However, there was a significant age related increase in auditory capacity, which is in accordance with the present study.

In conclusion, from the results obtained on the dichotic CV test, for Indian children in the age range of 8-17 years, it can be noted that -

1) At simultaneity, normal children get a score of 58.33% for the right ear and 48.33% for the left ear and an average score of 53.43% for single correct responses.

2) There is a significant right ear advantage.

3) There is a distinct lag effect, with performance improving from 0 ms. lag to 90 msec. lag.

4) Double correct scores also improve with increase in lag time, but because of the high amount of variability in scores, it is not a sensitive measure.

5) There is an improvement in scores with age (8-12 years vs. 13-17 years) at simultaneity and across the different lag times, but this difference was not statistically significant.

## SUMMARY AND CONCLUSION

The present study aims at generating normative data for the dichotic CV test, developed by Yathiraj (1994), at CID, St. Louis, on Indian children. The subjects taken up for the study were fifty, right handed normal children in the age range of 8-17 years. The subjects had no history of ear infection or any neurological involvement and were initially tested to ensure normal auditory functioning. On the dichotic CV test, the task involved identification of CV syllables when presented at simultaneity (0 ms.) and at different lag times. The lag times studied in the present study were 30 ms and 90 ms. given to both ears separately. The responses obtained were analyzed in terms of single correct (when the subject responded correctly to stimulus presented in either right or left ear) and double correct responses (when the subject responds correctly to stimuli presented to both ears). The raw data was statistically analyzed using mean, standard deviation, range and the t-test.

The results obtained were as follows:

a) **SINGLE CORRECT SCORES** : It was found that normal children in the age range of 8- 17 years got an average score of

63.43% at 0 ms lag, 55.30% at 30 ms right lag, 58.06% at 30 ms left lag.

63.69% at 90 ms right lag, and
64.03% at 90 ms left lag

These findings were obtained when average single correct responses were calculated.

ii) **LATERALITY** : There was a significant right ear advantage for the dichotic stimuli presented.

iii) **LAG EFFECT** : A significant lag effect was seen when lag was presented either to the right or left ear. That is, scores were seen to improve with increase in lag time from 0 ms to 30 ms and 30 ms to 90 ms. This increase with lag time was found to be statistically significant.

iv) **SINGLE CORRECT vs. DOUBLE CORRECT SCORES** - The findings on the single correct and double correct responses were similar. The scores were seen to improve with increase in lag time from 0 ms -30 ms. - 90 ms. However on the double correct scores a wide range of variability was seen when compared to the single correct scores. This indicates that the single correct score is a more sensitive diagnostic criteria when compared to the double correct scores.

v) **AGE EFFECT** : The performance of the age effects : older age group (13-17 years) was compared to that of children of the younger age group (8-12 years). The older group performed better than the younger group at simultaneity and at different lag times.

The results obtained was in accordance to the hypothesis and was consistent with previous studies.

In conclusion, the present study is in accordance to findings in the western population. Thus, similar trend in results is seen across the different populations. This confirms the use of this test with children from different linguistic backgrounds.

**FUTURE IMPLICATIONS**

The dichotic consonant-vowel (CV) task can be used to detect children with central auditory perceptual deficits. Thus, it can be included in the central auditory disorders (CAD) test battery for children for early diagnosis of such children and for appropriate management.

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# APPENDIX-A

Name Date

Age/Sex Mother Tongue

Education/ Other Languges Known

Qualification

Occupation Socio Economic Status

HANDEDNESS

AUDIOLOGICAL INVESTIGATION

| Ear | 250 | 500 | 1000 | 2000 | 4000 | 8000 | PTA | SRT | PB Max |
|---|---|---|---|---|---|---|---|---|---|
| | Frequency in Hz | | | | | | | | |
| Right | | | | | | | | | |
| Left | | | | | | | | | |
| **BC THERESHOLD** | | | | | | | | | |

Monotic Scores (%) Right Ear Left Ear

Dichotic Scores (%)

| R | L | R | L | R | L | R | L | R | L |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

Note: p, t, k, b, d, g : Any two of these sounds will be presented in both ears simultaneously. If possible mark off both the sounds heard. If not then mark off atleast one of the sound heard.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| p | t | k | b | d | g | p | t | k | b | d | g | p | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | p | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | p | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | p | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | p | t | k | b | d | g |
| p | t | k | b | d | g | p | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | p | t | k | b | d | g |
| p | t | k | b | d | g | p | t | k | b | d | g | p | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | p | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | p | t | k | b | d | g |
| p | t | k | b | d | g | p | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | p | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | p | t | k | b | d | g |
| p | t | k | b | d | g | p | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | p | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | p | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | p | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | p | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | p | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | p | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | p | t | k | b | d | g | p | t | k | b | d | g |
| p | t | k | b | d | g | p | t | k | b | d | g | p | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | P | t | k | b | d | g |
| p | t | k | b | d | g | P | t | k | b | d | g | P | t | k | b | d | g |

Five such lists as illustrated above, were given to the subjects.