BINAURAL FUSION TEST IS AN ALTERNATIVE TO MASKING IN PURE-TONE AIR-CONDUCTION AUDIOMETRY

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DECICATED TO THOSE FOR WHOM
THE NATURE HAS DENIED THE PRECIOUS
GIFT OF COMMUNICATION

CERTIFICATE

This is to certify that the dissertation “Binaural Fusion Test as an alternative to masking in Pure-tone air-conduction audiometry” is the bonafide work in part fulfillment for the Degree of M.Sc., Speech and Hearing, carrying 100 marks, of the student with Register No.16.

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DECLARATION

This dissertation is the result of my own study undertaken under the guidance of Mr. S.P.C. Pandalay, Lecture 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.

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CHAPTER I

INTRODUCTION

The measurement of puretone air-conduction thresholds is basic to, any consideration of clinical audiology. The principles of the first commercial clinical audiometer was presented in 1922 by the otologist Fowler and the physicist Wegel. In clinical practice puretone thresholds are determined for two main purposes:

1. to assist in the diagnosis of ear pathology, and
2. to acquire information which may be used in obtaining appropriate habilitation or rehabilitation programmes for hearing-impaired persons (David S. Green)

The task of obtaining puretone threshold measurements that are both reliable and valid is not a simple one. Many factors like calibration of the instrument, instruction to the patient, mode of responses demanded physiological conditions of the patient etc. would affect the test procedure.

Despite this the most important source of error is produced by the participation of the non-test ear. The first recognition of the need to mask a good ear while testing the poorer ear was made by Jones and Knudsen who introduced the use of noise in their audiometer. Though the need for masking has been recognized widely by all the clinicians, no one procedure is being accepted as a standard one. There is a lot of controversy over the methods of masking, the types of masking noise to be used, and the criteria for masking.

The problems of masking during audiometry are very many. To mention a few are:

1. What is the main amount of noise to be given to the non-test ear?

2. What is the maximum amount of noise that can be given without the danger of overmasking?

3. The problem of finding an efficient masker.

4. Calibration of masking noise in terms of effective masking levels creates problems.

5. The problem of central masking which raises the threshold of a tone in the test ear by upto 5 dB even though the level of masking stimulus is so low that the change cannot be attributed to the sound leaking around the head or to arousal of the acoustic reflex.
6. When we consider the narrow band noise as an efficient masker in pure-tone audiometry, it is more expensive than other types of noises.

By considering all these problems of conventional masking through air-conduction, the clinicians are of the opinion that a satisfactory substitute for masking in both and bone conduction audiometry must be developed.

These problems of masking can be overcome if Binaural Fusion Threshold technique is used. Feldman and Berger have critically evaluated the Binaural Fusion Test and have recommended that the technique should be used to a clinical tool.

The usefulness of Binaural fusion test is evidence if we consider the merits.

1. The subject finds the test more interesting
2. Tinnitus interferes with the listener’s judgment of the presence of the test tone in conventional audiometry. Binaural Fusion test overcomes this difficulty.
3. This has been extremely useful for the functional hearing loss patients where the thresholds are inconsistent for whatever reason.
4. The test measures the puretone air-conduction thresholds with the same reliability as conventional audiometry, without the use of masking noise. Hence the problem of masking noise is eliminated.
5. It is important to know for a test procedure that false positive findings will not occur. The Binarual fusion test is a satisfactory test in this regard as the results are uninfluenced by the tendency of the patient to give a shadow curve on a non-hearing ear.
6. Problems like when and when ear to mask, how much to mask, do not arise.

Every test will have some demerits and this also is not an exception to it. But the limitations compared with those of masking procedures are a few:

The major disadvantage of this technique is that it cannot be effectively used for children below 10 yrs. of age.

Another disadvantage of this technique is that the test requires either a two channeled audiometer or two perfectly synchronized single channeled audiometers which derive sinusoidal waves of the same frequency and which are in phase.

Another disadvantage stems from the clinical experience that it the patients with diplacusis, where two puretones of a particular frequency when administered at a particular sensation level are perceived separately the Binaural fusion test cannot be administered effectively since there would not be any fusion of the sound images.

In view of these discrepant reports, an attempt has been made here to find out if the technique can be used as an effective tool wherever masking is indicated. As the technique requires the thresholds of air-conduction obtained using masking noise and also thresholds obtained through the Binaural fusion test, the same have been determined on normals and pathological cases where there is aneed for masking through air-conduction.

No systematic study has yet been conducted to check the applicability of Binaural Fusion as a test with the Indian population. This will be an attempt to find out if binaural Fusion Test could be effectively employed as a substitute for masking in determining the puretone air-conduction thresholds in the clinical situation.

Statement of the problem:

The problems for the study was "could be Binaural Fusion Test be used on Indian population as a substitute to masking in pure-tone air-conduction audiometry with the same efficiency as that of masking?"

Statement of the hypothesis:

The study was planned to test the following null hypothesis:

“There is no significant difference between the masked air-conduction thresholds and the Binaural Fusion thresholds in all the pathological groups”.

Purpose of the study:

The purpose of the study was to evaluate the efficiency and utility of the Binaural fusion test in the determination of Pure-tone air-conduction thresholds as a substitute to masking in India settings.

Brief plan of the study:

33 Normal subjects and 100 pathological cases were tested for the study. Masked air-conduction thresholds of the pathological cases wee obtained using narrowband masking noise. Binaural Fusion Test was administered on these patients using a BEL-2 channeled audiometer of K-232 type and Beyer DT 48 earphones in an acoustically treated room. Normals were tested to see how they respond to the Binaural Fusion Test. Both the tests covered the frequency range from 250 Hz to 8 Khz.

The data was gathered and the Wilcoxon matched pairs signed ranks rest and product-moment correlation test were applied.

Limits of the study:

The present study is restricted to,

1. those cases who are above 15 years,
2. those cases whose air-conduction thresholds between the ears differ by more than 30dB or whose BC thresholds of the non-test ear and the Air-conduction threshold of the test ear differ by more than 30 dB. To say briefly, all those cases who need masking in order to eliminate the participations of the non-test ear, through air-conduction.

Definition of the terms used:

Air conduction:

A term used by clinicians to indicate the path through the air in the external ear canal and across the middle ear by which sound travels to the inner ear (Glorig A. 1965, p 244).

Narrow-band noise:

> Sound in which energy is concentrated within a small frequency interval (Glorig A. 1965, p 251).

White band noise:

> Sound in which energy is present over a wide range of frequencies. Those frequencies close to the specific one being tested cause masking interference (Glorig A. 1965, p 251).

Masking noise:

> Sound used deliberately to raise the threshold of audibility for a stimulus signal (Glorig A. 1965, p 251).

Masking:

> Masking is best defined operationally as an elevation in the threshold of one signal produced by the introduction of a second signal (Studebaker G.A. 1967 JSHD p 360).

Threshold:

> The minimal value of sound wave pressure which will produce a sensation of tone from a given frequency (Glorig A. 1965, p 254).

Sensation level:

Sensation level is the pressure level of the sound in decibels above its threshold of audibility for the individual observer or for a specified group of individuals (American Standard Acoustical terminology) (1960).

Binaural Fusion:

When two sinusoidal tones are presented simultaneously to both the ears through air-conduction at the same sensation level the tones interact and will be heard as one in normals at the midline of the head if both the tones are in phase and are of the same frequency. This phenomenon is called as 'Binaural fusion'.

Binaural Fusion Threshold:

Binaural Fusion Threshold is the level at which the interaction of 2 tones of same frequency takes place when presented simultaneously to both the ears.

Normal ear:

The ear with no apparent abnormalities revealed either by history or by ENT examination and with the hearing sensitivity for frequency 250 to 8 KHz below 20 dB.

CHAPTER II

REVIEW OF LITERATURE

The review of literature begins with an attempt to trace the development of air-conduction tests. Nest it deals with the problems involved in conventional air conduction testing with special reference to masking. Further the development of Binaural fusion test and various studies using this technique are dealt with.

The term ‘Audiometry’ originally meant only the measurement of auditory threshold for pure tones. But the field of audiometry now embraces purtone audiometry speech audiometry, screening audiometry and recently automatic audiomtry and electro-physiological audiometry.

Audiometry may be divided under broad subfields on the basis of type of stimulus used to elicit auditory responses. Puretone audiometry and speech audiometry. Puretone audiometry is used primarily to determine air conduction and bone conduction thresholds of hearing which are necessary for diagnostic evolutions.

The development of the audiometer, like many other scientific advancements, cannot be wholly attributed to any man of genius. The point of time that made the audiometer possible was the year 1875, when Alexander Graham Bell first introduced the electric telephone. The rapidity with which the principles of the telephone was applied to the problems of hearing tests indicates that the time was indeed ripe for the development of a hearing testing device. By January 1978, Arthur Hartman, head of Otolaryngology in a Berlin Hospital, reported that he had devised an 'Acoumeter' (in German 'Hornesses') which utilized a telephone receiver for the purpose of testing hearing. The principle of this instrument and all other instruments developed till 1914 was same – a tuning fork placed in the primary circuits of an induction coil interrupting the circuit at regular intervals. The interruptions induced an alternating current in the secondary circuit of which the telephone receiver was a part.

In 1879, D.E. Hughes, in England described an 'Induction balance' originally used to analyze metals, but applied with a tuning fork to the testing of hearing. He called this instrument an 'electric sonameter' but it inspired the first use of the term audiometer. It was Richardsen in 1879 who christened it the 'audiometer'.

Seashore in 1899 arranged the secondary winding as a series of coils in which the number of tunes varied in a longitudinal ratio. This gave variations in the loudness of the stimulus to correspond with the Weber Fechner law. This was the first introduction of the term audiometer into America.

In 1914, A Stefanine of Italy constructed an instrument which made the modern audiometer possible. This was an electric generator producing an alternating current with a complete range of frequencies. On the basis of Stefanine's principles Dean L.W., Head of the department of otolaryngology, Iowa and Bunch C.C., his assistant applied the electric generator to the first clinically useful "Pitch range audiometer" in 1919 (so named because it produced tones for 30 to 10000 Kc/s.)

After Dean and Bunch's contribution, the application of vacuum tubes to audiometer was reported by Minton, Wilson and Guttman 1921. The principles of the first commercial clinical audiometer were presented in 1922 by the otologist Fowler and the Physiologist Wegel. But he great otologist and educator, Max' Goldstein objected the use of air conduction tests without the knowledge of bone conduction which could be tested easily with the tuning fork. The use of a bone conduction receiver in connection with the puretone audiometer was finally reported in 1924 by Jones and Knudsen.

In reviewing the evaluation of tests of hearing capacity we find that in the early days of hearing testing the major aim was merely to discover if the individual has a hearing loss. Such an approach did not require the specification of the severity of loss. Thus it was possible to utilize very arude testing devices, such as the speaking voice, the whisper, the clicking of coins, the ticking of watch, or the observations of reactions to environmental sounds. Since hearing loss was considered a loss of sensory function that could not be alleviated, the individual possessing such a difficulty was 'labeled' and those around him reacted accordingly.

In a limited way these tests saved their purpose, but they did not offer the diagnostician information that was specific enough to plan any type of therapy programme. Investigators and clinicians therefore began directing their efforts towards discovering those frequencies or tones a person did not hear, thus making a qualitative analysis of the particular sounds that were not heard.

With the introduction of the tuning fork into clinical testing procedures it was possible to generate a relatively puretone stimulus within a frequency range from 16 c/s to 4000 c/s. Several specially constructed sets of tuning forks were in this testing, including those developed by Bruhl and Hartmann.

To differentiate conductive and sensori-neural loss many tuning fork tests have been used, namely Rinae, Weber and Schwabach. Other tuning fork tests like Gelle and Bing have been used to find the middle ear pathology. Gelle test assists in finding otosclerosis Bing test has been used to know whether the middle ear has normal functions.

Inspite of the variety of instruments used to test hearing, none provide for satisfactory control of the intensity of the stimulus alone. Also, testing was essentially "Sound-field" testing since ear-phone were not adaptable to such instruments.

With the advent of the diagnostic tuning-fork tests the testing horizon was broadened. One of the first attempts to develop a pure-tone audiometer was made by Hartmann in 1878. Audiometric testing techniques have taken many years to develop through trial and error and through experimentation. The principal objective of pure-tone audiometry is to determine the sensitivity of the human auditory system. A more sophisticated view holds that purtone audiometry is a measure of the sensori-neural apparatus and the adequacy of the mechanical system of the ear. Thus, tests of bone conduction acuity provide information for the first area while air conduction testing provides us with some information about both ears.

One of the major problems in audiometry is that of determining thresholds in monaural and asymmetrical binaural hearing losses. The clinician confronted with a patient whose two ears differ in acuity may have serious difficulty in obtaining accurate measures of hearing for the poorer ear, under such circumstances the clinician may arrive at estimates of hearing for the poorer ear that are better than the actual theresholds in that ear. Such erroneous results may even lead to attempted middle ear surgery on an ear having a profound sensori-neural hearing loss.

When the two ears differ sufficiently in acuity the intensity of the tone presented to the poorer ear may be used to such a level that it is heard in the better ear either across the head by air-conduction or through the head by bone conduction. A number of investigators (Hood 1960, Liden 1954, Liden, Nilsson and Anderson 1959, Zwislocki 1953) have shown that puretones may cross the head by air-conduction when air-conduction thresholds differ by 50-60 dB.

The problem is complicated still further by the fact that false air-conduction thresholds at the 50-60dB hearing level can be obtained in the poorer ear even when the better ear exhibits a 50-60 dB air–conduction loss if bone conduction thresholds in the better ear are at about 0 dB hearing level. In this instance, the test tone presented to the poorer ear by air-conduction at hearing level of 50 to 60 dB has reached an intensity level sufficient to stimulate the chochlea by none conduction. (Studebaker 1964).

As a result of cross-over of the test-tone an audiogram may be obtained for the poorer ear showing an air-bone gap with air and bone thresholds considerably better than actual acuity in that ear.

The solution to the problem posed by the patient whose ears differ in sensitivity is to insure that response is from the ear under test by eliminating the possibility of response from the nontest ear. This can be accomplished through the use of a masking noise in the nontest ear. The presence of a masking noise in the better ear shifts its sensitivity to a higher hearing threshold level, permitting the test signal to be presented at higher intensities to the poorer ear without crossover.

Much of the early work was conducted by the Bell Telephone Laboratories. Much earlier Mayer (1894) found that a tone could be rendered inaudible by another tone of lower frequency but not readily by one of higher frequency. Later A series of experiments done at the bell Telephone Laboratories by Wegel and Lane (1924) support Mayer's observation.

Jones and Knudsen's (1924) audiometer was provided with a masking noise device. Their noise apparatus consisted of an ordinary electric buzzer. This produced an interrupted direct current in the coils of the telephone receiver creating a loud noise in the receiver. Here is apparently the first recognition of the need to mask a good ear while testing the poorer ear.

The effectiveness or masking efficiency of a particular noise depends not only upon the intensity but also upon the nature of the noise. Previous studies (Egan 1950, Wegel 1924) have shown that a pure tone can be used to mask other pure tones but that over a range of test frequencies. The masking efficiency of a single frequency is low compared to the efficiency of a noise composed of many frequencies (Sanders and Rintelman 1964).

Masking of Pure Tones by Pure Tones is complicated by the fact that even at fairly low identities, distortion production may arise. These will indicate the presence of the masked tone even though the latter cannot actually be heard by itself. There for most practical instances of masking involve masking of a pure tone by speech or noise. (Glorig 1965).

Although technically there are differences, the term complex nose has come to mean any masking noise composed of a low frequency fundamental plus the multiples of that fundamental. The chief short coming of this is that the acoustic energy is present only at the discrete frequencies and is not speared continuously across the range. This poses a potential problem in masking. Since complex noise is composed of discrete frequencies it is possible for a given component of the noise to be within 3 or 4 cycles, of a test tone, producing a beat or pulsing phenomenon in the ear of the listener between that component and the test tone. As Liden, Nilsson and Anderson (1959) have pointed out, the fifth harmonic of a 50 Hz fundamental will beat with a test tone of 254 Hz.

The second important fact regarding complex noise is that energy decreases as frequency increases. Therefore more practical instances involve masking of a pure tone by white noise.

White noise, sometimes called thermal noise, is defined as a signal containing energy at all frequencies in the audible spectrum at approximately equal intensities, and is generated by the complicated random electron emission of specially designated electronic circuits. This is superior to complex noise, in that the energy is continuous across the spectrum and there is no significant intensity decrease with increased frequency until about 6000 Hz. This has been found to effectively mask the speech but not purtones.

Unfortunately, narrow band masking noises are considerably more expensive than other types of noises. Narrow band masking noises usually are obtained by filtering broad band noise or by means of timed circuits. A separate narrow band masking noise is required for each test frequency by the audiometer (Glorig).

The critical band concept developed by Flectcher (1940) is as follows:

The width of the restricted band of frequencies responsible for masking a puretone is critical. If a band is narrowed to less than the critical width without adding to the energy within the band, its masking effect is decreased. If the band is widened beyond critical width, its masking efficiency is decreased, in that noise is increased in overall intensity without further shift in threshold.

The intensity level within the critical band rather than the overall intensity determined the effectiveness of masking, since the overall level includes energy above and below the critical band which has no masking effect. Thus in determining the relative efficiency of several masking noises, the intensity level of concern to the clinician is the spectrum level within the critical band, often referred to as level per cycle.

The critical band concept will not hold entirely true for a complex noise, since the concept is specific to a noise of continuous and flat spectrum.

Of the three masking noises, narrow band noise clearly should have the greatest masking efficiency if the important factor in terms of intensity if the level per cycle in the critical band rather than the overall intensity.

The intensity calibration of masking noises in terms of effective masking possesses certain serious limitations. The amount of masking indicated on the noise gain control dial assumes that the noise is applied to a normal ear. The dial reading therefore is incorrect when the noise is applied to a “better” ear with a significant hearing impairment.

As Sander says (1964), “of all the clinical procedures used in auditory assessment, masking is probably the most often misused and least understood”. This is better realized when one considers the rules of how much to mask. Avoidance of improper masking intensities requires consideration of a number of factors, including the test signal level, effective level, internal attenuation, and the air-bone gap of each ear. Few clinicians find it feasible to manipulate this number of variable to day-to-day clinical practice. Therefore, various writers have presented procedures designed to simplify the clinician's task. Unfortunately, the simplest procedures provide the greatest opportunity for error. The use of a single masking nose intensity level (Harbert and Sataloff 1955, Hawkins and Stevens 1950, Hood 1960) must result in over and under masking in many cases. The masking effectiveness of a given level of Sawtooth or white noises varies as a function of test-signal frequency by 30 dB or more (Sanders and Rintelman 1964). This factor plus the influence of the hearing loss in each ear, requires frequent adjustments of masker intensity. The procedure is improve substantially if the proposed single level is a single effective level rather than a single intensity level (Studebaker 1964). Even under this condition adjustments must be made when the presentation level exceeds 80 dB hearing level by air-conduction and 40 dB Hearing level by bone-conduction.

A formula approach has been proposed to compute Minimum and Maximum masking levels, (By Liden 1959, Studebaker 1967).

The problems apparent in the formula approach are that the clinician would be required to work out formulae for each patient at each test frequency in order to obtain air and bone conduction thresholds separately. Further the formulae assume that the masking dial is calibrated in effective masking level. Therefore usable clinical procedures must be devised either to avoid or compensate for each of the factors which influence minimum and maximum levels.

Threshold shift is the basis for a number of solutions to the clinical masking level problems.

The procedure based solely on the threshold shift observation was first presented by Hood in 1957. His technique is referred to by various names such as the Platen method, the thresholds shift method, or the shadowing method. His procedure is as follows:

First, find the unmasked threshold, second, apply a masking noise to the nontest ear at an effective level of 10 dB SL. If no threshold shift is observed, threshold is the value obtained without contralateral masking. If the apparent threshold increases, then raise the noise in 10 dB steps, finding threshold at each step until further increases result in no further threshold shifts. The threshold of the tested ear is the value which does not increase with noise level.

This procedure has the following disadvantages:

1. The procedure, as originally presented does not compensation for the occlusion effect.
2. Intersubject variability of effective level and of the occlusion effect may be, in individual cases, sufficient to produce undermasking at the low effective levels used. Therefore, masking should be alteast applied at two levels to insure that the 10 dB SL effective level is not insufficient.
3. If more than the lowest levels are used, there is danger of overmasking in the presence of air-bone gap in the masked ear.

This method does not give not clinician the information necessary to recognize the danger of overmasking.

A second procedure is one reported by Luscher and Konig in 1955 based on earlier work by Zwislock (1951). This method was published by Konig (1962) in English. With this method an audiometer is used which automatically presents to the nontest ear a narrow band noise which centers on the test tone. The noise level is coupled to the test signal attenuator so that the noise level at the opposite ear is always just above the test-signal level, minus interaural attenuation plus occlusion effect. A secondary attenuator is used to increase the noise level above this value in order to compensate for an air-bone gap in the masked ear. In practice, the masking is presented at a just sufficient level automatically, except for the addition of the masked ear, bone gap by the examiner. The masked ear conductive component is estimated when testing the first ear by bone-conduction by noting the difference between the apparent bone-conduction, threshold of the tested ear obtained with the first contralateral masking level and the air-conductive threshold of the masked ear. It is recommended by Luscher and Konig (1955) that an additional 5 to 15 dB be added to compensate for individual variability and that, if there is any doubt threshold shift procedures should be carried out using 5 dB noise level steps.

Disadvantages:

1. The use of low effective levels requires additional noise-level increases of 5 to 15 dB, nullifying some of the advantage of the automatic procedure.
2. Special equipment is required.

A method was published by Studebaker (1964) based on Zwislocki's and Luscher and Konig's work. The method is as follows: First the unmasked threshold is obtained. Second, a noise is presented at an effective level of 40 dB above the bone-conduction threshold of the tested ear. Third, the noise is increased by an mount equal to any observed threshold shift. If a sizeable air-bone gap is observed in the masked ear, a threshold shift procedure is used with the calculated noise level as the starting point. Threshold is the presentation level which doe not shift upon masker application or masking level increase.

Disadvantages:

1. The basis for the procedure is more difficult to understand.
2. The noise levels used are relatively loud.
3. It is necessary to have bone conduction results

before precise masking levels for air conduction tests can be determined.

Another problem that exists with clinical masking is “masking Dilemma” as described by Naunton (1960) in Bilateral conductive loss cases. A conductive loss in the test ear reduces the test signal level but not the noise level at the test cochlea. Therefore the maximum permissible level is decreased by the amount of air-bone gap. In the case of an air-bone gap of about 45 to 50 dB or more, the maximum permissible level for air-conduction tests is equal to the maximum level for bond conductive tests.

In cases like this (Feldman 1961, Naunton 1962, Sanders and Rintelman 1964) it is virtually impossible to adequately mask.

Many authors (Hood 1960, Feldman 1961, Studebaker 1962, 1964) advocate the use of insert earphone to provide the better I.A. They have been reported to increase IA by upto 30 dB over the conventional earphone and cushion.

Insert receivers introduce a unique sort of problems that have probably discouraged their widespread use. Wide individual variations in canal size, the need to clear the inserts between tests, frequency response limitations of the insert system and calibration problems are some of the variables that have retarded general adoption of insert receivers.

Because of such divergent disagreement that exists over the use of masking during air-conduction testing, some use no masking while others routinely employ masking during such testing.

It has long been clear that satisfactory substitute for masking in both air and bone conduction audiometry would be desirable (Bergman. M. 1964).

Researches done by several authors at different times on the Binaural mechanism given hope for the development of Binaural fusion test.

As early as 1849, Joseph Henry has reported the fusion of 2 signals presented binaurally. However, a test based on this phenomenon was reported by Stenger in 1907 to detect feigned unilateral deafness.

Stengers test demonstrated clearly that when we are exposed to a sound presented simultaneously to the two ears, we experience not spate sensations at each ear, but rather a single sound which has a single location. This unitary sensation of two puretones or speech is dependent upon many factors. In pure tone, the time of arrival, phase relations, intensity of the toned and frequency are the important parameters.

Bekesy (1948) explaining the mechanism of Binaural fusion states that when the tones in the two ears are of the same frequency and loudness there need not be any doubling of the loudness because the magnitude of the excitation that passes from one ear into the neural pathways of the other cannot be as large as the excitation in the pathways of this ear itself.

If is of interest to note in this connection that the change of loudness is always attributed to the ear is which the stimulation is greater (Bekesy 1948, Stenger 1907). This is true even if the stimulation in one ear is constant and it is varying in the other ear.

This phenomenon has been observed both for continuous tones of single frequency and clicks (Bekesy 1948).

The interaction of clicks was studied by Bekesy (1948). When a click was introduced into one ear and then the other was stimulated with the same click at an intensity that was gradually raised above threshold, the image was perceived on one side for a time and then it jumped to an intermediate position.

Bekesy (1948) explaining the phenomenon of displacement of the image as follows: It is possible that the velocity of nerve conduction depends upon the sound intensity and in this way an intensity increase produces a time difference between two excitations. Hence changes in the velocity of nerve conduction along the path from the basilar membrane to the cell group determines the perceived direction.

If tow tones introduced into the same ear are too near in frequency, they stimulate the overlapping areas of the basilar membrane , whereupon some degree of masking may occur and may interfere with the summation of the two loudnesses. Strikingly different is the effect when the two tones are led to each ear separately. In this case, summation occurs, but only when the frequencies are close together (Stevens 1957 and Bekesy 1948). It appears that in order for loudness to sum arithmetically, in one ear, the tones must be far apart in frequency, for it to sum in tow ears separately the tones must be identical in frequency.

The claim that the same frequency presented to both ears always gives rise to a unitary pitch (Vander Tweel 1956) is incorrect. One exception to this rule occurs when tonal monaural diplacusis exists (Ward 1955). With this condition, a single frequency may give rise to several tones in a single ear so naturally the tone appears multiple when presented binaurally as well. A binaurally presented single frequency usually sounds single despite having a different pitch in each ear.

When two tones differing only in phase are led to each ear, the listener tends to image the source as located toward the side of the leading phase (Stevart 1922).

A number of investigators have reported Chochelle and Savlinear (1961); Tempest, Jacqueline and Bryan (1969); Hirsh, Hirsh and Pollack, Bergman (1964) that the interaural phase difference of 180^{o} has no effect upon absolute thresholds or upon loudness when tested in quiet. However, Dirks and Jeffress (1962) have reported that a phase change of 180^{o} at one ear significantly increased binaural sensitivity.

The auditory system can under some circumstances respond successfully to two signals as closely spaced as 2-4 msec has been reported by many investigators (Guttman 1965, Babkoff & Sultan 1966) but under other conditions will respond with a single image to identical signals separated in time by intervals much greater than 4 msecs.

It is well established that the binaural threshold of hearing is more sensitive than the monaural and the difference being in the range of 3 dB (Feldman 1967), Bekesy (1948), Tempest, Jacqueline and Bryan (1969), Hirsh (1951), Hughes (1938), Chochelie and Pin, Holloway an Upton). A number of possible explanations for the binaural advantage have been put forward including the hypothesis of independent detection at the two ears and some which regard the threshold as the level at which an audible stimulus can be distinguished from the internal noise of the auditory system. However, Silvian and White did not notice any significant difference between the monaural and binaural thresholds in their subjects.

Von Bekesy (1967) introduced a two step hypothesis of binaural integration in which signal onset is assumed to determine the locus of sensation and later actually determined the other qualitative aspects such as pitch and loudness.

Bothe the intensity and temporal characteristics of the binaural pattern at the ears have been suggested as basic stimulus information for the determination of the apparent locus of a sound image. Kemp and Robinson (1937) reported that increasing the intensity of auditory stimulation recues the latency period of evoking and N_1 response. These results indicated that differences in the intensity of signals at the ears, which produced interaural differences in the latency of N1 responses could be interpreted as dichotic time difference in the auditory system. Deatherge; Elderge and Davis (1959) noted that auditory fatigue produces an increase in the latency of a chochlear response. Thus one would predict and apparent shift of an image produced by binaurally matched signal away from less sensitive ear.

The experiments by Paul Skinner and James Shimota (1972) have shown that binaural hearing is neurogenic in origin. But the exact neurology of it is least understood. On the basis of anatomical evidence and the electrophysiological evidence, Galambos et al (1959), Van Bergeijk (1962) proposed a model of binaural interaction for the accessory nucleus. Current evidence from both anotomical and electro-physiological experiments indicates that the superior olivary complex is the centre of the auditory nervous system in which the first interaction of nerve impulses from the two ears takes place. (Rassmussen 1946), Galambos, Schwart, Korff and Rupat (1959), Hilali and Whitefitd (1952), Stotler (1953). Though the mingling of homolateral and contralateral fibres from the cochlear nuclei is complete by the time the superior olivary complex and lateral lumnisar have been reacted the exact place of occurrence of binaural interaction is not yet known.

Normal listening is almost always binaural. Binaural hearing is different, many ways, from monaural and the auditory system is aware of this fact. The nervous system contains many kinds of cells and some of them have unusual properties that make them especially valuable as participants in binaural analysis.

The principles of Bekesy (1948) and Stenger (1907) have been made use of in the present study in measuring the Pure tone air-conduction threshold as substitute to masking.

CHAPTER III

METHODOLOGY

The study was planned to test normals and clinical group on pure-tone audiometry and to compare their conventional air-conduction thresholds and Binaural Fusion Thresholds.

Subjects:

Normals: 33 Normals subjects between 17 and 27 years were selected randomly from the students and staff of the Institute who never had any history of ear illness. All the normals underwent an ontological examination made by otolarynogologists of the Institute. The examination received that the subjects did not have discharge of wax. The subjects with wax were tested only after the removal of the wax. The subjects were considered to have normal hearing if they obtained air-conduction and bone-conduction thresholds well within the accepted limits of normalcy, as given by ISO (1964).

Clinical group: Approximately 8000 case history files of the case who reported to the Institute during the period 1968 and 1973 were scanned and the subjects were selected on the following criteria.

1. The subjects must be older than 15 years of age.

2. They must possess normal intelligence. The assessment of intelligence was made by the Department of Psychology at the Institute.

3. They must have discrepancy of more than 40 dB either between the air conduction thresholds of the two ears or between the bone-conduction threshold of the non-test ear and the air-conduction threshold of the test ear atleast in three frequencies so that masking is essential to get valid thresholds of the test ear.

4. The subjects must be residing within a radius of 80 miles from Mysore city as it would be inconvenient to the patients to come from a very long distance grater than 80 miles.

On the basis of the above criteria a list of 600 cases was thus for the study. Follow-up cards were sent to al the above cases. For any number of reasons only 90 cases could turn up to the institute in response to the follow-up cards.

This test was also administered as a routine test to the new cases who attended the Institute during the study for their hearing problem and who satisfied our criteria. This way 10 cases were again included in the study making a total of 100 cases.

Equipment: All the experimental data were gathered using a BEL tow channeled audiometer of K 232 type. This was obviously a two channeled audiometer and enabled the investigator to feed both the signals of desired frequency simultaneously at different intensity levels. A Beyer DT 48 earphone mounted in an MX 41/AR cushion was utilized to obtain conventional air-conduction thresholds and Binaural Fusion thresholds. The audiometer was periodically calibrated using Bruel and Kjaer equipment. Block diagram for calibration is given in the appendix. The air-conduction calibration was carried out using SPL meter (BK 2203 type) with Octave filter set (BK 1613 type) and with artificial ear (BK 4152 type) with a condenser microphone (BK 4144 type No. 280896) in an acoustically treated room. The noise analysis of the test room was recorded for 5 consecutive days and was averaged. The noise levels in the room were satisfactory compared to the ISO (1964) specifications.

Average sound Pressure Levels in the sound treated room using weighted scales.

Sl. No.	Scale	SPL Value reference 0.0002 dynes/cm2
1	C	34 dB
2	B	27 dB
3	A	24 dB

II. Noise levels in the audiometric room measured in octaves

Sl.No.	Central frequency of the octave band in Hz.	ISO specifications (1963)	SPL value ref. 0.0002 dynes/cm^2
1	250	25	22
2	500	26	21
3	1000	30	12
4	2000	38	11
5	4000	51	21
6	8000	51	22

Procedure: The two tests which comprised the study were administered serially to individual subjects. The conventional air-conduction and Bone-conduction thresholds were obtained using Hughson and Westlake ascending and descending method. The frequencies ranged from 250 Hz to 8KHz for air-conduction thresholds and from 250 Hz to 4 KHz for bone-conduction thresholds. Studebaker's method of masking was employed for, determining the masked air-conduction thresholds in pathological cases.

The Binaural Fusion Test was administered to pathological cases in the following manner:

The subject would be seated comfortably in a chair-conventional air-conduction and bone-conduction thresholds are taken. He is given rest for 5 minutes after which the Binaural Fusion Test is administered to determine the air-conduction thresholds of the poor ear.

Instructions for Binaural Fusion Test:

Instructions were typed and a chart was made so as to minimize the extraneous variables that might otherwise operate –

“You will be hearing, in your better (left or right) ear a continuous sound. Be attentive and note the position where it is heard. Once the tone will take a sharp jump towards your worse ear i.e. the tone will start moving up the head to your worse ear. Whenever you notice such a shift or jump you must press the button. (He is provided a button to press after pressing which there will be a light in the audiometer which the investigator can see it). If you think there is a slight jump, you must press the button. If you don't press it, when there is shift or jump, the tone will be heard in your worse ear. Don't let the tone to be heard in your worse ear. Whenever there is a change in the tone, you might hear at the centre of the head. With little concentration you can do this. You must keep the button pressed until the tone gone back to your better ear (left or right) and then release it immediately. Even if you find difficult to locate the tone in the better ear (left or right) you may please indicate by pressing the switch".

When it was not followed by the subjects, the instruction was translated into Kannada.

The instructions in Kannada are as follows:

* ನಿಮಗೆ ಬಲಕ್ಕೆ ತಿರುಗುತ್ತ ಅಥವಾ ಎಡಕ್ಕೆ ತಿರುಗುತ್ತ (ಯಾವುದು ಎಂಬುದನ್ನು ತಿಳಿಸಬೇಕು) ಒಂದು ತರಹ ಕುಂಕುಮ ಬಣ್ಣದ ಚೆಂಡು ಬರ್ತಾ ಇರುತ್ತೆ. ದಯವಿಟ್ಟು ಗಮನವಿಟ್ಟು ನೋಡಿ. ಅಲ್ಲಿ ಆ ಚೆಂಡು ನಿಮಗೆ ಯಾವ ಭಾಗದ ಬಳಿ ಇದೆ ಅನ್ನೋದನ್ನು ಗುರುತಿಸಿಕೊಳ್ಳಿ. ಒಂದಷ್ಟು ಆ ಚೆಂಡು ನಿಮ್ಮ ಎಡಕ್ಕೆ ಕಡೆಗೆ ಅಥವಾ ಬಲಕ್ಕೆ ಕಡೆಗೆ (ಯಾವುದು ಎಂಬುದನ್ನು ತಿಳಿಸಬೇಕು) ಹಾರುತ್ತೆ. ಅಂದರೆ ಆ ಚೆಂಡು ತಲೆಯ ಮಧ್ಯದ ಮಾರ್ಗವಾಗಿ ಹಾರುತ್ತೆ. ಆ ಥರ ಚೆಂಡು ಹಾರಿದ ಹಾಗೆ ನಿಮಗೆ ತೋರುತ್ತಿರುವ ಸ್ಪರ್ಶವನ್ನು ಒತ್ತಿ. ಸ್ವಲ್ಪ ಹಾರಿತು ಅನ್ನಿಸಿದರೂ ಸ್ಪರ್ಶ ಒತ್ತಿ. ಚೆಂಡು ಹಾಗೆ ಹಾರಿದಾಗ ಸ್ಪರ್ಶವನ್ನು ನಿಲ್ಲಿಸಿ ಒತ್ತಬೇಡಿ ಇಲ್ಲಿ, ಚೆಂಡು ನಿಮ್ಮ ಎಡಗಡೆ ತಿರುಗುತ್ತ ಅಥವಾ ಬಲಕ್ಕೆ ತಿರುಗುತ್ತ (ಯಾವುದು ಎಂಬುದನ್ನು ತಿಳಿಸಬೇಕು) ಕೇಳಿಸುತ್ತೆ. ಹಾಗೆ ಆ ತಿರುಗುತ್ತ ಕೇಳಿಸ್ತೋ ಇಲ್ವೋ ಹೇಳ್ಬೇಡಿ. ಚೆಂಡು ಸ್ವಲ್ಪ ಹಾರಿದರೂ, ನಿಮಗೆ ಆಗ ಮಧ್ಯದಲ್ಲಿ ಕೇಳಿಸುತ್ತೆ. ಸ್ವಲ್ಪ ಗಮನ ಇಟ್ಟರೆ ನಿಲ್ಲಿ ಈ ಕೇಳುವ ಮಾಡಬಹುದು. ಚೆಂಡು ಪುನಃ ಮೊದಲಿನ ಜಾಗಕ್ಕೆ ಹೋಗ್ಹೋಗ ಹಂತ ಸ್ಪರ್ಶವನ್ನು ಒತ್ತಿ.* ಕೇಳಿ ಮುಕ್ತಾಯವಾಯ್ತು ಇದೆ. ಅದೇ ರೀತಿ ಮಾಡುತ್ತಾ. ನಿಮಗೆ ಚೆಂಡು ಎತ್ತ ಕೇಳಿಸುತ್ತಲ್ಲೆ ಎಂದು ಹೋಗುತ್ತಿದ್ದರೆ ಅದು ಸ್ಪರ್ಶವನ್ನು ಒತ್ತಿ.*

A practice trial was given at a comfortable level to demonstrate the subject how the tone moves from one ear to the other ear and how it returns to the same position again.

The better ear is kept as the reference ear. The tone is presented to the reference ear at a 5 dB SL while the intensity of the tone at the test ear is increased from a sub threshold level until the listener reports a change in the location of the tone or that he is hearing two tones independently. The reason for presenting the tone to the reference ear at 5 dB SL is that the subject feels it comfortable at louder levels to locate the position of the tone. The Binaural Fusion Threshold is obtained by deducting 5 dB from the obtained level.

The criterion for threshold is the standard 50% response point.

The test was performed with a typical 5 dB stepped manually controlled audiometer.

In this procedure the typical sequence of presentation of tone would be as follows: If the tone in the reference ear is considered as A and that in the test ear B, the random pattern of presentation always starting with A, would be AA, AB, AA, AA, AB (This time with B at a slightly higher level) and so on until B has reached a level which results in the patients' report that the tone has shifted the position from the canal of the reference ear or that tow independent sounds are heard or he has difficulty in localization.

Care was taken to see that adaptation would not take place in the reference ear. This was done by the following procedure. Each time the tone is to be presented the test ear at different levels, the tone at 5 dB SL is presented to the reference ear along with that simultaneously.

The threshold is judged based on the following criteria:

1. The level at which the subject reports that there is a shift.
2. The level at which he has difficulty in localization.

3. The level at which he is hearing two independent sounds.

The conventional Air-conduction thresholds and Binaural Fusion thresholds were obtained for the following frequencies and in the same order as given here: 1000 Hz, 2000 Hz, 4000 Hz, 6000 Hz, 8000 Hz, 500Hz and 250 Hz.

Classification of cases:

The cases were grouped for scores and analysis into 4 categories based on the type of loss in the worse ear. Thus if right ear shows conductive loss and left ear sensori-neural loss and if left ear is worse, then the subject would be put under sensori-neural category.

1. Conductive group:

All the cases who had their conductive ear as worse ear and whose masked air-conduction thresholds of the conductive ear were taken were grouped into this category. Thus subjects who had normal hearing in one ear and conductive loss in the other ear or/and conductive loss in both ears, were classified into this category.

2. Mixed group:

All the cases who had their worse ear as mixed ear and whose masked air-conduction thresholds of the mixed ear were taken were categorized into this category – Thus subjects who had either normal hearing or conductive loss or S.N. loss aim their better ear and mixed loss in the worse ear were categorized into this group. Subjects who had mixed loss in both the ears fell into this group.

3. Sensori-neural group:

All those cases who had either normal haring or conductive loss or mixed loss in the better ear were grouped into this category. Subjects who had bilateral sensori-neural loss were also included in this group.

To check the efficiency and validity of this test, cases with total deafness in one ear were taken for the study. They all had complete deafness in one ear and either normal hearing or mixed loss or high frequency loss or sensori-neural loss in the better ear. Thus 18 cases were studied.

Reliability:

10 Normal subjects were tested two times on different days for checking the reliability of the results for the Binaural fusion Test. However, the pathological cases could not be tested again for checking the reliability since they hand come from different places.

Brief plan of the analysis of the data:

The data were analyzed according to each group. Each subjects' air-conduction thresholds on both the tests were tabulated. The difference between the air conduction thresholds of the two tests was studied for statistical significance.

The thresholds of normals were tabulated separately and the test for significance was employed.

The unilateral total loss cases were not amenable for statistical treatment and hence no statistical test for the significance of differences was employed.

The produce-Moment correlation was computed to find out the test – retest reliability of the normals.

The Non-parametric Wilcoxon-matched pairs-signed ranks test was employed for the study.

CHAPTER IV

RESULTS AND DISCUSSION

The Binaural Fusion Test has been performed on subjects with normal hearing, at all audiometric frequencies. The subjects were 33 normal individuals ranging in age from 17 years to 17 years with a mean age of 20.06 years. Out of this 25 were males with an age range of 17 to 27 years and with a mean age of 20.56 years and 8 were females with an age range of 17 years of 21 years and with a mean age of 18.50 years.

Table 1 in the appendix gives the responses of 33 normal subjects for both conventional air conduction test and Binaural Fusion test.

Table II provides the mean conventional air-conduction thresholds and mean Binaural fusion thresholds for normals at each of the test frequencies.

TABLE II

TABLE showing the Mean Conventional Air-conduction Thresholds and Mean Binaural Fusion Thresholds for Normals.

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	6000 Hz	8000 Hz
Mean conventional Air-conduction threshold of the test ear (in dBs.)	8.64	11.51	7.58	9.24	10.30	11.37	11.21
Mean Binaural Fusion Threshold of the test ear (in dBs)	9.39	11.97	9.85	10.00	9.85	9.85	10.91

Table III provides the Standard Deviation in normals for both conventional air-conduction test and Binaural Fusion test.

To test the significance of the differences between means of the two tests in normals, the t test was employed. Table IV provides the observed t scores and the critical values of t (Table values).

Fig. 1 graphically represents the difference between the mean conventional air-conduction thresholds and the mean Binaural Fusion thresholds in Normals.

To test the hypothesis i.e. test the significance of difference between the two thresholds viz. conventional air-conduction thresholds and the Binaural Fusion thresholds in all the 3 pathological groups, Wilcoxon Matched-Pairs-Signed-Ranks test was used.

The main reasons for having used the Non-parametric statistics in the analysis of the threshold of the cases obtained on conventional air-conduction test and the Binaural Fusion test are the following.

Firstly, the tests are often called “distribution free” one of the their primary merits being that they do not assume that the scores under analysis were drawn

TABLE – III

TABLE III – Showing the standard deviation in normal for both conventional air-conduction thresholds and Binaural Fusion Thresholds.

	250 Hz	**500 Hz**	**1 K**	**2K**	**4K**	**6K**	**8K**
Conventional air-conduction thresholds.	5.802	5.0	5.39	4.78	6.27	5.95	6.40
Binaural Fusion Thresholds.	4.88	4.11	3.97	3.48	3.58	5.70	5.03

Fig 1 : Graph showing the mean conventional air-conduction thresholds and the mean Binaural Fusion Thresholds **in Normals**

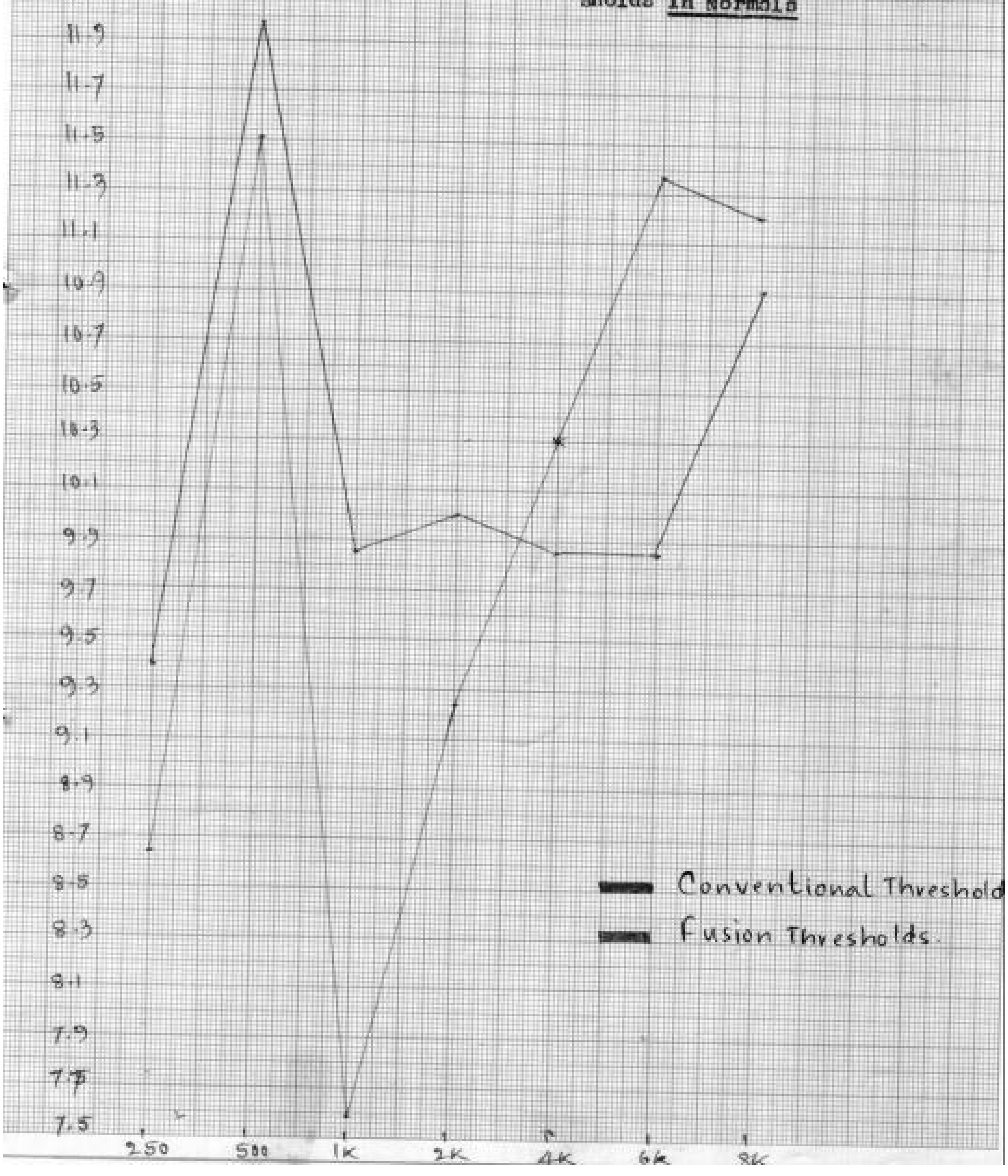


TABLE IV

TABLE IV Showing t score and table values when t test was computed to test the significance of the difference between means of the two tests in Normals.

Frequency	Observed t score	Critical value of t given in the table	Results
250 Hz	1.407	2.704	0.01 level accepted.
500 Hz.	1.222	2.704	0.01 level accepted.
1K	3.212	3.551	0.01 level accepted.
2 K	1.222	2.704	0.01 level accepted.
4 K	1.000	2.704	0.01 level accepted.
6 K	1.971	2.704	0.01 level accepted.
8 K	0.849	2.704	0.01 level accepted.

a population distributed in a certain way eg. from a normally distributed population.

Another advantage of the non-parametric tests is their usefulness with small samples.

To test hypothesis in conductive loss group, 22 cases were studied whose age ranged from 16 years to 47 years with a mean age of 24-50 years. The group consisted of 16 males and 6 females. The T scores and Table Values on the Wilcoxon-Matched-Pairs Signed-Ranks-Test are given in Table V.

The mean conventional air-conduction thresholds and the mean Binaural fusion thresholds were computed for conductive loss cases and Table VI provides the same. This difference in graphically represented in Fig. 2.

To test the hypothesis in Mixed Loss group, 40 cases were studied. They ranged in age from 17 years to 63 years with a mean age of 30.42 years. The group consisted of 31 males and 9 females. The T scores and Table Values on the Wilcox-Matched

TABLE V

TABLE showing T scores and table values when Wilcoxon Matched Pairs Signed Ranks test was computed to test the significance of the differences between conventional air-conduction thresholds and Binaural Fusion Thresholds in conductive loss group.

Frequency	**Observed T Score.**	**Critical values of T given in the table.**	**Results.**
250 Hz	22	11	0.01 Level – A.
500 Hz	35	21	0.01 Level – A.
1000 Hz	22	11	0.01 Level – A.
2000 Hz	67.5	30	0.01 Level – A.
4000 Hz	39	14	0.01 Level – A.
6000 Hz	66	21	0.01 Level – A.
8000 Hz	5	0	0.01 Level – A.

Fig 2 : Graph showing the mean conventional air-conduction thresholds and the mean Binaural Fusion Thresholds in conductive loss group

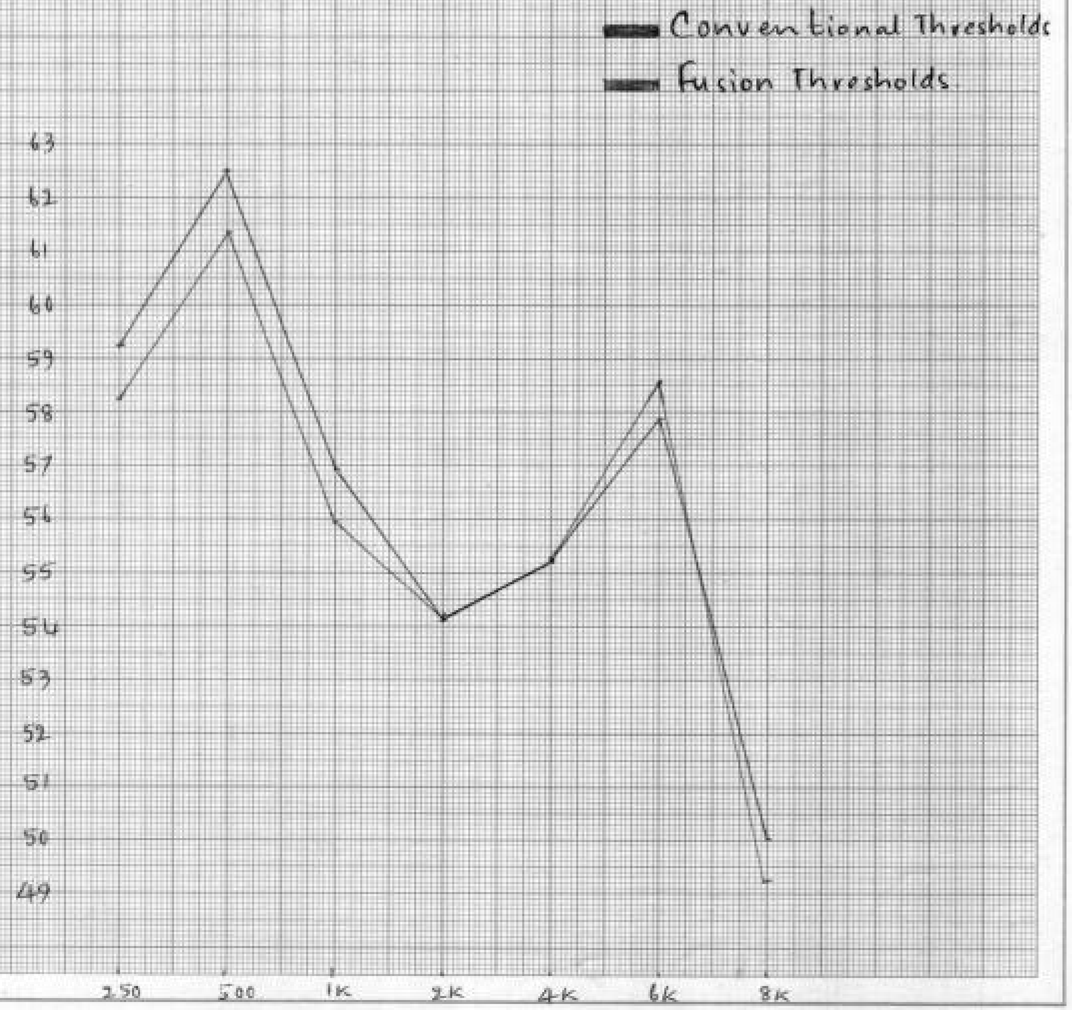


TABLE – VI

TABLE showing the Mean Conventional air-conduction thresholds and Mean Binaural Fusion Thresholds in conductive loss group.

	250 Hz	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**	**6000 Hz**	**8000 Hz**
Mean conventional air-conduction thresholds (in dBs).	56.25	61.37	55.95	54.10	55.22	58.57	49.26
Mean Binaural Fusion Thresholds (in dBs).	59.25	62.50	56.90	54.10	55.22	57.86	50.00

Pairs Signed-Ranks Test are given in Table VII.

The mean conventional air-conduction thresholds were computed for mixed loss case and are represented in Table VIII. This difference is graphically represented in Fig. 3.

To test the hypothesis in Sensori-neural loss group, 20 cases were studied. The age ranged from 17 years to 72 years with a mean age of 41.85 years. The group consisted of 19 meals and 1 female. The T scores and table values on the Wilcoxon Matched-Pairs Signed-Ranks Test and given in Table IX.

The mean conventional air conduction thresholds and mean Binaural Fusion thresholds were computed for Sensori-neural loss group and are given in Table X. This difference in graphically represented in Fig. 4.

In cases where air-conduction thresholds exceeds the audiometric limits Binaural fusion also failed to yield threshold. Since the difference between two thresholds could not be quantified, Wilcoxon

TABLE VII

Table showing T Scores and Table values when Wilcoxon Matched pairs Signed Ranks test was computed to test the Significance of the difference between conventional air- conduction thresholds and Binaural Fusion Thresholds in Mixed loss group.

Frequency	**Observed T Score.**	**Critical values of T given in the table.**	**Results.**
250 Hz	65	35	0.01 Level – A.
500 Hz	67.5	52	0.01 Level – A.
1000 Hz	76	73	0.01 Level – A.
2000 Hz	93	66	0.01 Level – A.
4000 Hz	63	52	0.01 Level – A.
6000 Hz	22.5	21	0.01 Level – A.
8000 Hz	22.5	21	0.01 Level – A.

TABLE – VIII

TABLE showing the Mean Conventional Air-Conduction Thresholds and Mean Binaural Fusion Thresholds in Mixed loss group.

	250 Hz	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**	**6000 Hz**	**8000 Hz**
Mean conventional air-conduction thresholds (in dBs).	65.77	72.00	74.42	73.52	74.51	64.74	65.28
Mean Binaural Fusion Thresholds (in dBs).	66.33	73.33	76.00	74.69	76.10	66.84	67.50

TABLE – IX

TABLE IX showing T scores and table values when Wilcoxon Matched Pairs signed Ranks test was computed to test the significance of the difference between conventional air-conduction thresholds and Binaural Fusion Thresholds in sensori-neural loss group.

Frequency	**Observed T Score.**	**Critical values of T given in the table.**	**Results.**
250 Hz	11	8	0.01 Level – A.
500 Hz	8	2	0.01 Level – A.
1000 Hz	24	14	0.01 Level – A.
2000 Hz	16.5	8	0.01 Level – A.
4000 Hz	9	0	0.01 Level – A.
6000 Hz	5	0	0.01 Level – A.
8000 Hz	7	0	0.01 Level – A.

TABLE – X

TABLE showing the Mean Conventional Air-Conduction Thresholds and Mean Binaural Fusion Thresholds in Sensori-Neural loss group.

	250 Hz	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**	**6000 Hz**	**8000 Hz**
Mean conventional air-conduction thresholds (in dBs).	59.64	70.00	73.44	70.24	68.75	67.00	61.67
Mean Binaural Fusion Thresholds (in dBs).	61.78	70.94	75.00	71.47	69.17	65.00	62.78

Fig 5 : Graph showing the mean conventional air-conduction thresholds and the mean Binaural Fusion thresholds in mixed loss group

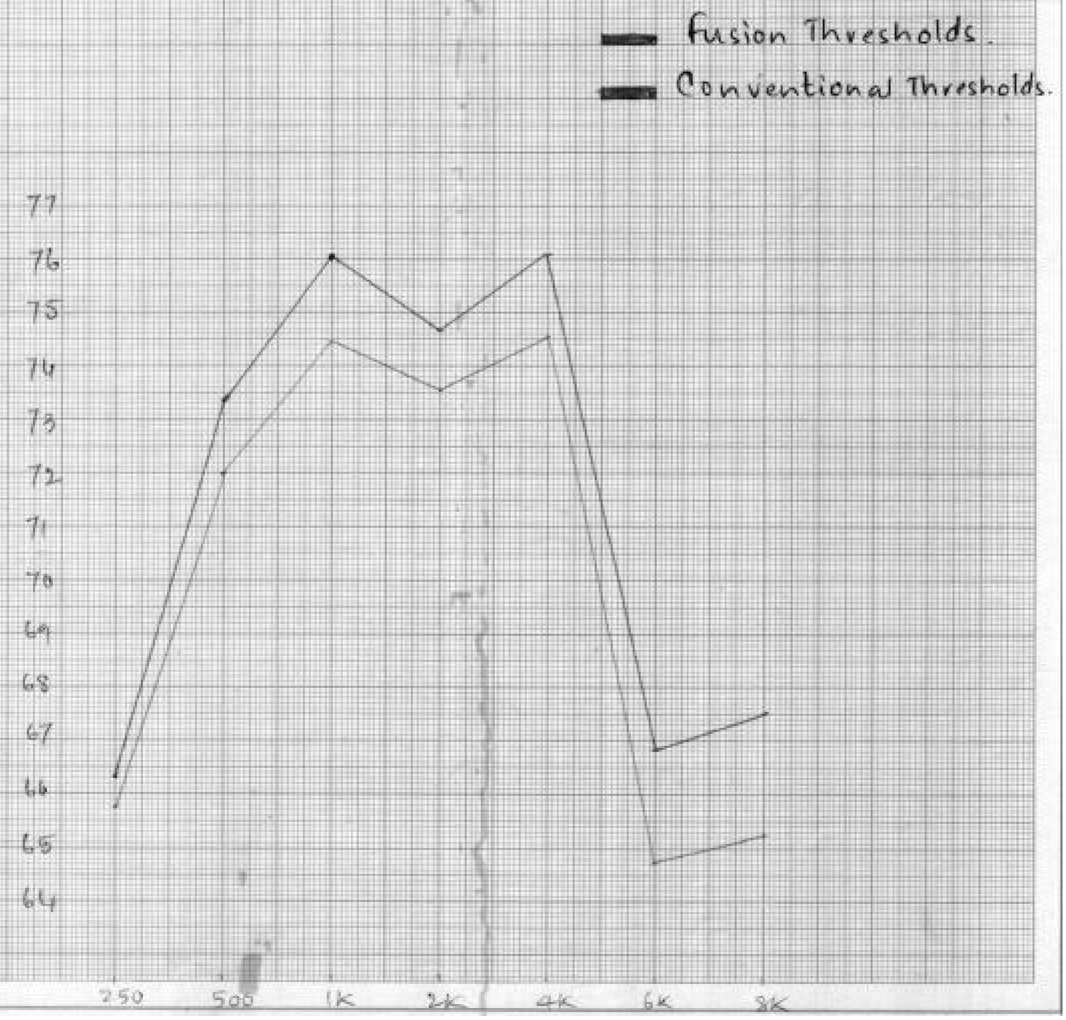
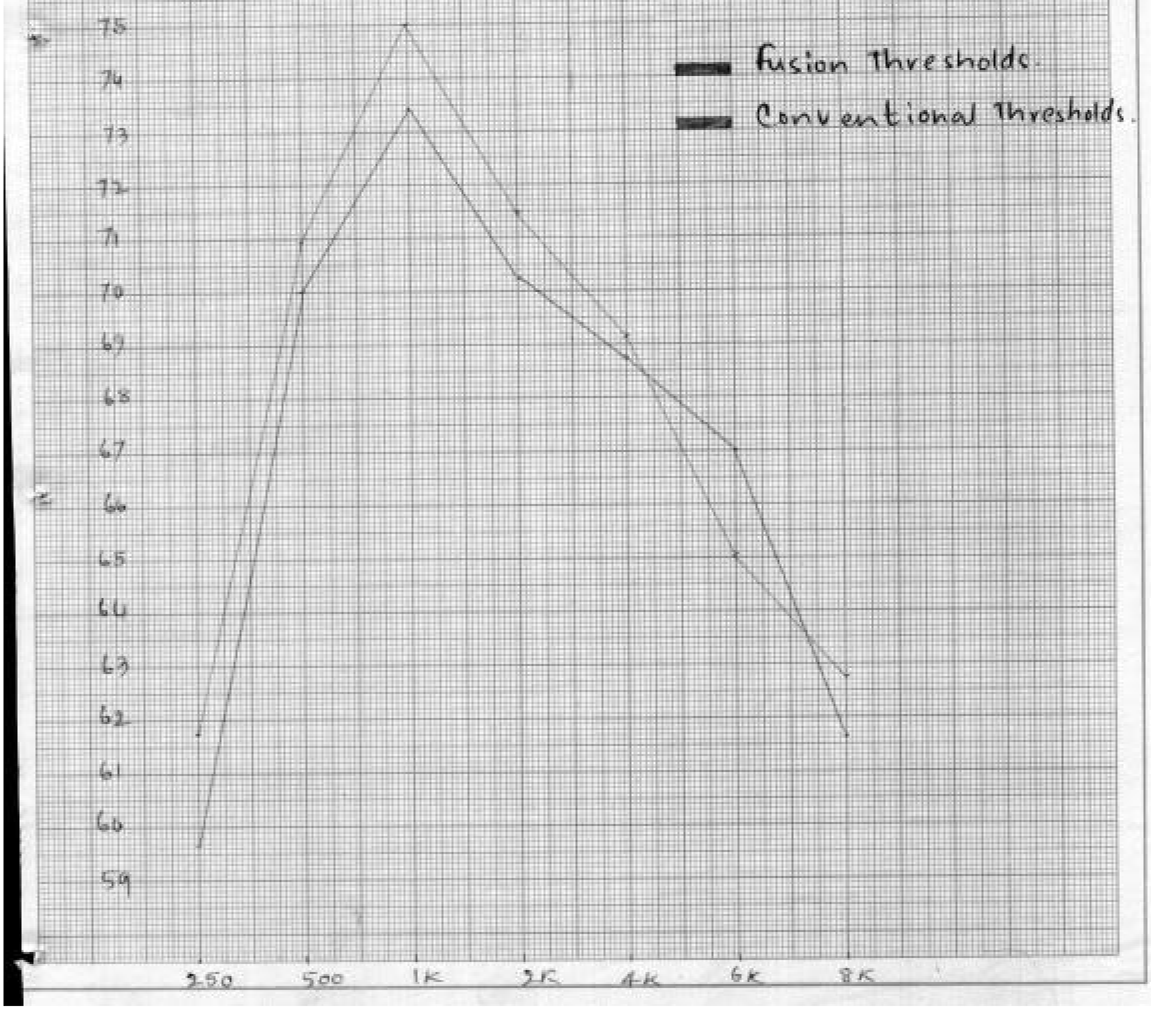


Fig 4 : Graph showing the mean conventional air-conduction thresholds and the mean Binaural Fusion thresholds in sensori-neural loss group



Matched-Pairs Signed-Ranks test was not applied. These cases are designated as unilateral total deaf cases since no fusion occurred even at maximum output level of the audiometer. Thus 18 unilateral total deaf cases were excluded from analysis.

Test – retest reliability was confirmed by administering the test to ten randomly selected normal subjects from the original sample for a second time ten days after the first test with the same test conditions. To check the reliability product-moment correlation method was used. The results are shown in Table XI.

DISCUSSIONS:

The results on the t test show that there is no significant difference between the mean conventional air-conduction thresholds and the mean Binaural Fusion thresholds in normals even at 0.01 level at any of the test frequencies. This is suggestive of good agreement being existed between conventional air-conduction thresholds and Binaural Fusion thresholds.

TABLE – XI

PRODUCT MOMENT CORRELATION VALUES FOR NORMALS

250 Hz.	0.92
500 Hz.	0.52
1000 Hz.	0.89
2000 Hz.	0.87
4000 Hz.	0.87
6000 Hz.	0.99
8000 Hz.	0.92

The null hypothesis is accepted for conductive loss group at all levels and makes an indication that there is no significant difference between the two thresholds even at 0.01 level on the Wilcoxon-Matched-Pairs-Signed Ranks test.

The Wilcoxon Matched-Pairs Signed-Ranks test when applied to Mixed loss group reveals that there is no significant difference between the two thresholds even at 0.01 level.

The subjects with sensori-neural hearing loss show statistically no significant difference between conventional air-conduction thresholds and Binaural Fusion Thresholds.

In the unilateral total loss cases, the Binaural fusion did not occur. The lack of fusion at any level tends to indicate the total audiometric loss in their test ears.

Table VI shows the product-moment correlation values for normals. The values indicated high correlation between the conventional air-conduction test and Binaural Fusion test.

Thus the Binaural Fusion test proves to be valid and reliable substitute for masking in air-conduction audiometry.

CHAPTER - V

SUMMARY AND CONCLUSIONS

The Binaural Fusion Tests and conventional air-conduction tests were administered to 33 normal subjects and 100 pathological cases consisted of 4 groups.

1. Conductive loss group
2. Mixed loss group
3. Sensori-neural loss group and
4. Unilateral total loss group

Categorization of these groups was on the basis of the Binaural Fusion Thresholds were gathered using Beyer DT 48 earphones enclosed in MX/41 AR cushion. The Wilcoxon-Matched-Pairs Signed-Ranks test was administered to test the significance of difference between the thresholds obtained through these two methods. The following observations were made.

1. The results showed no significant difference between the Binaural fusion thresholds and the conventional masked air-conduction thresholds for all the three groups.

2. The results of test-retest reliability on Product-Moment correlation shows high correlation between the two tests at all the frequencies (250 to 8KHz).

3. Normals also did not show any significant difference between the Binaural Fusion thresholds and the conventional unmasked air-conduction thresholds. This substantiates the phenomena of Binaural fusion test that when to tones of the same frequency are fed simultaneously to both ears at a particular sensation level, the tones will get fused and will be heard at the center of the head.

4. It is hence concluded that Binaural Fusion test can be used clinically as a useful tool for determining the Pure-Tone air-conduction thresholds of the poor ear where masking is needed. It can be employed as an alternative to conventional masking with the same efficiency and maximum simplicity. It can also be administered by all audiometricians.

Limitation of the study:

The only limitation of this study is that cases with other pathological symptoms like recruitment, tone decay, diplacusis are not included and hence the applicability of this test on them is not known.

Recommendations for further research:

The test provides further scope for research in the same area. Firstly, to check whether the fusion can be applied to Bone-conduction audiometry when there is minimum amount of attenuation. Secondly, its effect during noise audiometry: - Will Binaural fusion for noise yield any information in pathological cases especially with central auditory disorders?

Thirdly, will there be any difference in the binaural fusion test during speech audiometry?

APPENDICES

AUDIO-FREQUENCY ANALYZER B & K TYPE 2107

(used for calibration)

Type 2107 is an alternating current operated audio-frequency analyzer of the constant percentage band width type.

It has been designed especially as a narrow band sound and vibration analyzer, but may be used for any kind of frequency analysis and distinction measurement t within the specified frequency range.

This instrument is used with artificial ear type 4152 and artificial mastoid type, 4130 for air-conduction and bone-conduction calibration.

Artificial ear type 4152:

Artificial ear type 4152 is designed to enable acoustical measurements on ear-phones to be carried out under well-defined acoustical condition (-ISO specifications). If consists basically of a replaceable acoustical coupler and 2 sockets for the mounting of a condenser microphone cartridge type 4131 and a cathode follower amplifier type 2163, connected to the Audio-frequency analyzer 2107.

A spring arrangement is provided to fulfill certain standard requirements regarding the force applied to the object under measurement. To enable acoustical tests, to be made on head phones used in audiometers, a 6 cm cube acoustical coupler is provided in this type.

The artificial ear satisfies the ISO specifications (ISO/TC 43)

ARTIFICIAL MASTOID TYPE 4930

Artificial Mastoid Type 4930 was used to measure objectively for the calibration of bone vibrators. This artificial mastoid could present to the bone vibrator exactly the same mechanical impedance as human mastoid. All preliminary adjustments such as, static load and the calibration for the impedance head are made periodically before bone-conduction calibration.

SPL meter 2203:

The precision sound level meter type 2203 and octave filter set type 1613.

The Precision Sound Level Meter type 2203 is a highly accurate instrument designed for outdoor use as well as for precise laboratory measurements. It covers the I.E.C. Publication 123, draft specifications regarding the sound pressure level meters.

The SPL meter is provided with octave filter network type 1613. The unitc contains 11 band pass filters for octave analysis. The SPL meter was calibrated prior to noise measurements using Piston phone type 4220.

The above 2 instruments are used in connection with the noise measurements in the test room.

TABLE – I

TABLE-I(A)-Showing the conventional unmasked air-conduction thresholds and Binaural Fusion Thresholds at 250 Hz for 33 normals.

Subjects	**Age Years**	**Sex**	**250 Hz**			
			Conventional unmasked air-conduction thresholds.		**Hearing level in the reference ear.**	**Binaural Fusion Thresholds at 5 dB SL.**
			Right	**Left**		
1	**2**	**3**	**4**	**5**	**6**	**7**
1.	19	M	20	15	20	15
2.	18	M	15	20	20	20
3.	19	M	0	0	5	5
4.	23	M	0	0	5	0
5.	21	F	0	10	5	10
6.	25	M	5	0	5	5
7.	19	F	5	0	5	5
8.	24	M	5	10	10	10
9.	17	M	0	0	5	5
10.	19	M	10	10	16	10
11.	19	F	5	15	10	10
12.	18	M	5	10	10	10
13.	19	M	0	0	5	0
14.	21	M	5	10	10	10
15.	20	M	0	5	5	5
16.	18	M	5	10	10	10

Cont….

1	**2**	**3**	**4**	**5**	**6**	**7**
17.	22	M	10	10	15	15
18.	17	M	10	20	15	15
19.	17	F	0	0	5	5
20.	22	M	10	10	15	10
21.	18	F	5	10	10	10
22.	17	F	0	10	5	5
23.	19	M	10	15	15	15
24.	19	M	5	5	10	5
25.	18	F	10	5	10	15
26.	27	M	10	10	15	15
27.	20	M	5	0	5	10
28.	19	F	5	5	10	5
29.	25	M	5	5	10	10
30.	25	M	10	10	15	15
31.	18	M	5	10	10	10
32.	20	M	0	0	5	5
33.	20	M	10	15	20	20

TABLE –I (B)

TABLE - I(B) - showing the conventional unmasked air-conduction thresholds and binaural Fusion thresholds at 500 Hz. for 33 normals.

Subjects	**Age Years**	**Sex**	**500 Hz**			
			Conventional unmasked air-conduction thresholds.		**Hearing level in the reference ear.**	**Binaural Fusion Thresholds at 5 dB SL.**
			Right	**Left**		
1	**2**	**3**	**4**	**5**	**6**	**7**
1.	19	M	15	20	20	20
2.	18	M	20	20	25	25
3.	19	M	10	5	10	15
4.	23	M	0	5	10	10
5.	21	F	15	10	15	10
6.	25	M	5	0	5	5
7.	19	F	5	10	10	10
8.	24	M	10	10	15	10
9.	17	M	10	5	10	10
10.	19	M	10	10	15	10
11.	19	F	10	15	15	15
12.	18	M	5	10	10	15
13.	19	M	0	5	5	10
14.	21	M	5	10	10	10
15.	20	M	0	10	5	10
16.	18	M	10	10	10	10

Contd…

1	**2**	**3**	**4**	**5**	**6**	**7**
17.	22	M	10	5	10	10
18.	17	M	10	5	10	10
19.	17	F	5	0	5	5
20.	22	M	20	15	20	15
21.	18	F	20	5	10	15
22.	17	F	5	5	10	15
23.	19	M	10	10	15	10
24.	19	M	5	0	5	5
25.	18	F	15	0	5	15
26.	27	M	15	15	20	15
27.	20	M	15	5	10	15
28.	19	F	10	0	5	10
29.	25	M	50	10	15	15
30.	25	M	10	10	15	15
31.	18	M	10	10	15	15
32.	20	M	0	5	5	10
33.	20	M	20	15	20	15

TABLE –I (C)

TABLE –I (C) – Showing conventional unmasked air-conduction thresholds and Binaural Fusion Thresholds at 1000 Hz for 33 normals.

Subjects	**Age Years**	**Sex**	**1000 Hz**			
			Conventional unmasked air-conduction thresholds.		**Hearing level in the reference ear.**	**Binaural Fusion Thresholds at 5 dB SL.**
			Right	**Left**		
1	**2**	**3**	**4**	**5**	**6**	**7**
1.	19	M	15	20	20	20
2.	18	M	15	15	20	20
3.	19	M	0	0	5	5
4.	23	M	0	5	5	5
5.	21	F	0	5	5	5
6.	25	M	0	5	5	5
7.	19	F	5	10	10	10
8.	24	M	5	5	10	5
9.	17	M	5	5	10	10
10.	19	M	0	0	5	5
11.	19	F	10	10	15	10
12.	18	M	5	15	10	10
13.	19	M	0	0	5	5
14.	21	M	0	10	5	10
15.	20	M	10	10	15	15
16.	18	M	0	10	5	10

Contd…I(C)

1	**2**	**3**	**4**	**5**	**6**	**7**
17.	22	M	5	5	10	10
18.	17	M	5	0	5	10
19.	17	F	10	0	5	10
20.	22	M	10	5	10	10
21.	18	F	5	5	10	5
22.	17	F	5	0	5	10
23.	19	M	5	5	10	5
24.	19	M	0	0	5	5
25.	18	F	5	0	5	5
26.	27	M	0	10	5	10
27.	20	M	5	10	10	10
28.	19	F	5	20	10	15
29.	25	M	10	5	10	10
30.	25	M	0	0	5	10
31.	18	M	10	5	10	10
32.	20	M	0	0	5	10
33.	20	M	15	10	15	15

TABLE –I (D)

TABLE –I (D) – Showing conventional unmasked air-conduction thresholds and Binaural Fusion Thresholds at 2000 Hz for 33 normals.

Subjects	**Age Years**	**Sex**	**2000 Hz**			
			Conventional unmasked air-conduction thresholds.		**Hearing level in the reference ear.**	**Binaural Fusion Thresholds at 5 dB SL.**
			Right	**Left**		
1	**2**	**3**	**4**	**5**	**6**	**7**
1.	19	M	10	15	15	15
2.	18	M	10	15	20	15
3.	19	M	0	0	5	5
4.	23	M	10	0	5	5
5.	21	F	15	10	15	15
6.	25	M	10	0	5	10
7.	19	F	5	10	10	10
8.	24	M	5	5	10	10
9.	17	M	10	0	5	10
10.	19	M	5	5	10	10
11.	19	F	15	5	10	10
12.	18	M	10	10	15	10
13.	19	M	0	0	5	5
14.	21	M	10	15	15	10
15.	20	M	10	10	15	15
16.	18	M	10	15	15	15

Contd…I(D)

1	**2**	**3**	**4**	**5**	**6**	**7**
17.	22	M	5	5	10	10
18.	17	M	5	0	5	10
19.	17	F	10	0	5	10
20.	22	M	100	5	10	10
21.	18	F	5	0	5	0
22.	17	F	0	0	5	10
23.	19	M	5	0	5	5
24.	19	M	15	0	5	10
25.	18	F	10	15	15	10
26.	27	M	5	10	10	5
27.	20	M	10	0	5	10
28.	19	F	5	10	10	10
29.	25	M	10	10	15	10
30.	25	M	10	0	5	10
31.	18	M	10	5	10	15
32.	20	M	5	5	10	10
33.	20	M	15	10	15	15

TABLE –I (E)

TABLE –I (E) – Showing conventional unmasked air-conduction thresholds and Binaural Fusion Thresholds at 4000 Hz for 33 normals.

Subjects	**Age Years**	**Sex**	**4000 Hz**			
			Conventional unmasked air-conduction thresholds.		**Hearing level in the reference ear.**	**Binaural Fusion Thresholds at 5 dB SL.**
			Right	**Left**		
1	**2**	**3**	**4**	**5**	**6**	**7**
1.	19	M	10	15	15	10
2.	18	M	15	15	20	15
3.	19	M	0	0	5	5
4.	23	M	10	15	15	10
5.	21	F	15	10	15	10
6.	25	M	5	15	10	10
7.	19	F	5	0	5	10
8.	24	M	15	15	20	10
9.	17	M	20	15	20	15
10.	19	M	0	5	5	10
11.	19	F	10	10	15	10
12.	18	M	5	10	10	10
13.	19	M	0	0	5	5
14.	21	M	10	20	15	10
15.	20	M	10	5	10	10
16.	18	M	5	10	10	10

Contd…I(E)

1	**2**	**3**	**4**	**5**	**6**	**7**
17.	22	M	10	10	15	10
18.	17	M	10	10	15	10
19.	17	F	15	0	5	10
20.	22	M	10	20	15	15
21.	18	F	10	10	15	10
22.	17	F	5	5	10	15
23.	19	M	0	0	5	5
24.	19	M	15	0	5	10
25.	18	F	10	15	15	10
26.	27	M	20	20	25	20
27.	20	M	10	5	10	10
28.	19	F	10	15	15	15
29.	25	M	5	5	10	5
30.	25	M	0	0	5	5
31.	18	M	5	5	10	5
32.	20	M	0	0	5	5
33.	20	M	5	5	10	5

TABLE –I (F)

TABLE –I (F) – Showing conventional unmasked air-conduction thresholds and Binaural Fusion Thresholds at 6000 Hz for 33 normals.

Subjects	**Age Years**	**Sex**	**6000 Hz**			
			Conventional unmasked air-conduction thresholds.		**Hearing level in the reference ear.**	**Binaural Fusion Thresholds at 5 dB SL.**
			Right	**Left**		
1	**2**	**3**	**4**	**5**	**6**	**7**
1.	19	M	20	20	25	20
2.	18	M	20	20	25	20
3.	19	M	0	0	5	5
4.	23	M	10	0	5	0
5.	21	F	15	10	15	10
6.	25	M	10	0	5	10
7.	19	F	0	10	5	5
8.	24	M	15	10	15	15
9.	17	M	15	5	10	15
10.	19	M	0	5	5	5
11.	19	F	15	20	20	10
12.	18	M	10	5	10	10
13.	19	M	5	0	5	0
14.	21	M	5	10	10	0
15.	20	M	0	0	5	5
16.	18	M	0	0	5	0

Contd…I(F)

1	**2**	**3**	**4**	**5**	**6**	**7**
17.	22	M	10	5	10	5
18.	17	M	10	5	10	5
19.	17	F	5	0	5	10
20.	22	M	10	15	15	15
21.	18	F	15	20	20	15
22.	17	F	10	5	10	15
23.	19	M	0	10	5	5
24.	19	M	10	0	5	10
25.	18	F	15	10	15	10
26.	27	M	15	15	20	15
27.	20	M	10	0	5	15
28.	19	F	15	5	10	10
29.	25	M	20	15	20	15
30.	25	M	10	15	15	15
31.	18	M	10	15	15	15
32.	20	M	0	0	5	5
33.	20	M	15	10	15	15

TABLE –I (G)

TABLE –I (G) – Showing conventional unmasked air-conduction thresholds and Binaural Fusion Thresholds at 8000 Hz for 33 normals.

Subjects	**Age Years**	**Sex**	**8000 Hz**			
			Conventional unmasked air-conduction thresholds.		**Hearing level in the reference ear.**	**Binaural Fusion Thresholds at 5 dB SL.**
			Right	**Left**		
1	**2**	**3**	**4**	**5**	**6**	**7**
1.	19	M	20	15	20	20
2.	18	M	15	20	20	15
3.	19	M	0	0	5	5
4.	23	M	5	10	10	5
5.	21	F	15	10	15	20
6.	25	M	0	0	5	5
7.	19	F	5	0	5	0
8.	24	M	0	0	5	5
9.	17	M	15	15	20	15
10.	19	M	0	5	5	5
11.	19	F	10	10	15	10
12.	18	M	5	5	10	10
13.	19	M	0	0	5	5
14.	21	M	15	15	20	15
15.	20	M	0	5	5	5
16.	18	M	10	5	10	5

Contd…I(G)

1	**2**	**3**	**4**	**5**	**6**	**7**
17.	22	M	15	5	10	15
18.	17	M	15	20	20	10
19.	17	F	15	5	10	15
20.	22	M	20	20	25	20
21.	18	F	15	20	20	15
22.	17	F	20	0	5	15
23.	19	M	0	10	5	10
24.	19	M	5	5	10	5
25.	18	F	10	5	10	15
26.	27	M	15	15	20	15
27.	20	M	5	15	10	10
28.	19	F	10	10	15	10
29.	25	M	10	15	15	10
30.	25	M	15	10	15	10
31.	18	M	15	10	15	10
32.	20	M	5	5	10	10
33.	20	M	10	0	5	10

RECOMMENDED REFERENCE EQUIVALENT THRESHOLD S.P.L. IN THE IMPEDANCE AUDIOMETER COUPLER.

Reference: Equivalent threshold SPL relative to 2 x 10^{-5} N/m^2

(2 x 10^{-4} dynes/cm^2)

Frequency	dB	Lt.	Rt.
250	28.5	87.5	87.0
500	14.5	72.5	74.0
1000	8.0	67.5	68.5
2000	8.0	66.5	68.0
4000	5.5	63.5	64.0
6000	8.0	69.5	68.0
8000	14.5	73.5	75.0

Pattern of earphone: Beyer DT – 48 with flat cushion.

Binaural Fusion Test

NAME :

DATE :

AGE :

CASE No. :

SEX :

TYPE OF LOSS:

Frequencies (Hz)	**Conventional Air conduction Thresholds**	**Binaural Fusion Thresholds at 5 dB SL.**
250		
500		
1000		
2000		
4000		
6000		
8000		

ANALYSIS OF PATHOLOGICAL CASES

TOTAL CASES: 100

Conductive Loss Group: 22 cases

Bilateral conductive loss	4 cases
Unilateral conductive loss	18 cases

Mixed loss Group: 40 cases.

Bilateral Mixed Loss	5 cases
Mixed loss in one ear & Normal hearing in the other ear.	21 cases
Mixed loss in one ear & conductive loss in the other ear.	6 cases
Mixed loss in one ear and Sensori-Neural loss in other ear.	4 cases
Mixed loss in one ear and High Frequency loss in the other ear.	4 cases

Sensori-Neural Loss Group: 20 cases.

Sensori-neural loss in one ear & Normal hearing in the other ear.	10 cases
Sensori-neural loss & High Frequency loss	2 case
Bilateral Sensori-neural loss.	5 cases
Sensori-nerual loss in one year & Mixed loss in the other	1 case
Sensori-neural loss & Conductive loss	2 cases

Unilateral Total Loss Group: 18 cases.

Total loss & Normal hearing	7 cases
Total loss in one ear & High Frequency loss in the other.	2 cases
Total loss in one ear & Mixed loss in the other	4 cases
Total loss & Sensori-neural loss.	5 cases

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