DICHOTIC CV TEST: NORMATIVE DATA ON ADULTS

REG. No.M9410

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Mom Dad

periamma periayya

I couldn't have been what I am to-day without your biessings and prayers.
I thank the Lord no end for having blessed me with such wonderful parents ..

You guys are really a cut above the rest!

CERTIFICATE

This is to certify that the Dissertation entitled DICHOTIC CV TEST : NORMATIVE DATA ON ADULTS is a bonafide work done in part fulfillment for the degree of Master of Science (Speech and Hearing), of the student with Reg.No. M9410.

Mysore
May 1996

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CERTIFICATE

This is to certify that the Dissertation entitled DICHOTIC CV TEST : NORMATIVE DATA dN ADULTS has been prepared under my supervision and guidance.

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DECLARATION

I hereby declare that the Dissertation entitled DICHOTIC CV TEST : NORMATIVE DATA ON ADULTS is the result of my own study under the guidance of Dr. Asha Yathiraj, Reader, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.

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INTRODUCTION

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

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

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

Dichotic listening tasks have been used in the evaluation of both normal and disordered auditory processes at the cortical level (Kimura, 1961; Berlin et al. 1972). The term 'dichotic' refers to the simultaneous competing presentation of two different speech signals to opposite ears. Subjects ar asked to repeat back what is heard in one or both ears. Generally when speech is presented dichotically to normal listeners, higher scores are obtained from the material to the right ear, than the left. This has been referred to as the right ear advantage and is believed to reflect the dominance of left hemisphere for speech and language perception (Studdert-Kennedy, Shankweiler, 1970).

The present study was taken up to generate normative data regarding the performance of young Indian adults on a dichotic CV test. The task involved identification of dichotic non-sense CV syllables at simultaneity (0 msec, lag) and at various onset time asynchronies of 30 msec and 90 msec, under right and left lag conditions. The dichotic CV test developed by Yathiraj (1994) at CID, St. Louis, was the test administered.

On dichotic tasks, speech signals are preferred to non-speech signals as they can be manipulated in more complex ways than tones or other non-speech stimuli (Berlin, 1972). Speech signals that are linguistically similar and spectrally time aligned, short and of similar duration are preferred to other types of speech stimuli in CANS evaluation due to their greater lesion detection capacity (Speaks, 1974). The use of stop CVs generally has become accepted as the most precise means by which to assess ear advantage, and other aspects of speech perception (Niccum, 1981). These CVs have been found to allow for a greater degree of control over linguistic influences (e.g. vocabulary, dialect and other syntactic and semantic components than have other speech-stimuli (Berlin,1976) . When normal hearing listeners are stimulated dichotically with speech stimuli, the right ear performs somewhat better than the left ear, a phenomenon referred to as the right ar advantage (Cullen, Berlin, 1974).

It has also been demonstrated that when the dichotic stimuli are presented to the two ears at onset time asynchronies of 30 msec to 90 msec, the lagging member of the pair is perceived more accurately than the stimulus presented first. The analysis of the lead syllable appears to be interrupted by the presence of the lagging syllable. Because of this 'lag-effect', the right ear advantage is overcome when the lagging syllable is presented to the left ear (Studdert-Kennedy, 1970) .

NEED FOR THE STUDY

1. The need for the present study was to incorporate the dichotic CV test as part of the CANS evaluation battery, because dichotic measures have demonstrated sensitivity

in identifying and differentiating cerebral level lesion (Berlin, 1976; Noffsinger, 1979). Especially, those with learning disabilities and other cortical lesions are known to perform poorly on dichotic listening tasks. In order to identify deviant performance on such tasks, it is necessary to obtain normative data.

2. To date, no normative data is available on dichotic CV tests, on the Indian population. Hence, the data, so obtained on the Indian population can be compared with that of the western population to see if a similar trend is observed. Also to see if the multilinguistic background as seen in the Indian population has an effect in the perception of the CVs, used in the present study.

3. The study also aimed at verifying the presence of a lag-effect for the dichotic stimuli presented at different onset time asynchronies. This information would also be of use in the differential diagnosis of various central auditory processing problems.

REVIEW OF LITERATURE

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

BASIS FOR EAR DIFFERENCES

When the signals are speech material, the right ear is most frequently favoured. This right ear superiority is seen for both, meaningful speech and non-meaningful speech material such as non-sense syllables (Shankweiler, Studdert-Kennedy, 1967), and backward speech (Kimura, Folb, 1968). In contrast, left ear superiority has been reported for certain complex non-speech sounds e.g. music, sound-effects (Kimura, 1964; Curry, 1967). Kimura (1967) attributes this difference in ear accuracy as a function of stimulus type to bilateral asymmetry of brain function (BAF). The BAF hypothesis suggests that

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

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

Kimura (1968) demonstrated a right ear superiority of recall for verbal material based on physiological mechanisms and related it to a left hemisphere dominance for speech. Shankweiler and Studdert-Kennedy (1967) presented synthetic CV syllables and steady state vowels dichotically and found a right ear superiority, similar to one found for meaningful words. However, right ear superiority was larger for CV syllables and relatively small for vowels. It could be argued that right ear superiority decreases when some of the normal characteristics of speech are removed. Liberman et al. (1967) interpreted that, the hemispheric dominance is obtained only for highly encoded speech sounds but not for minimally encoded ones. It is well known that recognition of speech is directly dependent on the frequency characteristics of the speech-signal (Miller, 1951). If the high frequency part of the signal is removed, primarily the consonant part of the speech signal is affected. With large amounts of filtering, speech is eventually reduced to vowel components only.

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

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

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

PERFORMANCE ON DICHOTIC LISTENING USING DIFFERENT REPORT STRATEGIES

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

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

DICHOTICALLY STIMULATED EAR DIFFERENCES IN MUSICIANS AND NON-MUSICIANS

Bever and Chiarello (1974) found a right ear preference in the detection of musical stimuli, when they used musician as subjects. Previously, a left ear superiority had been noted with non-musicians on several occasions (Kimura, 1964; Spreen, Spellacy and Reid, 1970). As Bever and Chiarello, 1974 point out, their finding may be due to the musician's analytic perceptions of melodies as opposed to gestalt synthesis of naive listeners.

Johnson (1977) conducted a study, wherein a dichotic listening task involving violin melodies was given to 32 musicians and 32 non-musicians. The former group demonstrated a right ear superiority, while the latter performed better with the left ear. Right ear scores distinguished between the groups, but left ear scores did not. Additionally, the left handed subjects in both groups showed smaller amounts of ear asymmetry than their right-handed counterparts. The results were interpreted as demonstrating that musicians mainly use the left hemisphere to process musical stimuli, while non-musicians use the right. It is thought that as a person becomes more musically adept, increasing use is made of a left hemisphere's sequential analytic mechanism. The apparent functional symmetry of left-handers could also be due to the confounding effect of having two distinct sub-groups within this population, i.e. true left handers and those with cortical organization of right handers.

STABILITY OF DICHOTIC LISTENING TESTS

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

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

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

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

FACTORS AFFECTING DICHOTIC LISTENING

Effect of stimulus material in dichotic listening tasks.

Several test procedures have been developed to measure dichotic listening in normals and to see how the performance varies in abnormals. Most dichotic speech tests aim at reducing the redundancy of a speech signal by either altering the temporal characteristics of the signal (Bocca, 1958; Calearo et al. 1957) or by use of filtered speech (Matzker, 1959). Tests such as Dichotic Digits (Kimura, 1961), Dichotic CV Test (Berlin, 1972), Staggered Spondaic Word Test (Katz, 1962) Synthetic Sentence Identification (Speaks and Jerger, 1965) and Dichotic Rhyme Test (Wexler and Halwes, 1983) have also been commonly used to assess the central auditory processing in normals and disordered population. Comparing the performance of normals on the dichotic speech tests it was seen that right ear performance was good for both the CV material, and for the meaningful words of the SSW or Dichotic Digits. However, when comparing the performance of normals on Dichotic CV

Test with the Dichotic Digit Test it was seen, it was seen that normals scored poorly on the Dichotic CV Test when compared to Digit Test. This finding was confirmed in a study by Rajgopal, Ganguly and Yathiraj (1995) on the Indian population. It was seen that normals performed poorly on the dichotic CV test when compared to the dichotic digits. This could be because in the Dichotic CVs Test the presentation of stimulus is more simultaneous. Also the nonsense CV syllables are less meaningful when compared to digits and rarely occur in isolation, unlike digits. Niccum et al(1981) stated that the Dichotic CV Test is a more difficult task when compared to Dichotic Digit Test. However, dichotic speech tests, have found wide diagnostic and clinical utility in the evaluation of central auditory processing.

Effect of frequency on dichotic listening tasks

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

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

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

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

Effect of intensity on dichotic listening tasks

To date, it has been shown that dichotic listening tests are influenced by factors such as lesions of the central nervous system (Berlin, 1972; Kimura, 1971), the age of the subjects {Craik, 1965; Inglis, 1962) handedness (Curry, 1967; Zurif, 1970), reporting strategies (Bryden, 1962; Gerber, 1971) and the use of linguistic and non-linguistic stimuli (Chaney and Webster, 1966; Curry, 1967; Kimura, 1964). One parameter not systematically investigated is the intensity level of presentation. Roeser, Johns and Price (1972) designed a study to investigate the intensity function of the right ear effect and to determine, whether there was an intensity or a general range of intensities at which the effect is most observable. Results indicated that there was a significant tendency for subjects to report fewer correct responses at lower intensity levels. Subjects, however reported significantly more stimuli from the right ear across intensity, i.e., the right ear scores were not found to vary as a function of intensity.

Rayan (1969) showed that REA was held constant even when the left ear signal was 6 dB more intense than the right ear.

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

Effect of temporal aspects on dichotic listening tasks

When normal hearing listeners are stimulated dichotically with speech materials, there is a right ear advantage observed. However when the stimuli are presented to the ears at onset time asynchronies of approximately 30 to 90 msec, the lagging member of the pair is perceived more accurately than the stimuli presented first. In a study by Berlin et al. (1972), the amount of time separation between message onsets to overcome the right ear advantage was investigated. It was found that when one of the CVs trailed the other by 30-60 msec, the trailing CV became more intelligible than when it was given simultaneously.

Gelfand et al. (1980) examined dichotic speech perception at various lag times in young versus elderly subjects with normal hearing. An aberration of the lag effect for CVs was observed in the older group even though the REA was maintained. Berlin et al. (1973) demonstrated that REA and lag effect are independent of one another and there is evidence that lag effect might be a case of temporal masking not limited to speech stimuli (Darwin, 1971; Porter, 1975). The difference in lag effect seemed to implicate temporal processing in the aging central auditory system. This was in agreement with reports on how time alteration degrades speech intelligibility in the elderly (Sticht and Gray, 1969; Bergman, 1971; Konkle, 1977). Since the competing CVs were presented dichotically, the interaction between them and thus any aberration of the lag effect must occur at some central level, where signals from both sides are simultaneously represented. Both lateralization (Herman, 1977) as well as lag effect are affected by aging.

Bingea and Raffin (1986) conducted a study to generate normative data involving the identification of dichotic consonant vowels at onset time asynchronies of 120, 90, 60, 30 and 0 msec under right and left lag conditions. The dichotic test results for the group supported the hypothesis, which was consistent with previous studies, that there was a significant right ear advantage at 0 msec. and that there was significant variation of scores as a function of onset time asynchrony, in which scores improved as the onset time asynchrony lengthened (at least for those which were 90 msec, or more apart). But unlike the group data, the individual results did not support the presence of a lag effect. The group data suggested that maximum improvement in scores occurred even for normal listeners, when the interaural onset time increased. Although this study failed to demonstrate a significant lag effect, those who have identified such a phenomenon found that it was most obvious at 0 to 90 msec (Berlin, and Lowe-Bell, 1973; Kirstein, 1971; Bellaire and Noffsinger, 1978).

Hence, when normal hearing listeners are stimulated dichotically with speech material there is a right ear advantage observed. But when the stimuli are presented to the two ears at different onset time asynchronies it was seen that the lagging member of the pair is perceived more accurately. However, there have been studies which have failed to support the presence of a lag effect and this could have been due to procedural variations or variations in the statistical analysis utilized.

Effect of stimulus dominance in dichotic listening

Although ear advantage in dichotic listening tasks has been studied with a variety of speech signals, none has received more attention than the CV non-sense syllables formed by one of the six stop consonants /p, t, k, b, d, *g/* in combination with a vowel. One obvious advantage is the reduced size of the corpus of speech, and their relative homogeneity, both articulatorv and acoustic. Thus one might expect accuracy of recognition within the set of stop CV syllables to be relatively invariant. This however does not seem to be the case when the syllables are presented dichotically. /Berlin et al. (1973) for example, reported that scores were higher for voiceless stops than for voiced stops in pairs of natural syllables that contrasted in voicing. The voiceless stops are said to "dominate" the voiced stops. This finding was replicated by Roeser, et al. (1976) and by Niccum, et al. (1976).

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

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

i) One possibility could be the inherent intelligibility of the syllables. It might be assumed that certain syllables are more intelligible than others and that the differential intelligibility would be evident regardless of whether the syllables are presented dichotically or in some other mode, for example, diotically. Speaks et al. (1981) tested this notion by presenting six CV syllables binaurally in noise to four listeners. They found that the two most intelligible syllables diotically /ba/, and /da/ were the two least dominant syllables dichotically. Clearly, this showed that binaural intelligibility scores in noise did not explain dichotic stimulus dominance.

ii) A second possibility is the "lag-effect" which has been explained by Berlin et al. (1973). They confined their attention to the dominance of voiceless over voiced stops in voicing-contrasted pairs of natural syllables. Voiceless stops were found to have, longer voice-onset times (VOT) than voiced stops. Therefore, when the competing stops are aligned by reference to the onset of noise burst, the large amplitude vocalic portion of the voiceless stop is delayed relative to the vocalic portion of the voiced stop. Berlin et al. (1973) reasoned that the "later arriving voiceless stop" (later in terms of the vocalic portion of the syllable) might interrupt processing of the earlier arriving voiced stops. However, in the study conducted by Speaks et al. (1981) few of their findings appeared to be at variance with the lag effect notion. Firstly, the explanation was applied to only nine voicing-contrasted pairs used in the study, and those pairs differed substantially in VOT. Another problem was that the lag effect did not account for the dominance of [/ga/] voiced velar over voiceless labial (pa). Yet another problem with invoking the lag effect to explain stimulus dominance was the observation that the pattern of stimulus dominance for synthetic syllables was reversed from that described for natural syllables. With synthetic syllables, presented dichotically, voiced stops dominated voiceless stops in voicing-contrasted pairs. Thus, it appeared that the differences observed for natural and synthetic syllables show that the lag effect was an unsatisfactory explanation since the VOTs for the synthetic stops were virtually identical to those of the natural stops.

iii) Repp (1980) proposed a category goodness model to explain stimulus dominance. The essence of Repp's model was that the perceptual system is assumed to determine how well a stimulus matches any of several category prototypes. When two competing dichotic stimuli enter the system, a stimulus that is close to the prototype will tend to dominate over a stimulus that is far from any prototype. Repp (1980) claimed support for this model from his experiments on within-category acoustic changes with synthetic syllables involving systematic manipulation of second formant transitions (1976) and VOT (1977). He reported that stimulus dominance could be changed systematically with variations in VOT of the competing stimuli and he accepted that the competitive strength-of a signal was due, at least in part, to its acoustic structure. Comparing the VOTs corresponding to category boundaries published by Lisker and Abramson (1970); labials +20 msec, alveolars +35 msec, and velars +40 msec, the model would predict that the syllable, most distant (in VOT) from its category boundary would be the pair's dominant member. Again analysis of results obtained by Speaks et al. (1981) in their study, showed that of the 15 syllable pairs used, only five showed agreement between prediction and observation. The other ten showed no agreement. Belanger (1979) obtained a nearly identical outcome for the same syllables used by Speaks et al. (1981). Thus, analysis provided fairly persuasive evidence that Repp's model (1980) was not a satisfactory framework within which the pattern of stimulus dominances for the natural syllables could be understood.

iv) A final explanation is concerned with the relative amplitudes of the brief burst of frication noise that correspond to the moment of articulatory release. Because the spectral properties of the burst of frication constitute one cue for perceiving the different classes of stops (Halley, Hughes and Radley, 1957), conceivably the burst was also partly responsible for producing stimulus dominance.

The properties of the burst are different for voiced and voiceless stops. There is a greater drop in pressure across the oral occlusion, at the moment of release for a voiceless stop (Lisker, 1970; Lisker and Paris, 1970). As a consequence of this and longer drop in pressure across the oral constriction, the peak intensity of the burst as well as its duration is generally greater in voiceless stop than for voiced (Klatt, 1975). In the study conducted by Speaks et al. (1981), the wave forms of the six stops (p, t, k, b, d, g) were examined and the voltage of the initial burst frication was measured and converted to decibels relative to the peak intensity. It was seen that velars (k, g) had greatest peak intensities followed by alveolars and labials.) The role of burst intensity in determining the pattern of stimulus dominance is still to be clarified with further experiments. In any case, stimulus dominance does seem to exert a strong influence on the direction of ear advantage for a given pair of syllables.(A recent study by Rajgopal, Ganguly and Yathiraj (1995) on the Indian population also yielded similar results. The results of the study indicated that voiceless syllables were better perceived than voiced velars were the best perceived followed by labials and alveolars.

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

STUDIES OF DICHOTIC LISTENING IN ABNORMAL POPULATION

The following discussion is aimed at reviewing studies of dichotic listening tasks used in the abnormal population such as brain stem lesions, temporal lobe lesions, aphasics and stutterers. Audiologists have been involved in central auditory testing for over 30 years. Bocca and his associates were the first to use special tests to evaluate problems at various levels of the central auditory nervous system (CANS). The audiologist can hence assess auditory function to provide the best management strategies. Audiometric investigations of lesions of the central auditory paths have now become very fashionable and the question is being debated by an increasing number of investigators. In the course of about a decade, experience has allowed the establishment of a series of tests which have been found to be practical and adequate for this particular branch of audiology.

The following section deals with the studies of dichotic listening conducted on patients with different disorders such as cortical lesions, brain stem lesions and peripheral disorders.

STUDIES ON PATIENTS WITH CORTICAL LESIONS

1. Temporal Lobe Lesion

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

When two competing stop consonant-vowel (CV) syllables were presented dichotically to a listener with a temporal-lobe lesion, the scores for syllables in the ear contralateral to the lesion usually was much lower than scores for syllables in the ipsilateral ear. Ample documentation exists to show that the weak-ear score for temporal lobe patients was suppressed markedly in dichotic tasks. The existence of suppression has been documented with CV syllables (Berlin et al. 1972, 1973), digits or words (Kimura, 1961; Speaks, Goodglass, 1970), sentences (Jerger et al. 1969; Speaks et al. 1973) and non-speech sounds such as melodies (Shankweiler, 1966). The inference seems to be that the cortical processing areas for speech, presumably located in the left-hemisphere, do not receive an effective dichotic input. Because of the temporal lobe lesion, the signal was degraded sufficiently such that correct processing of the weak ear signal was unlikely.

Speaks, Gray and Miller (1974) however, in their study with temporal lobe lesion patients demonstrated that the auditory pathways from the weak ear and speech information presented to the weak ear were not completely suppressed during dichotic stimulation. It was observed that speech in the weak ear frequently interacted with competing speech information in the strong ear causing interference with correct processing of signals from the strong ear. Olsen (1983) conducted a study on patients with temporal lobectomy and results demonstrated that not all patients with temporal lobectomy had performance below the lower limits of normal subjects, on the dichotic CV test. He also administered the staggered spondaic words (SSW) on them and compared the results. It was observed that the dichotic CV test material used were more sensitive to temporal lobe lesions than is the SSW. This could have been because the SSW was not as difficult as the CV test and hence was less sensitive to cortical lesions. Lynn (1972) and Niccum et al. (1981) reported similar observation on patients with temporal lobectomy.

Hughes, Tobey and Miller (1983) measured the temporal aspects of dichotic listening in brain damaged subjects. they tested around 13 cortically injured subjects using dichotic speech and non-speech stimuli. Subjects with injuries outside the temporal and frontal lobes performed the dichotic tasks as well as normal subjects. This indicated that temporal order performance did not appear to be effected when a lesion did not encompass either temporal or frontal cortical areas. However, poor temporal order performance was found in persons with temporal or frontal lobe lesions, regardless of the hemisphere involved or the type of stimulus set used.

In general, studies have shown that central auditory deficits existed in patients with temporal-lobe lesions. When such patients were presented with, dichotic simultaneous and time staggered, speech-material (non-sense CVs), they showed poorer scores for the contralateral ear than for the ipsilateral ear. The lag effect was also found to be absent. Patients showed a distinct failure to accurately perceive messages in the ear contralateral to the lesion. The inference seems to be that the cortical processing areas for speech do not receive an effective dichotic input because of the temporal lobe lesion. Studies have shown that dichotic CV test material was more sensitive to cortical lesions than tests like SSW, because the SSW was not as difficult as the CV test and hence was less sensitive, to cortical lesions.

Intracranial lesions

Studies have revealed that a number of dichotic tests may be useful in evaluating the integrity of the central auditory nervous system. Musiek (1983) demonstrated results of three dichotic speech tests on subjects with intracranial lesions. Thirty adults (12 brainstem and 18 hemispheric) with intracranial lesions were tested using competing sentences, staggered spondaic words, and dichotic digits. In comparing these dichotic test for their ability to detect abnormal performance for individual subjects, the digit test appeared most sensitive, followed by the staggered spondaic word test and then competing sentences. All three tests showed slightly better sensitivity for detecting abnormality in hemispheric than brainstem lesion. None, however, could consistently differentiate brain stem from hemispheric lesions. This inability of various central tests to reliably differentiate cortical from brain stem lesions has often been reported. Laterality effects were consistently different for hemispheric and brain stem involved subjects. Those with hemispheric involvement showed the greatest deficit for the ear contralateral to the lesion, whereas those with brain stem involvement showed greatest deficit ipsilateral to the lesion on all three tests. These results are in general agreement with many previous reports by different authors like Katz (1968), Kimura (1961), Lynn et al. (1972), (1977), Speaks (1975).

Results from the dichotic tests conducted on patients with intra-cranial lesion and brain stem lesion revealed that laterality effects were different for hemispheric and brainstem involved patients. Those with hemispheric involvement showed the greatest deficit for the ear contrlateral to the lesion, whereas those with brain stem involvement showed greatest deficit ipsilateral to the lesion. Also among the dichotic tests administered, the dichotic digit test appeared most sensitive, followed by staggered spondaic. Word test and then competing sentences. All the three tests showed slightly better sensitivity for detecting abnormality in hemispheric than brain stem lesion.

Split Brain Patients

Dichotic listening tasks in split brain patients have demonstrated a right ear enhancement which might suggest a release from central auditory competition in the left hemisphere. Studies by Springer et al. (1975) reported high right ear scores from split brain subjects using dichotic CVs. In split brain patients, as the callosal pathway is severed, information from the left-ear is not transmitted as the interconnection between the right and left hemisphere is not intact. Hence, the left hemisphere is required to process only the input coming from the right ear.

Dichotic speech testing in split brain patients has been valuable in delineating various brain functions involved in auditory perception. It is well known that lesion of the auditory portions of the corpus-callosum result in severe left ear deficits on dichotic speech tasks that require verbal report of the stimuli (Milner, et al. 1968; Musiek et al. 1984). The Dichotic Rhyme Task (DRT), introduced by Wexler and Halwes (1983) was used in this study. The patient, although presented with two words, generally reports only one with slightly more than 50% of all words recognized being those presented to the right ear (Wexler and Halwes, 1983).

In a study by Musiek et al. (1989), monosyllabic rhyme words were dichotically presented to normal and complete split-brain subjects. Normals yielded a small but significant right ear advantage. The split brain patients yielded the expected marked left-deficit, as seen on other dichotic speech tests and demonstrated a right ear enhancement, producing a large inter ear difference. The right ear enhancement on the dichotic rhyme task may suggest a release from central auditory competition in the left hemisphere. Springer and Gazzaniga (1975) reported high right ear scores (near 100%) from split-brain subjects using dichotic CVs. In dichotic listening, the left hemisphere receives direct contralateral input from the right ear and input via the corpus callosum from the left ear. If the competition via the corpus callosum is removed by sectioning or by a lesion in this area, the left hemisphere is released from processing these stimuli, and it has to process only right ear input.

Performance of Aphasic Patients on Dichotic Listening Tasks

Since Broadbent's studies on auditory stimulation and memory span using simultaneous presentation to both ears with pairs of dissimilar digits, other researchers have used dichotic listening to investigate phenomena as : ear prefernce in auditory perception (Bryden, 1963), laterality (Bryden, 1967) effects of temporal lobectomy (Oxbury, 1969) , cerebral dominance for speech (Dirks, 1964), cerebral dominance for hearing (Kimura, 1963), and the effect of hemispheric lesions in a sample population of aphasic and non-aphasic brain damaged adult males (Sparks, 1970). This word has established the fact that majority of normal people show a right ear preference for linguistic stimuli, reflecting the dominance of the brain's left hemisphere for language; and that injury in either hemisphere results in reduced efficiency of the contralateral ear, unless the damage is below the auditory cortex. In a study conducted by Hutchinson (1973), ten receptive aphasics were given dichotic listening task comprised of 34 pairs of single syllable words. Results indicated that the ear preference for the aphasic group was similar to that of normals, except for three of the patients, where a left ear dominance was observed. One explanation could be that these patients had a right hemisphere dominance for speech. A more likely explanation could be that damage to the left-hemisphere was severe enough to cause non-functioning for speech reception tasks. The dichotic test was sensitive to receptive language problems typical of aphasia. Zurif and Ramier (1971) have found the similar effects for brain damaged patients in a dichotic listening test using either CV syllables or words. Both right and left temporal lesions disrupted the identification of the syllables, but only the left hemipshere lesions interfered with processing of words.

The dichotic test was sensitive to receptive language problems typical of aphasia. Zurif (1970) have found the similar effects for brain damaged patients in a dichotic listening test using either or syllables or words. Both right and left temporal lesions disrupted the identification of the syllables, but only the left hemisphere lesions interfered with processing of words.

John, Sommers and Weidner (1977) reported of finding a significant dichotic left ear preference for verbal stimuli among their left brain injured subjects with aphasia as opposed to the right ear preference among normals. They reported that the initial severity of aphasia was a significant determinant of the extent of left ear preference. The authors interpreted these results as reflecting the superiority of the right hemisphere, over the damaged left, in auditory verbal recognition. Craig (1978) reported that the left ear preference observed among subjects with aphasia was not caused solely by the superiority of the right hemisphere over the damaged left, in auditory verbal recognition, rather the left ear preference seemed to be in part, as a result of the more efficient processing of the left ear signal transmitted via the initial right primary auditory cortex as opposed to that of the right ear input.

Crosson and Warren (1981) studied the dichotic ear preference for CVC words in Wernickes and Brocas aphasics, as compared to normals. Results indicated that while normals demonstrated the usual right ear advantage both the Brocas and Wernickes aphasia groups demonstrated left ear advantage. One explanation for these results was that any severe defect in the language system of the left hemisphere affects the way that the left-hemisphere processes the linguistic information. It was postulated that the left ear stimuli which arrive at the left hemisphere later, disrupted the processing of the right ear stimuli in subjects with aphasia. A more definite explanation requires further research.

The interpretation of dichotic listening test performance by aphasic patients remains a controversial issue in literature. Several investigators have postulated that the direction and magnitude of the ear advantage observed for aphasic listeners reflect the hemispheric dominance for language processing, while other investigators have interpreted the ear advantage to be a 'lesion effect'. The "dominance effect' interpretation originated as an explantion for the ear advantages observed with normals (Kimura, (1961) . The nature of the effect is that the ear contralateral to the dominant hemisphere has some "advantage" relative to the other ear. Niccum, and Rubens (1983) postulate that the dichotic tests are useful to determine whether language recovery is based on the transfer function to the right hemisphere. A left ear advantage was interpreted as evidence that latralization of language processing had shifted to the right hemipshere. The 'lesion effect' interpretation of ear advantages was based on the assumption that degradation due to the lesion might interact with and possibly override the premorbid ear assymetry so that dominance can be longer be inferred (Schuloff and Goodglass, 1969). Linebaugh (1978) stated that determination of lateral dominance based on dichotic listening tests assumes the integrity of the entire auditory system including the primary sensory and association areas of both hemispheres and their callosal connections. Niccum et al. (1981) are in agreement with Linebaugh (1978) where they emphasize the integrity, of the posterior, superior temporal area in the left hemisphere to be essential for perception of the right ear stimulion dichotic tests and also for performance of specific language tests.

Numerous studies have been conducted on aphasics (Hutchinson (1973), Johnson et al. (1977), Linebaugh (1978), Crosson et al. (1981), Niccum et al. (1983). Studies have reported a dichotic left ear preference for verbal stimuli as opposed to the normal right ear advantage. A left ear advantage was interpreted as evidence to the fact that lateralization of language processing had shifted to the right hemisphere. However, the performance by aphasic patients remains a debatable issue, where different explanations have been put by the experts (Kimura, 1961) to explain ear advantage.

Dichotic Listening In Learning Disabled

Data on dichotic listening in learning disabled children is less and the data that is there, show conflicting results. With respect to right ear advantage, Bryden (1970) and Thompson (1976) suggested that children with learning disability have diminished or non-existent REA. Auditory capacity studied by Dermody (1976) and Tobey et al. (1979) has shown that this measure is significantly reduced in learning disabled subjects.

Morton and Siegel (1991) in a study on reading comprehension disabled, reading and word recognition disabled matched with normal controls concluded, that on the dichotic CV test, the learning disabled group showed a high left ear advantage. The learning disabled children in the study did show an attentional bias. The right ear report was lower, when subjects were directed to report what was heard at the left ear first. Presumably, this was due to difficulty in shifting to the right ear in those who were directed to report the left ear stimulus first.

Ganguly, Rajgopal and Yathiraj (1996) compared the performance of normal children with those having learning disability. It was found that, on the dichotic CV test, the children with learning disability performed poorly when compared to the normal group. The difference in scores was found to be statistically significant. However, even those with learning disability did demonstrate significant right ear advantage' when presented with dichotic speech material.

Studies *on* children with learning disability have shown that, their performance on dichotic tests are poorer when compared to normal controls. This could be due to the inherent deficits in central auditory processing that is characteristic in children with learning disability, and hence can be easily identified on dichotic tasks. Studies have shown that the learning disabled children do show right ear advantage. But, there are mixed views on this, where some studies have shown ear preference to vary as a function of attentional bias.

Performance Of Stutterers On Dichotic Listening Tasks

Dichotic listening has been used to ascertain cerebral laterality in stuttering. Curry and Gregory (1969) compared 20 right handed adult stutterers with 20 controls on a dichotic word test. It was found that 75% of controls showed right ear superiority, while this was seen for only 45% of the stutterers. Quinn (1972), Brady and Benson (1975) however failed to confirm the group differences as found by Curry et al. (1969). But they observed that a few of the stutterers had higher scores in the left ear while none of the normal controls had a left ear advantage.

Studies on children with stuttering (Slorach and Noehr, 1973; Gruber and Powell, 1974) showed no difference between experimental and control groups in dichotic listening.

Rosenfield and Goodglass (1980) presented dichotic CVs and melodies to matched groups of right handed male stutterers and controls. Right ear advantages were obtained for CVs and left ear advantage for melodies, without significant ear differences between groups. However a significantly greater number of stutterers than controls failed to show the expected ear laterality for either type of material.

The results obtained in the study are consistent with the accumulation of evidence that the population of stutters includes a disproportionately large number of individuals who fail to demonstrate clear left cerebral dominance on dichotic testing.

Studies on Patients With Brainstem Lesions

Cases with brainstem lesions are found to perform poorly on tasks which require identification of speech stimuli that have been sensitized. Sensitization of speech material has been obtained by methods such as time compression (Calearo et al. 1957) or use of words in the presence of noise (Greiner, et al.1957). The use of such tests along with audiometric investigations would show the presence of auditory deficits in most of the cases (Calearo and Antonelli, 1968).

Studies on Multiple Sclerosis

Dichotic paradigms in multiple sclerosis was investigated by Jackobson, et al. (1983). In their study 20 patients with multiple sclerosis were administered three commonly used dichotic speech paradigms. The test included dichotic CV test (Berlin, 1972), the synthetic sentence identification test (SSI) (Speaks and Jerger, 1965) and the staggered spondaic word test (SSW) (Katz, 1962). Results of the procedures were variable, with higher percentage of abnormalities obtained with the CV test, followed by the SSI and finally the SSW. These findings suggest that braistem lesions may influence higher order auditory processing as measured by certain dichotic test procedures. It is generally agreed that the central auditory system could be adversely insulted with little or no neurological or peripheral evidence of abnormality. The results of Jackobson et al (1983) study suggested that the use of certain dichotic speech paradigms may contribute in the overall diagnosis of multiple sclerosis.

Studies on patients with multiple sclerosis (Jackbson et al. 1983) have again revealed poor performance on dichotic tests. It was reported that the greater percentage of abnormalities was obtained with the dichotic CV test, than with the SSI or the SSW test. These findings suggested that brain stem lesions influenced higher order auditory processing and that the use of certain dichotic speech tests would help in the overall diagnosis of such deficits.

Effects Of Peripheral Hearing Loss On Dichotic Listening Tasks

A number of experiments have been designed to investigate the effects of a bilateral moderate sensorineural hearing loss on the central processing of dichotic CV syllables. Roeser et al. (1976) and Cattley (1977) indicated that subjects with such losses failed to demonstrate right ear advantage (REA). Both studies indicated that a sensorineural hearing loss affects the central processing of dichotic CV syllables. Porter (1976) indicated that central processing may be responsible for the lag effect reported by several authors (Berlin et al.1973; Porter, 1974 and Berlin and McNeil, 1976). Cattey (1981) investigated the effects of a sensorineural hearing loss on the central processing of dichotic CV syllables, by establishing the function of the lagging dichotic syllable in subjects with sensorineural hearing losses. Results showed that the right ear advantage existed even when the lagging syllable was presented to the left ear and was not enhanced when the lagging syllable was presented. to the right ear.

Speaks and Niccum (r985) studied the effects of stimulus material on the dichotic listening performance of patients with bilateral mild sensorineural hearing loss. They tested the performance of 27 patients with sensorineural hearing loss in response to four dichotic speech tests : digits, vowel words (e.g. key vs. cow), consonant words (fan vs. pan) and CV non-sense syllables. Monotic performance intensity function for each ear was defined. The four dichotic tests produced reliable differences among scores for the left ear and right ear, performance level and the ear advantage. The digit test, however, appeared most promising for assessing central auditory function when the patient had a sensorineural hearing loss, because performance for digits was only slightly affected by the peripheral loss. It was not possible to estimate with confidence, the true contribution of the hearing loss on the dichotic test results because the scores for left and right ears, that would have been obtained with the sample of patients in the absence of a hearing loss, could not be known. The authors however believed that the digit test was most promising as a test of central auditory function, because it seemed to be relatively insensitive to the presence of peripheral hearing-impairment.

Speaks et al. (1983) in an experiment, assessed the extent to which a peripheral hearing loss may confound interpretation of dichotic listening test and assessment of central auditory deficit. In their study a normal hearing listener was tested monotically and dichotically with nonsense CV syllables in two conditions. In one, an ear plug was inserted in the ear canal to simulate a unilateral conductive hearing loss. In the second condition, no plug was inserted. It was seen that with the plug inserted, both magnitude and direction of ear advantage varied. In other words, the inserted plug produced a reasonably pure loss in sensitivity.

Thus, it has been found by various researchers that a peripheral hearing loss does effect the scores of a dichotic test. Both the magnitude and the direction of ear advantage are altered.

From the review of literature on dichotic listning, it is found that several variables such as the stimulus material, frequency, intensity and temporal factors, stimulus dominance and also the presence of central and peripheral abnormalities influence the scores. However, studies on individuals with various disorders reveals that dichotic tests yield useful information for diagnosis.

METHODOLOGY

SUBJECTS

The subjects were fifty normal young adults (25 males and 25 females) ranging in age from 18 to 27 years. Subjects selected for the present study were those who

i) had no known history of hearing loss
ii) no chronic otologic problems
iii) no neurologic problems or brain trauma
iv) no previous experience with dichotic listening tasks
v) all subjects were right handed

All subjects were initially tested to ensure normal auditory function and had to fulfill the following criteria to be selected:

i) 15 dB HL or better puretone air conduction and bone conduction thresholds for the frequencies 250 Hz - 8000 Hz and 250 Hz - 4000 Hz respectively.

ii) Speech-reception thresholds (SRT) that were +10 dB of the three frequency pure tone averages. The SRT was established using the tests either, the W-22 word list in English developed by Hirsh (1965) or the Kannada version developed by Rajashekhar (1976). Depending on the language the subjects were familiar with, they were administered either the Kannada or the English SRT test.

iii) Speech discrimination score of 100% at 40 dB SL (re: SRT). PB max material developed and standardized by Mayadevi (1974) was used.

iv) On monotic presentation of the CVs used in the present study, at least 25 out of 30 stimuli should be correct. For the monotic presentation the single track of the dichotic test was presented to each ear separately.

DICHOTIC MATERIAL

The dichotic material consisted of thirty randomized pairs of the stop consonant-vowels (CVs) /pa/, /ta/, /ka/, /ba/, /da/, /ga/, in which each of the initial consonants appeared in all possible combinations. The dichotic CV test, developed by Yathiraj (1994)* at CID, St.Louis was used. The CVs were recorded on two tracks using a computer software program called Sound Ed.Pro. The CVs were generated such that the onsets of the pairs were simultaneous (at 0 msec), or delayed at asynchronies of 30 msec and 90 msec,

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

with 30 pairs in each condition for both right and left lag conditions. That is, the stimuli were presented in the following manner:

i) at 0 msec, onset where the stimuli occurred in both ears simultaneously.

ii) with a 30 msec, right ear lag, where the syllable in the right ear was presented after a lag time of 30 msec.

iii) with a 30 msec, left ear lag, where the syllable in the left ear was presented after a lag time of 30 msec.

iv) with a 90 msec, right ear lag, where the syllable in the right ear was presented after a lag time of 90 msec.

v) with a 90 msec, left ear lag, where the syllable in the left ear was presented after a lag time of 90 msec.

Prior to each list, a 1 KHz calibration tone was recorded. The output from the computer was recorded on to a magnetic tape.

Thus, five lists, each consisting of thirty randomized pairs of stop CVs at different onset time asynchronies were compiled. The five lists were randomized using a statistical random table (Mahajan, 1990) to form two sets.

These two sets were recorded separately on an audio cassette (MELTRACK) using a tape deck (SONY FH-411R). Each set contained all five lists.

INSTRUMENTATION

Initial testing, to ensure normal auditory function was carried out using a clinical audiometer (MADSEN-OB 822} coupled to acoustically matched earphones (TDH-39) and bone vibrator (RADIOEAR B-71). The responses were noted down on a score sheet (Appendix-A). For the dichotic CV test, the audio cassette, consisting of the dichotic stimuli, was played on a tape recorder, (PHILIPS-AW 606). The signal from the tape-recorder was fed to the tape input of the audiometer. The output of the audiometer was given to earphones (TDH-39) housed in ear cushions (MX-41/AR). 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.

PROCEDURE

Subjects who passed the subject selection criteria were administered the dichotic CV test. The VU meter was adjusted to the 1 KHz calibration tone. The dichotic stimuli were presented at an intensity level of 70 dB HL. Of the two sets, so formed one set was givento25 subjects and the other set was given go another 25 subjects. Subjects were instructed to respond on a multiple choice answer form (Appendix-B). The task involved circling the two CVs heard (from among six printed forced choice alternative) after each presentation. They were also told to guess if unsure of the correct answers. Subject responses were scored in terms of single correct scores (total number of correct responses for the right ear or the total number of correct responses for the left ear). The double correct responses were also scored (i.e. when the subject correctly reported both the stimuli presented to the two ears). The raw data was subjected to statistical analysis where the mean, the range and standard deviation were calculated. The t-test was used to find the significance of difference for various parameters which are discussed in the following chapter.

RESULTS AND DISCUSSION

In this chapter, the results obtained from the present study are discussed. The results were analyzed by calculating the mean, standard-deviation and the range. The t-test was used to find the significance of difference between scores for the different parameters. Analysis was done to obtain information on :

i) Single correct scores (i.e. correct responses for either the left ear or right ear) at simultaneity and different onset time asynchronies.

ii) Double correct scores (i.e. scores obtained when the subject reports both the stimuli correctly, when stimuli are presented simultaneously) at simultaneity and different onset time asynchronies.

SINGLE CORRECT SCORES AT SIMULTANEITY

Table-1 : Mean, Standard Deviation (SD), Range and t-scores and level of significance for single correct responses (Lt and Rt), at simultaneity.

Ear	Mean	S.D.	Range	t-scores	Level of significance
Right	19.3	4.38	12-29	4.69	.01
Left	14.8	5.21	8-27		

Max. Scores = 30.

Table-2 : Single correct scores (Lt and Rt) and averaged scores (in %) for 50 normal subjects at simultaneity.

Ear	% Correct Scores	Range in%
Right	64.3	40 - 96
Left	49.3	26 - 90
Average score for RE & LE (in %)	56.5%	

RE : Right ear; LE : Left ear

Table-1 gives the mean values, standard deviation, the range and t-scores along with the level of significance for the single correct scores at simultaneity.

The values given in table-2 are the percentage of scores for each ear and the average of the right and left ear scores at simultaneity or 0 msec.lag.

At simultaneity, the right ear scores were found to he greater than the left ear scores and this difference in scores was statistically significant. As depicted in table-2, the average scores obtained at simultaneity (0 msec) was 56.5%, where the scores for the right ear was 64.3% and the left ear score was 49.3%. The results obtained from the present study are consistent with results from studies conducted on the Western population by Berlin et al. (1973). Berlin et al. (1973) reported that there existed a right ear advantage (REA) for dichotic speech stimuli. This REA is seen in normals because the left anterior temporal lobe is closer to the left primary speech areas than the right anterior temporal lobe. Therefore, it is postulated that there is less 'transmission loss' to the left posterior-temporal-parietal lobe on the basis of proximity within areas of the brain. Due to this proximity there is more efficient interaction between the shorter pathways. Similar findings have been reported in studies conducted by Studdert-Kennedy and Shankweiler (1967). They reported of a right ear superiority in the perception of speech stimuli, when normal hearing listeners are stimulated dichotically with speech stimuli.

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

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

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

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

Studdert-Kennedy (1967) presented synthetic CV syllables and steady state vowels dichotically and found a right ear advantage similar to one found for meaningful words. However, right ear superiority was larger for CV syllables and relatively smaller for vowels.

Experiments conducted by Tartter (1984) demonstrated a significant right ear advantage for consonant judgments.

Thus, the results of the present study indicated that there existed a significant REA for the dichotically presented CV stimuli even in the Indian population.

Single Correct Scores at Different Onset Time Asynchronies

Table-3 : Mean, Standard deviation (SD), Range and t-scores and the level of significance for single correct response (Lt and Rt) at different onset time asynchronies.

Lag Time	Ear	Mean	SD	Range	t-scores	Level of significance
30 ms R Lag	RE	20.9	4.27	11-28	7.52	0.01
	LE	15.8	2.26	5-28		
30 ms L Lag	RE	18.3	4.37	9-28	1.12	Not Significant
	LE	19.2	4.56	13-30		
90 ms R Lag	RE	22	4.47	10-29	1.76	.05
	LE	20.2	5.72	10-29		
90 ms L Lag	RE	20.3	5.09	9-30	.42	Not Significant
	LE	21	10.42	15-28		

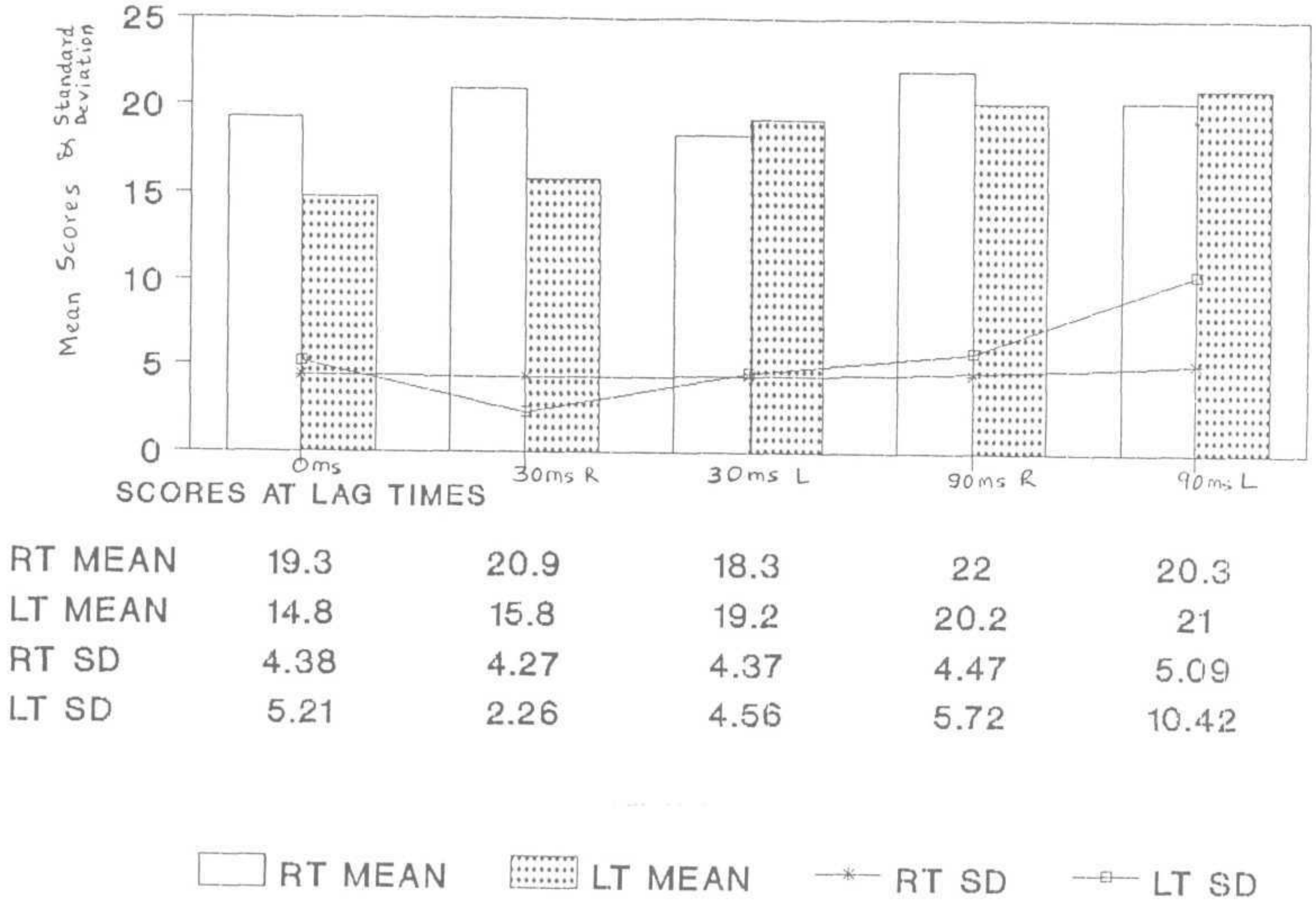
Max. Scores = 30

Table-4 : Single correct scores (Rt and Lt) and averaged scores (in %) at different onset time asynchronies.

Lag time	Ear	% scores	Range (in %)
30 ms R Lag	RE	69.6%	36.6 - 93
	LE	52.6%	16 - 93
	AC	61.1%	
30 ms L Lag	RE	60%	30 - 93
	LE	61%	43 - 100
	AC	60.5%	
90 ms R Lag	RE	73%	33 - 96
	LE	67.3%	33 - 96
	AC	70.3%	
90 ms L Lag	RE	67.6%	30 - 100
	LE	70%	50 - 93
	AC	68.8%	

AC - Average correct scores (in %)

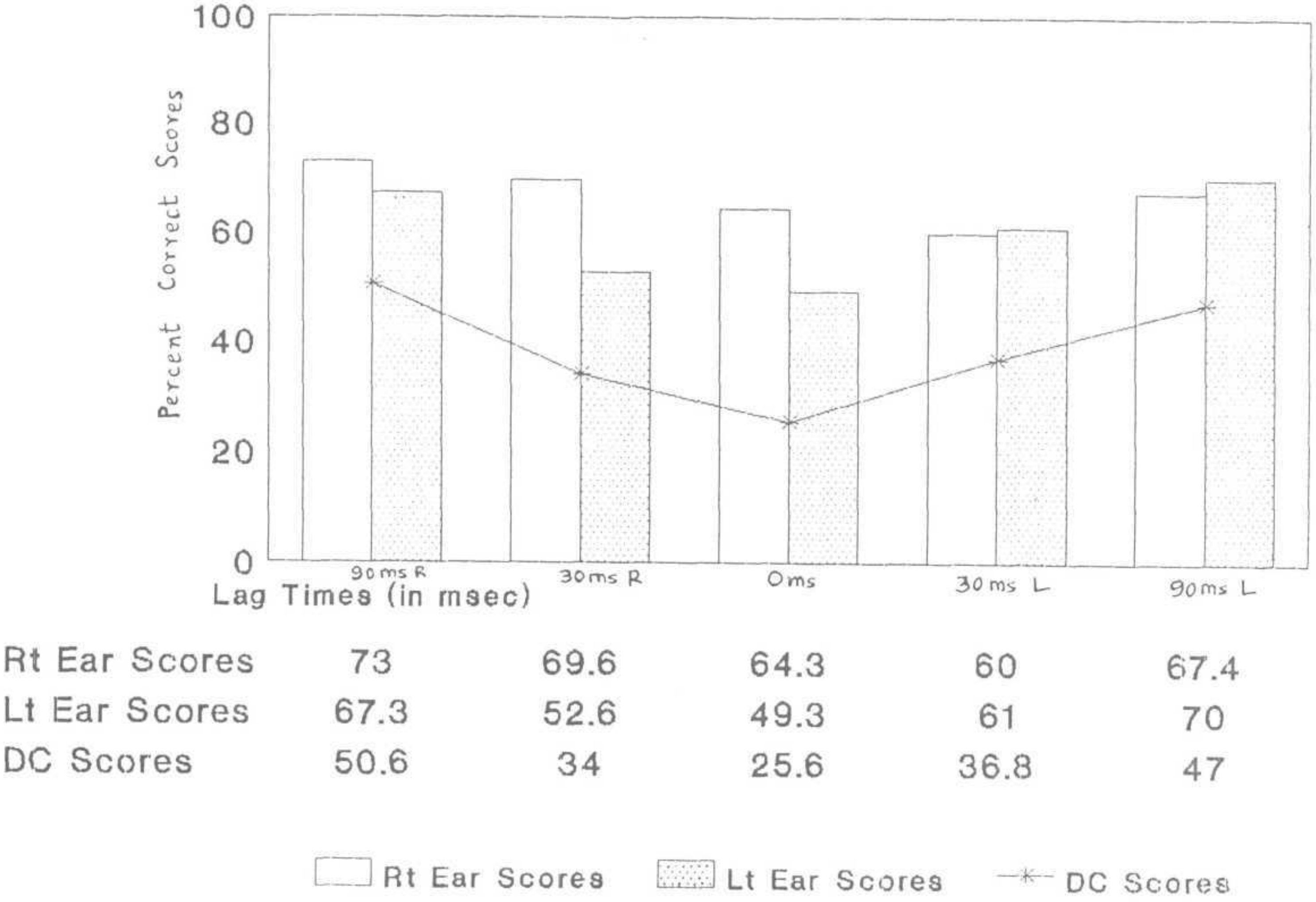
Table-3 depicts the mean scores, standard deviation, the range and t-scores along with the level of significance. Table-4 gives the percent correct scores for each ear at different onset time asvnchronies and the average scores are also given in percentage.



	0ms	30ms R	30ms L	90ms R	90ms L
RT MEAN	19.3	20.9	18.3	22	20.3
LT MEAN	14.8	15.8	19.2	20.2	21
RT SD	4.38	4.27	4.37	4.47	5.09
LT SD	5.21	2.26	4.56	5.72	10.42

Fig.1

Fig.1 is the graphical representation of the mean and standard deviation for the right and left ear at different onset time asynchronies.



	90ms R	30ms R	0ms	30ms L	90ms L
Rt Ear Scores	73	69.6	64.3	60	67.4
Lt Ear Scores	67.3	52.6	49.3	61	70
DC Scores	50.6	34	25.6	36.8	47

Fig.2

Fig.2 depicts the single correct and double correct scores at different onset time asynchronies. The scores are given in percentage.

On analyzing the data using t-test for the single correct scores, it was seen that the lowest mean single correct scores were at the shortest onset time asynchrony, and the highest mean scores were obtained when the lag times increased.

RIGHT LAG CONDITION

When a 30 msec, or a 90 msec, lag was given to the right ear, higher scores were obtained for the lagging ear (Table 3 and 4, Fig.l and 2). The difference in scores between the right ear and left ear was found to be statistically significant.

LEFT LAG CONDITION

When a 30 msec, or a 90 msec, lag was qiven to the left ear,higher scores were obtained for the lagging ear (table 3 and 4, fig.l and 2). However, unlike in the right lag condition, the difference in scores between the two ears, was not statistically significant, when the lag was given the left ear. This could be explained on the basis of the left hemisphere superiority for processing speech material, during dichotic presentation and due to greater number of contralateral auditory fibers crossing over to the left hemisphere. Hence, this would indicate that the right ear performance is not completely suppressed even when a lag is given to the left ear.

The data in table-4 are the norms for the Indian population when the single correct response are calculated. Results from the present study revealed that higher scores were obtained for the ear in which the lagging syllable was presented. These results are in accordance with results obtained from studies on the Western population by Berlin et al. (1972). When normal hearing listeners are stimulated dichotically with speech material, there is a right ear advantage observed. However, when the stimuli are presented to the ears at onset time asynchronies of approximately 30 to 90 msec, the lagging member of the pair is perceived more accurately than the stimulus presented first. In a study by Berlin (1972), the amount of time separation between message onsets, necessary to overcome the right ear advantage was investigated. It was found that when one of the CVs trailed the other by 30-60 msec, the trailing CV became more intelligible than when it was given simultaneously.

Table-5 : Comparison of difference in single correct scores (in %) at simultaneity and across lag times.

Lag Ear	Comparison between lag times	Mean Scores (%)	t-scores	Level of significance
Right	0 ms	64.3	1.86	.05
	30 ms	69.6		
	0 ms	64.3	3.07	.01
	90 ms	73.3		
	30 ms	69.6	1.27	Not Significant
	90 ms	73.3		
Left	0 ms	49.3	4.58	.01
	30 ms	60		
	0 ms	49.3	6.07	.01
	90 ms	70		
	30 ms	60	1.91	Not Significant
	90 ms	70		

Table-5, highlights the difference in single correct scores at simultaneity with the different lag times. As indicated in Table-5 and Fig.2, it was seen that scores improved significantly when the lag times were increased from 0 msec, to 30 msec, to 90 msec. respectively. The difference in scores were found to be statistically significant, when the lag times increased from 0 msec, to 30 msec. or when increased from 0 msec, to 90 msec. Hence, despite an improvement in scores when the lag time was increased from 30 msec, to 90 msec, it was not found to be statistically significant. The results from the present study indicated that normals would show significant differences between scores as a function of longer onset time asynchronies.

The results obtained from this study are in accordance with previous studies by Berlin et al. (1972), Kirstein (1971) and the results confirmed the presence of a lag effect, where scores improved as the lag times were increased from 0 msec, to 30 msec, to 90 msec. Studies that confirmed the presence of a lag effect found that it was most obvious at 0 msec, to 90 msec. (Berlin et al. 1972; Noffsinger, et al. 1978) . The present study also indicated that the lag effect was most obvious as lag times varied from 0 msec, to 90 msec.

Double Correct Scores At Simultaneity and at Different Onset time asynchronies

Table-6 : Mean, Standard deviation (3D) and Range, for the double correct responses.

Lag times	Mean	Standard deviation	Range
0 msec	7.68	3.1	0-22
30 ms R Lag	10.24	3.4	0-22
30 ms L Lag	11.6	4.27	4-29
90 ms R Lag	15.2	5.4	1-27
90 ms L Lag	14.2	6.4	1-28

Max. score = 30.

Table-7 : Double Correct Scores (in %) at different onset time asynchronies

0 ms	30 ms (R) Lag	30 ms (L) Lag	30 ms (R) Lag	90 ms (L) Lag
25.6%	34%	36.8%	50.6%	47%

Table-6 depicts the mean scores, the standard deviation, and the range Tble-7 gives percent correct scores for the double correct scores. The double correct scores (in %) at the various onset time asynchronies in comparison with the single correct responses are illustrated . in Figure-2.

On analyzing the scores for the double correct responses, it was seen that scores improved as a function of onset time asynchronies. This was true for both the right and left lag conditions. Here too, the lowest double correct scores were obtained for the shortest onset time asynchrony and scores improved as the lag times increased (Table 6 and 7). However, on the whole, the double correct scores were found to be lower when compared to the single correct scores (Fig.2) at simultaneity and at different onset time asynchronies. The range was also calculated which showed the double correct scores to be highly variable across subjects.

It is suggested that the single correct scores be used to calculate the norms rather than the double correct scores because of the high variability in scores of the latter among subjects. Hence, the computation of double correct responses would not be recommended as it did not provide accurate measurement of the ear performance. This finding is in accordance with the finding by Dermody et al. (1983) where they found that the double correct scores do not provide information about differential ear effects, when compared to the single correct scores.

In conclusion, analysis of the results obtained from the present study revealed that -

i) there existed a significant right ear advantage for dichotically presented speech stimuli.

ii) there existed a lag effect, where higher scores were obtained for the ear in which the lagging syllable was presented.

iii) there was a statistically significant improvement in scores as the lag times were increased from 0 msec. to 30 msec, to 90 msec, respectively. But there was no statistically significant improvement in scores when lag times were increased from 30msec. to 90 msec.

iv) It is suggested that the single correct scores be used to calculate the scores for the dichotic CV tests because of the high variability for the double correct scores seen across the subjects.

SUMMARY AND CONCLUSIONS

The purpose of the present study was to generate normative data for the dichotic CV test, on the Indian population. The CV test administered was developed by Yathiraj at CID, St. Louis. The task involved identification of dichotic non-sense syllable (CVs) at various onset time asynchronies (lag times). The lag times used in the present study were that of 0 msec, lag, 30 msec, lag and 90 msec. lag. The lags were given in either the left ear or the right ear.

The subjects taken for the study were fifty, right handed normal young Indian adults in the age range of 18-27 years. None of the subjects had history of any neurological involvement and were initially tested to ensure normal auditory functioning prior to administering the dichotic CV test. The responses were scored in terms of single correct and double correct responses. The raw data was subjected to statistical analysis using t-test. The mean, standard deviation and range were also calculated. The results from the present study supported the hypothesis consistent with previous studies by Berlin and Lowe-Bell (1973), Kirstein (1971).

The results were as follows :

i) There existed a significant right ear advantage for the dichotic stimuli.

ii) There existed a difference in scores as a function of onset time asynchrony (lag time). That is, the scores improved as the lag times increased from 0 msec, to 30 msec to 90 msec respectively. There was a statistically significant improvement in scores when the lag times were increased from 0 msec, to 30 msec, and from 0 msec, to 90 msec. However, when the lag time was increased from 30 msec, to 90 msec, there was an improvement in scores but the difference in scores was not statistically significant.

iii) On comparing the single correct and double correct scores, it was found that the variability was greater for the latter. Since the variability for the single correct score was much lesser, it is recommended that single correct scores be utilized while scoring the responses on the dichotic CV test.

It was found that normal, young adults get an average score of 56.5% at 0 msec, lag time, 61.1% for a 30 msec, left lag condition, 70.3% for a 90 msec, right lag condition and a score of 68.8% for a 90 msec. left lag condition. These findings are obtained when the average single ear scores are calculated. The variations seen from the average scores have been discussed.

In conclusion, the findings of the present study on the Indian population are consistent with the findings obtained on the Western population. Thus, a similar trend is seen in the performance of normals on a dichotic CV test across populations exposed to various linguistic backgrounds. The present study hence revealed that the dichotic CV test is a language free test and can be administered on a multilingual population without adversely affecting the results.

FUTURE IMPLICATIONS

Dichotic listening tasks can be used in the identification of potential cortical lesions. Hence the dichotic CV test can be incorporated as part of the CANS evaluation battery, to evaluate the central auditory processing in the Indian population. It is anticipated that future utilization of this test will better our understanding of the central auditory nervous system in the elderly population and in the disordered population.

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APPENDIX-A

Name
Date
Age/Sex
Mother Tongue
Education/ Qualification
Other Languges Known
Occupation
Socio Economic Status
HANDEDNESS

AUDIOLOGICAL INVESTIGATION

Ear			Frequency in Hz			PTA	SRT	PB
	250	500	1000	2000	4000	8000		Max
Right								
Left								
BC THRESHOLD								

Monotic Scores (%) Right Ear Left Ear

Dichotic Scores (%)

R	L	R	L	R	L	R	L	R	L

APPENDIX-B

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.