CANDIDACY FOR BIVAURAL AMPLIFICATION USING MERCON METHOD

REG NO. M.9804

An Independent Project submitted as a
(Speech & Hearing) to the
University of Mysore

All India Institute of Speech & Hearing,
Mysore-570 006.

May, 1999

Dedicated to

God

My Parents
&
My Sisters
&
Brothers

With Love Beyond Words

CERTIFICATE

This is to certify that Independent Project entitled ***"Candidacy for Binaural Amplification using Mercon Method*** *, is bonafide work in part fulfillment of the First Year M.Sc. in Speech & Hearing of the student with Reg. No. M.9804.

Mysore
May, 1999

Director
All India Institute of Speech & Hearing
Mysore

CERTIFICATE

This is to certify that Independent Project entitled ***"Candidacy for Binaural Amplification using Mercon Method',*** has been prepared under my supervision and guidance.

Guide
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Mysore

May, 1999

Declaration

I hereby declare that this Independent - Project entitled ***"Candidacy for Binaural Amplification using Mercon Method[1]*** is the result of my own study under the guidance of Mrs.Manjula.P. Lecturer in Audiology, All India Institute of Speech & Hearing, Mysore, and it has not been submitted earlier to any University for any other Diploma or Degree.

Mysore **Reg. No. M.9804**

May, 1999

Acknowledgement

I thank my guide **Mrs.Manjula.P.,** Lecturer in Audiology, Department in Audiology, All India Institute of Speech & Hearing, Mysore, for her tireless guidance and help. Madam I thank you for introducing me to the promising mystery of binaural hearing and its potentials. Doing this project I have come to love the subject Hearing Aids. I cannot thank you enough Madam for your invaluable support and inspiration.

I am thankful to **Dr.(Miss) S.Nikam,** Director, All India Institute of Speech & Hearing, Mysore, for allowing me to take up this project.

I thank all my classmates for all their help and support in big and small ways in bringing out this Independent Project.

I thank all my subjects for giving me their valuable time and cooperation.

I thank Mr.Shivappa and Mr.Basavaraju for their help in the last minute in finding someone to type my work.

I thank M/s Sharu's Touch, Mysore for being good enough to undertake my typing in the last minute and for giving it its final form.

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CHAPTER - 1

INTRODUCTION

What is hearing ? Very broadly, hearing refers to the various ways in which human beings react to sound waves. Though put forward so simply here, the actual processes involved in hearing are very complex.

Examination of man's central auditory system reveals that the process of hearing ends in the brain and not in the ears. The ears are merely receptors of sound which, through a complex network of direct and contralateral neural connections to each of the two hemispheres provide the signals to the brain for hearing. The signals from each ear are combined to form a single auditory sensation. Although this process occurs simply enough, the resultant auditory image is dependent in complex ways upon the interaural frequency, intensity and time relationships between the two signals arriving from the two ears. It is however this combination of different interaural signals that provides the superiority of binaural hearing over monaural hearing.

Almost every psychoacoustic effect is enhanced with binaural hearing, including binaural summation, localization and improved speech intelligibility in noise, etc. These effects are interesting by themselves, but they are of even greater interest because they provide considerable insight into the hearing process and help us in our efforts to provide optimum rehabilitation for the hearing impaired.

Hearing impairment causes a decrease in the sensitivity (response), of either one or both ears, to sound. It can be of various degrees (mild, moderate, moderately-severe, severe, or profound) and of various types (conductive, mixed, sensori-neural and central). This also causes the signals from each ear to be dis-congruent with each other, thus the binaural integration process becomes less effective and the binaural advantages are correspondingly diminished or even lost. Such is the case for an unaided unilateral hearing loss, or for an unaided asymmetrical bilateral loss.

In treating bilateral hearing losses, symmetrical and asymmetrical, with amplification binaural candidacy traditionally has been determined by an evaluation of monaural test data. To a large extent this has been because binaural test procedures have not been tried out. Because the binaural advantages occur when the two monaural signals are in balance i.e, in proportion with each other, the concept was refmed-that only those persons with bilaterally symmetrical losses were good binaural candidates and this concept became the accepted practice.

Modern fitting philosophies advocate binaural fittings as the method of choice for bilateral hearing losses. But what has been lacking yet, is a procedure to help identify these candidates who benefit from binaural amplification.

In 1984, at the Hearing Aid association of California, Peter Mercola and Connie Wenke-Mercola presented the paper "A new test procedure for determining binaural candidacy" - based on the criteria that aided signals are generally centered around the MCL with relatively small departures from that level and, that binaural fusion occurred even with small differences between the signals to each ear. This procedure claimed to sort out not only the binaural candidates but also the monaural candidates and those who should not be fitted with any aids at all. For monaural candidates, it claimed to provide guidance as to which of the two ears to fit In the case of unilateral loss, it helped determine whether the fitting should be monaural or CROS. The procedure 'Mercon method' had been used successfully by the authors for more than four years before the presentation of their research result.

The Mercon test procedure was claimed to be effective because;

1. It relied upon actual binaural measurements rather than on monaural measurements,
2. It developed these measurements at MCL rather than at thresholds and,

3. It produced equal aided levels rather than requiring symmetrical unaided losses.

Besides it provided a new set of criteria for recommending a binaural hearing aid system. This set of criteria used the result of the procedure for obtaining binaural fusion and in conjunction with other evaluation procedures, such as, comparative speech discrimination testing qualifies the binaural candidates.

The procedure not only identified binaural candidates, but also provided guidance as to which ear to aid for the monaural candidates and segregated^ those who needed no amplification.

The present study aimed therefore, to evaluate the validity of the Mercon **test procedure for hearing aid selection. Then, to** determine the candidacy **for** binaural amplification in **the** clinical **population** using the same procedure.

CHAPTER-2

Fitting Procedures

Much of the interest in binaural hearing was first stimulated by a short letter from Koenig published in 1950 stating the advantages of binaural hearing. Ever since a lot of research has been done on binauraf hearing. But the review of literature reveals not many methods exist for fitting binaural hearing aids. The few available are reviewed below -

Stearns (1982) believed that both quantitative and qualitative results were important aspects in a fitting procedure, and over the years has found the testing of word discrimination in noise to be among the most effective methods in fitting binaural hearing aids.

The basic procedure consisted of placing the subject in a sound field with both noise (Cocktail party, speech babble or other simulated "real world" noise conditions) and PB words emanating from the same speaker (typically + 5 dB S/N or +10 dB if severe understanding problems were encountered). An individual first had to be checked unaided at 65 dB sound pressure level for a data base. Then, each ear is tested independently at an initial "best guess" adjustment of the aid to determine the aided speech understanding. Depending upon the aided speech improvement and noting the characteristics of words missed, an adjustment was made to improve the speech understanding such as addition of more high frequencies or movement of a break frequency, with the goal in mind of achieving a 75% or 100% or more improvement in speech understanding (eg: Speech discrimination scores (SDS) increase from 30% to 70% or 45% to 85%).

Before any sound field testing began, it was determined if the user was comfortable with the aids, did not feel stuffy, had a fairly "natural" voice and if the gain / power levels in the aids were adequate for good balance. If only one aid was being fit, the question of hearing balance was to be posed to determine if the individual could tell in which ear sounds were being heard. Finally, a check of binaural performance would determine overall speech understanding.

However, "real world" conditions could alter aid response settings determined as optimum for speech understanding during testing. Therefore, when the patient was rechecked in one or two weeks, questions should be posed carefully to elicit information concerning stereo balance, loudness of sounds, men's versus women's voices, music appreciation, directionality of sounds and overall comfort and naturalness of the individual's voice. Stearns (1982) recommended checking the individual once or twice after the initial fitting followed by a three month check and aid re-adjustment. A subtle change in the user's hearing acuity and a possible improvement in the threshold response may precipitate and aid(s) re-adjustment to reduce background noise and/or provide other fine tuning. Sometimes the instrument may need its spectrum sharpened, i.e., by inserting additional highs or reducing compression as a user becomes adjusted to the 'real world' of sounds.

In 1984, Mercola & Mercola put forward a method called the 'Mercon Method' to identify and fit a binaural candidate. The procedure produced a balanced, binaurally fused signal that was perceived in the centre of the head on the median plane. A slight unbalance in loudness between otherwise similar signals presented to each ear would cause the fused signal to shift to the louder side. Therefore, if the signal presented to one ear was considerably louder than the one presented to the other ear, example - 10 dB or more, then the perceived signal was merely the louder one, heard at the ear to which it was presented. The softer signal was masked by the louder one and was not heard at all (Stenger effect). However, if the signals to each ear were perceived to have the same loudness the fused signal would be located in the center of the head.

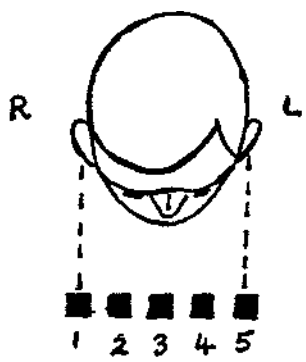
The procedure did not require any unusual or expensive equipment. It could be performed with any two-channel speech audiometer with independent adjustable attenuators. The signal recommended for use with this procedure was speech, so that the binaural balance between ears was obtained over the frequency range of speech. Any speech signal of sufficient duration, such as cold running speech Could suffice.

The first step was obtain monaural MCL's for each ear. Any MCL procedure couid be used, i.e., what ever was effective in arriving at the most comfortable listening level for speech.

In the next step, binaural balance was begun by applying the speech signal tothe ear having the lower MCL, i.e., the reference ear, at 5 dB below the MCL for that ear and keeping it at that same level throughout the balancing procedure.

The identical speech signal was then simultaneously applied to the opposite ear, beginning at a level well below its MCL and increased gradually until the perceived speech signal was moved to the median plane. When the fused signal was heard in the median plane, a binaural balance was achieved. The relative intensity to each ear was then maintained, and a binaural MCL was obtained by either raising or lowering both intensities slightly if necessary. The binaural MCL, therefore, was the individual intensities applied to ear at the most comfortable listening level. Because of the binaural summation effect, the binaural MCL was usually about 5 dB lower for each ear than the individual monaural MCL's. However, the true binaural MCL cannot be extrapolated from monaural MCL data. There are far too many cases with surprising results obtained while using this procedure.

The instructions to the patient for the balancing procedure were that he indicate clearly with his hand at which location he was perceiving the sound. If the sound was perceived at his left ear, for example, his hand would be at his left ear. If the sound was perceived between the median centre plane and his left ear, then his hand would be at his left eye, and so forth. For simplicity the diagram in Figure 2.1 indicates five equally spaced speech positions. However, in actual practice the perceived sound may be heard at any location between the two ears, depending on the relative intensities of the two signals. Furthermore, the perceived sound would move in a continuous fashion if the signals presented were changed continuously.



MERCON ' METHOD

FOR BINAURAL MCL.

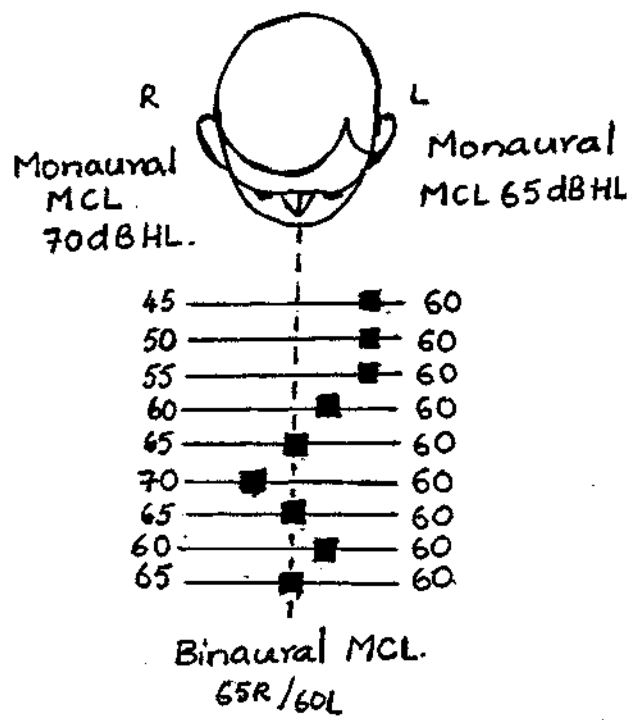


Figure 2-2: ***The. indication of*** *the* location *of speech signal* **as *level in right car is changed* to find *binaural MCL.***

The balanced condition was achieved when the sound was perceived at the median plane. Mercola & Mercola (1984) recommended that the opposite-ear signal be increased above and decreased below the level required for balance. This was to verify that the patient had understood all instructions for this procedure and that the true binaural balance was achieved, a procedure much the same as verifying a threshold. This is illustrated in Fig.2.2. Note that the median plane was crossed from both directions and that the levels for balance was thus verified several times.

The review of literature shows that there is as yet, no consensus on a binaural testing procedure that could help identify a binaural candidate from those who are not, and provide an insight into how to fit binaurally. The various criteria advanced to date all extrapolate binaural candidacy from monaural test data rather than rely upon binaural measurements directly.

In each set of criteria for binaural candidacy the basic requirement has been symmetrical hearing loss. Most authors have required not only symmetrical hearing loss but also similar UCLs, MCLs and SD. This conservatism centres around the argument that unless the threshold losses were symmetrical and other hearing parameters were also equal, the loudness growth patterns would be different for the two ears. Hence what was in balance at one listening level may be out of balance at another level. This may well be true and the binaural advantage may be limited to less than the entire range of hearing. However, it should be kept in mind that the aided signals are generally centered around the

MCL with relatively small departures from that level and that binaural fusion occurs even with small differences between the signals to each other. The argument of different loudness growth patterns for each ear, may have some validity for widely varying losses between ears but is generally not defensible because the alternative it offers to binaural hearing over a somewhat limited range is monaural hearing.

'Mercon Method helps determining the suitability of binaural fitting regardless of symmetry of the hearing loss. This procedure sorted out not only the binaural candidates but also the monaural candidates and those who should not be fitted with any aids. For monaural candidates, it provided guidance as to which ear to fit. In the case of a unilateral loss it helped determining whether the fitting should be monaural or CROS.

This method was powerful and its results were far reaching because (1) It was based on actual binaural measurements rather than on extrapolation from monaural measurements. (2) The measurements were made directly at the 'use' level (MCL) rather than at threshold. (3) The procedure produced equal aided levels rather than requiring symmetrical unaided losses.

Thus in the Mercon Method we are provided with a simple but powerful test procedure that could be used easily on all to be candidates of different types of hearing aids.

CANDIDACY

Who is a candidate for binaural amplification ? This is a frequently asked question and many professionals have offered answers to this question. As you can imagine the spectrum of answers has been quite wide. There appears to be one common ground in literature about which most seem to agree. Apparently the patient who will receive the greatest potential benefit from binaural amplification displays the following audiometric data: a mild-to-moderate hearing loss, a fairly wide dynamic range, a symmetrical hearing loss (±10 to15 dB) and good word discrimination scores.

Considering the point of symmetry most would agree that the more symmetrical the hearing loss, the greater the probability of success with two aids. There has been much controversy, however, about what constitutes symmetry. Is it + 10 dB or + 15 dB ? Does one look at symmetry of audiometric thresholds from 250 to 8000 Hz, or symmetry between pure-tone averages [500,1000,2000 Hz]? Further, should one look at symmetry at threshold [audiometric or speech detection threshold], or at supra threshold levels (Loudness Discomfort Level, Word Discrimination Scores and Dynamic Ranges) ?

Some investigations, at the other extreme have suggested that lack of symmetry does not preclude that the patient cannot achieve greater benefit from binaural than monaural amplification [Mac Keith and Coles 1971, Markides, 1980, Moncur and Dirks 1967].

These same types of contrasting view points concerning candidacy for binaural amplification also can be reported in relation to the importance of magnitude of hearing loss, presence of central auditory dysfunction, financial responsibility, advancing age and Word Discrimination scores.

Valente (1984) in Table 2.1 provides a summary of suggestions that have appeared in literature concerning the problem of candidacy typically goes beyond looking at the audiogram and speech audiometric results. For instance, Valente (1984), reported from his experience, a patient who had prior experience with amplification (monaural and especially binaural) is a much stronger candidate for a recommendation of binaural amplification than the patient who is an inexperienced user of amplification.

Candidate	Non-candidate
1. Good fine motor control	1. Problems with fine motor control
2. Highly motivated	2. Poorly motivated
3. Better success if has previous experience with amplification	3. None or limited experience with amplification
4. Financially responsible	4. Third Party Payment
5. Ability to adapt	5. Impatient or reduced ability to adapt
6. High activity index	6. Low activity index
7. Audiological consideration	7. Ill or elderly
a. Symmetrical hearing loss	8. Audiological considerations:

i) Threshold ii) WOS iii) MCL iv) LDL v) DR b. Magnitude i) Mild i') Moderate c. Type of loss i) Conductive i') Mixed iii) Cochlear pathology d. Miscellaneous i) Little recruitment 8. Binaural scores greater than monaural scores by 6, 8 or 10% 9. Electro- acoustic characteristics of hearing aids should be similar	a. Asymmetrical b. Severe-Profound c. Retrocochlear lessions d. Central lesions e. Excessive Recruitment f. Poor word discrimination g. Flat configuration in better ear; falling configuration in poorer ear h. Binaural diplacusis i. Unilateral hearing loss 9. Binaural score poorer than monarual score

Table 2.1 Summary of comments appearing in the literature concerning candidacy for binaural amplification.

Johnson (1987) feels "Every patient able to utilize amplification should be considered a candidate for binaural hearing instrument". This opinion finds its support in his 30 years of experience working with a group of 10 ear doctors who were positively oriented towards hearing instruments and supportive of binaural recommendation.

Binaural fitting was recommended for -

Individuals with minimal hearing loss or with high frequency impairment. Asymmetrical hearing patterns also were fit with binaural instrumentation. Further discussion according to Johnson (1987) of each of these points follows:

1. Minimal Hearing Loss: Assumptions often are made what the patient with minimal or mild loss needs just a little help and, therefore, one instrument should suffice. Patients often will express this attitude themselves, "My loss is so mild, why is it necessary to wear two hearing instruments?" Yet, trying to fit this type of patient with one hearing instrument is seldom, if ever, accomplished satisfactorily.

   Carhart's (1958) contention remains a valid observation. He stated, "Many of these people find a monaural system more distracting than helpful, except under the most uncomplicated listening situations. Yet, they often have the need to hear relatively faint material in less favourable, albeit not really noisy, circumstances. This enhanced capacity to establish figure-ground relationships, which a binaural system allows, often means successful hearing".

The personal experience of Johnson has confirmed Carhart's contention repeatedly. One grateful patient served as an example. This individual was a librarian who had difficulty communicating in the quiet environment of the library. Her supervisor asked her to "do something" about her hearing. She agreed to try binaural instruments. As per her audiogram, she was within what is normally classified as "serviceable" hearing, both for pure tones and speech. Mild gain instruments with IROS earmoulds were recommended and proved to be very successful. During subsequent follow-up with the patient, she indicated that she was wearing her instruments not only at the library but also at the theatre, meetings and conferences and, to a certain extent, in her home.

Interestingly, many children with audiograms with minimal hearing loss also have been successfully fit, therefore, enabling them to achieve better results at school.

High Frequency Impairment: In the past, patients with normal speech reception thresholds, but with high frequency roll-off, usually were told that nothing could be done or that they perhaps should enroll in a class in speech reaching. The patient's audiogram illustrated an essentially normal response when tested in a quiet environment. The threshold for speech is 15 dB or better bilaturally, and he has a discrimination score of 100% on the right ear and 92% on the left ear in quiet. Without testing this individual in noise, one might have questioned how he could be experiencing a problem. Testing with one syllable, phonetically balanced (PB) words in background noise, however, quickly illustrated his difficulties. His discrimination score dropped to 80% on the right ear and 64% on the left ear.

The difficulty was understanding speech in any kind of background noise. As an active businessman who conducted numerous meetings and conferences, understanding was critical to his business. A monaural hearing instrument would have proven unsuccessful, as background sounds would have overwhelmed the soft speech sounds and further impaired discrimination ability. The use of high frequency instruments with IROS type vent shifted his discrimination ability from 60% in noise unaided to better than 80% in noise when binaurally aided. The patient was well motivated and felt the hearing instruments were of inestimable value in conducting his business.

A second example involved a man in lumber business with normal hearing* with respect to speech reception threshold (SRT) and with reasonably good discrimination ability in quiet. He too, however, was experiencing marked impairment in noise. Unaided in noise, he could discern only 68% of PB words. Properly aided naturally, his discrimination ability in noise : shifted to over 90%.

In summary, many individuals with SRTs that are normal, or at least within serviceable limits, experience frustration and marked communication impairment because of high frequency loss and because they have been fit monaurally. In conclusion, high frequency impairments rarely can, if ever be satisfactorily fit with monaural instrumentation. Both ears need to be fit.

Asymmetrical Loss: In the past, many investigators have suggested that symmetrical hearing configuration is the only criteria for using binaural hearing instruments. In addition, it once was believed that an individual with normal hearing in one ear experienced very little hearing impairment despite a loss on the contra lateral side. The assumption was that normal speech threshold and normal discrimination ability in one ear equated normal hearing function. There are no longer valid assumptions. It now is realized that this is true only in very quiet surroundings. Individuals with unilateral loss experience significant hearing handicaps in the presence of noise.

Two cases are cited as examples, the first individual had essentially normal hearing in one ear with more than a 40 dB loss on the impaired side. He could tolerate a hearing instrument well. Even with successful fitting on the right ear, as a classroom teacher, she felt she still did not function as well as she would like in the classroom. She liked to be fit on the left ear as well. A very mild gain instrument, primarily boosting the higher frequencies, was recommended, and she found this met her hearing requirements.

The second example is that of a patient with relatively good hearing and good discrimination ability on the right ear but a marked sensorineural impairment with very poor discrimination on the left ear. she initially was fit with a mild gain, high frequency instrument for her right ear, but no fitting was attempted for her left side because of her poor discrimination ability. After wearing her instrument on the right side for a few weeks, she reported that it was helpful but asked to have an instrument on her left ear as well. With binaural instrumentation, her speech discrimination in noise was shown to improve significantly. Her subjective reaction was that now she was a 'whole' person and was able to hear on both sides of her head. This patient had been given the true binaural effect because she was again receiving auditory signals in both ears.

A more extreme example in a 19-year-old who had experienced progressive hearing loss from age one and had worn binaural hearing instruments for 18 hears. Upon testing, she still had fragmentary pure tones results in one ear but no understanding for speech. When an instrument was tried on the better ear, producing a better than 50% speech discrimination ability, she found the results to be unsatisfactory because she was no longer perceiving useful auditory signals from the left side. In other words, she was lacking the binaural effect she had experienced over the past 18 years. In this case, a hearing instalment was fit on the greatly impaired side simply to provide her with auditory input from that side of the head and to give some sense of binaural effect.

In conclusion, Johnson (1987) feels that asymmetrical losses should be fit with binaural hearing instruments. Binaural instruments may be used even with markedly asymmetrical patterns, with good discrimination on one side and marked impairment on the other side. The end results remain the same despite the many possible combinations of pure tone and speech discrimination asymmetry. A patient with normal hearing on one side, so the normal ear and the amplified ear together produce the desired natural binaural hearing effect The bottom line must be to consider binaural amplification as the rule and let the patient judge as to how much help he/she receives.

4. Tinnitus: Experience has shown that many patients with severe tinnitus problems could be helped with hearing instalments. In many cases, amplifying sound slightly overcomes the subjective perception of tinnitus. Whether the person's impairment is symmetrical or not, binaural fitting usually is more effective in controlling the patient's tinnitus. In Johnson's (1987) view, the use of binaural hearing instruments in tinnitus control even seems preferable to the use of tinnitus masker.

Markides (1977) gave the following criteria for selecting hearing aid candidates.

1. Subjects with symmetrical conductive or symmetrical sensorineural hearing impairment and with average hearing levels of 30 to 90 dB (averaged across 500, 1000, and 2000 Hz) were found to derive significant advantages in terms of speech discrimination and localization ability from binaural hearing aids as opposed to a single hearing aid, under conditions where the speech level is around or below the threshold of the aided ear, A second aid will not be of benefit unless the hearing impairment is greater than about 50 dB. For maximum advantage, binaural hearing aids should be of similar type.

2. Provided a person with bilateral hearing impairment of either the conductive or sensorineural type can accept speech delivered through hearing aids at an intensity level which is around 20 dB (10 dB for

localization) above his speech detectibility threshold at each ear, then such a person can derive significant advantages in terms of speech discrimination and / or localization from binaural hearing aids as opposed to monaural hearing aids.

3. Where possible, priority should be given to ear-level hearing aids rather than body worn ones, as they provide head-shadow advantages as well as squelch ones and better localization ability. For subjects with average hearing levels of 80 dB +, body worn hearing aids instead of ear-level hearing aids are indicated for obvious reasons.

4. Subjects with relatively flat hearing impairment in their better ear and with a steeply falling pure tone audiogram configuration in their worse ear were found to derive no advantage in terms of speech discrimination when wearing two hearing aids as opposed to one. These subjects, however, did benefit in localization ability from two hearing aids as opposed to one.

5. Similarly, all the subjects who exhibit diplacusis derive no help from binaural hearing aids in terms of speech discrimination. Again however these subjects derived benefit in localization ability from two hearing aids as opposed to one.

6. Subjects suffering from presbycusis were found to derive similar binaural hearing aid advantages in terms of speech discrimination and localization ability to subjects suffering from other causes of hearing impairment.

7. Both the speech discrimination and localization performance of subjects without previous binaural hearing aid experience were only slightly (not significantly) inferior to those of subjects with previous binaural hearing aid experience.

8. Speech audiometry through earphones has little predictive value regarding subsequent binaural hearing aid candidature.

Berger (1984) used the following guidelines for binaural fitting, at his clinic, based on a goal of achieving binaural hearing where deemed feasible.

1. If the average hearing threshold level in the worse ear is 40 dB or better at 1000 and 2000 Hz, fit monaurally unless binaural fitting provides localization where monaural fitting will not.

2. Fit binaurally if the dynamic range and the uncomfortable level of each ear is similar (within 15 dB suggested) if at the same sensation level word discrimination scores are not significantly different and if pure-tone - thresholds by bone conduction differs by no more than 15 dB at any of the speech frequencies and are roughly parallel.

Berger (1984) said that these guidelines are, to an extent, admittedly arbitrary. Part of their value is that they are reasonably specific. Their specificity provides a yardstick against which to test and compare, so as to refine or reject all or part of them. The alternatives to specific guidelines are vague ones which cannot readily be contested, but neither do they permit focussing on the question of who is or who is not a likely binaural hearing aid candidate.

Lundeen (1988) proposed a moderate approach to fitting a binaural candidate.

Degree of hearing loss: He said that a two frequency average of hearing thresholds obtained at 1000 Hz and 2000 Hz, computed for each ear separately was most appropriate for evaluating the degree of hearing loss for binaural hearing and candidates. The use of 3-frequency average, as recommended by Markides, required more involved computations and rounding rules which increased the likelihood of error. Also criteria based on three-frequency averages tended to disqualify individuals will high frequency hearing loss but normal thresholds at low frequencies even though binaural hearing aids might be beneficial in many such cases.

When is hearing too good ? According to the literature, individuals whose hearing loss was 50 dB HL or greater generally derived significant benefit from binaural hearing aids. In contrast, individuals whose hearing loss was less than 40 dB HL generally did not understand speech any better with binaural hearing aids than any did with a single, monaural instrument. When the degree of hearing impairment was in the 40 dB HL to 50 dB HL range, some patients benefit from binaural amplification while other did not. In this border line region, hearing test results cannot differentiate good binaural hearing aid candidates from poor ones.

On this basis it appears that a two frequency average of 40 dB HL was a reasonable "low fence" for identifying almost all patients whose hearing was bad enough to benefit from binaural hearing aid use.

When is hearing too bad ? Even the most powerful hearing aids do not amplify speech levels above 110 dB to 115 dB HL. Because higher intensities would only cause non-auditory sensations. Therefore binaural hearing aid will not be appropriate in cases where the average thresholds at 1000 HL and 2000 HL was greater than 90 dB HL in one or both ears.

Symmetry of hearing Impairment: When there are large interaural differences in residual hearing, binaural hearing aids might yield poorer speech discrimination performance than when one ear alone was aided.

Lundeen (1988) suggested that evaluation of the threshold difference between ears should be based on the same two-frequency averages used for evaluating the degree of loss - the average of 1000 HL and 2000 HL thresholds for better ear should simply be subtracted from the value obtained for the poorer ear. Binaural hearing aids will be of maximum benefit whenever the threshold difference value was 15 dB or less. In contrast, binaural fittings were not the indicated for patients with threshold differences greater than 30 dB. When the threshold difference value was in the range from 16 dB to 30 dB, inclusive, the dispenser had to consider additional test results and / or observations to determine whether a binaural hearing aid fitting was warranted.

Speech discrimination differences between ears: Lundeen (1988) adopted a lenient criterion, and recommended binaural hearing aids even though the difference in speech discrimination scores obtained from the two ears was fairly large. However, when scores differed by 20% or more, odds were better that they reflected a true difference in speech understanding capacity. Therefore as long as the speech discrimination scores obtained for the right and left ears did not exceed 20%, binaural hearing aids were appropriate.

Mueller (1988) found it difficult to view Lundeen's minimum hearing loss criteria as a moderate approach. Similar concerns could be raised according to him regarding recommendations for speech - recognition scores within 20% and more hearing loss not exceeding 90 dB. As yet he does not have an alternate method.

Briskey and Cole (1983) suggested the following criteria when considering binaural fitting of those with asymmetrical loss.

1. The average hearing loss at 500, 1000 & 200 HL should be within 15 dB HL or less between ears.
2. Two of three frequencies must be 15 dB HL or less between ears.
3. The speech recognition, scores between ear should be within 8% of each other.
4. The decibel values of the uncomfortable loudness level (UCL) in each ear should be within 6 dB of each other.
5. The most comfortable loudness level (MCL) in each ear should be within 6 dB of each other.
6. There should be a high activity index [ie., based on the life style of the individuals].

Day, Browning and Gatehouse (1988) assessed the relative benefits of binaural as opposed to monaural hearing aids by the use of diotically presented audio-visual speech-in-noise task in a group of bilateral, severely hearing-impaired individuals.

The results showed a significantly greater benefit in a group of severely hearing impaired individuals of binaural over monaural amplification. Audio visual testing was more appropriate than auditory testing for assessing benefit in this population, because most individuals with a severe impairment need to make extensive use of speech-reading. As the sentence-in-noise FASIN* (Day et al,1988) test was performed diotically in noise, these binaural advantages can be due only to central summation.

Day et al (1988) felt provided the necessary manual skills were available, fitting binaural aids to elderly individuals with severe impairment was not contra-indicated and should be positively encouraged.

Frederiksun, Blegvad and Rojskaer (1974) conducted a study on the treatment with binaural hearing aid of presbyasis patients aged 70 to 80 years and found uncritical and general use of binaural hearing aids not justified.

Gelfand, Silman and Ross (1987) studied the long-term effects of monaural, binaural & no amplification, in 86 subjects with bilateral loss, upon PB scores and auditory thresholds.

Their findings confirm and expand upon those previously reported (Silman et al, 1984). There was a significant decrease in speech recognition

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* Audio Visual test of hearing disability using free field sentences-in-noise.

performance over time for the unaided ear of adults with bilateral sensorineural hearing loss who use monaural hearing aid. In contrast, the changes in speech recognition scores were not significant for the aided ears of these subjects, or for the ears of subjects using binaural hearing aids or those who were not using amplification.

The results of Gelfand et al (1987) study suggest that the unaided ears of monaurally aided subjects with bilateral sensorineural hearing loss are subjected to a deprivation effect which is reflected as a drop in PB scores over a period of more than 4 years. Aided and unaided ears did not differ with respect to the progression of hearing loss between tests, suggesting that there was no acoustic trauma effect associated with hearing aid use among the subjects in this study.

Gelfand et al (1987) state that further research is required on binaural fitting, including issues such as whether deprivation effects are reversible and whether these effects have psychoacoustic electrophysiological and / or structural correlates.

Newman (1996) did further a research on Late-onset auditory deprivation effect for the results of his study indicate that the use of monaural amplification may result in reduced supra threshold speech recognition performance in the unaided ear of a individual with bilateral symmetrical sensorineural loss. The reduction in performance usually occurs after at least a year of hearing aid use, though the time course was highly variable. The clinical profile of hearing aid candidates who showed such a degradation was reportedly unknown to date. Research has also shown that the deprivation effect can be reversed in some listeners. Again information relevant to identifying hearing aid candidates in whom the effect could be reversed was unavailable.

Newman (1996) says that until more information is available, it would seen advisable to recommend binaural amplification for all persons with bilateral symmetrical hearing loss. When there is an asymmetrical hearing loss, binaural amplification should be considered as an option.

Hood and Prasher (1990), had conducted an experiment to study the effect of simulated bilateral cochlear distortion on speech discrimination in normal subjects. Normal subjects were presented with simulated, dissimilar cochlear distortion at the two ears. It was found that discrimination scores with binaural presentation were poorer than the best monaural score (though not reaching the level of significance). There were clear indications that in the former case subjects selectively attended to one ear and neglected the other, in contrast, monaural presentation of the same simulated distortion resulted in a significant improvement, compared with the binaural discrimination score.

Inability of the cortex to contend with discongruent speech input from the two ears was thought to be a factor contributing to the rejection of binaural hearing aids in some individuals according to the authors.

Advantages of Binaural Amplification:

A great deal of literature exists on binaural hearing. For normal hearing listeners the overwhelming evidence is for binaural advantage in most listening tasks. More recently professionals have become increasingly vocal in favour of binaural fittings, the rationale being that since binaural hearing, is the natural condition, binaural hearing aids should be recommended unless it can be shown that a monaural fitting is better.

Mueller(1986) opined that considering that most hearing impaired persons are binaural candidates, there appears to be a sizeable gap between the fields of acceptance of theoretical advantage of binaural fitting and its applications in clinical practice. Although the cost to the patient of a second hearing aid is an important consideration that might hinder binaural fitting, the gap seems too large to be attributed simply to economic factors.

A possible explanation for the apparent discrepancy between theory and practice according to Mueller(1986) might have been related to attitudinal factors that existed prior to the hearing aid fitting.

Over the years there has been a gradual shift in favour of binaural amplification among clinician/dispensers. This shift was probably due to the interaction of three factors (1) Research published (2) Alterations in hearing aid trial (3)Changing occupational setting of the audiologist.

(1) Published Research: During the 1970s and early 80s most research comparing monaural and binaural has favoured binaural - a point made especially obvious by packaging of pro-binaural research findings in special journals issues or books.

The changing attitude in audiology community also was reflected in major audiological texts. For example Pascoe in the Third Edition of the 1985 Handbook of Clinical Audiology presented his beliefs more directly, stating, "Hearing aids should be chosen to help restore binaural hearing. They should in fact be sold in pairs just like eyeglasses."

(2) Hearing aid selection procedures: As binaural amplification has gained popularity changes even in hearing aid selection procedures have occurred.

Earlier speech recognition testing comparing monaural and binaural performance was used to prove that binaural is better since this test paradigm does not reveal most binaural advantages this method has been abandoned by audiologists & it has been necessary to develop new criteria for deciding see patients to fit binaurally or monaurally. Therefore, it has often been necessary to base fitting decisions on theoretical models, on clinical experience or on patients subjective preference for one or the other fitting arrangement following a trial-and-use period - all of which strategies are more likely to reveal the potential benefits of binaural amplification.

(3) A changing Occupational setting: Each year, more audiologists become directly involved in hearing aid dispensing. Direct dispensing makes for more interaction with the patient following the hearing aid fitting, and as a result, the patients comments often play a larger part in the audiologists final monaural / binaural determination. Research suggests, according to Mueller (1986), that approach would result in more binaural fittings.

Following is a brief discussion on the actual advantages of binaural hearing. Koenig (1950), asserted that binaural hearing offered the following advantages.

1. A remarkable ability to "squelch" reverberation and background noises.
2. The power to select one stimulus from a number of stimuli and as it were to tune in to one sound source or one person, the "Cocktail Party Effect", and

3. To understand speech under extremely unfavourably signal to noise ratios.

Later Bergman (1957), Groen and Hellma (1960), Mac Keith and Coles (1971) supplemented the above advantages with the following:

1. Enhanced localization
2. Summation of energy both at threshold and at supra-threshold levels.
3. Summation of information content especially when the hearing losses in the two ears are dissimilar in frequency distribution.
4. Avoidance of head - shadow especially when listening with a background noise.
5. Better discrimination of speech in quiet and in noise
6. Ease of listening and
7. Quality of sound

Valente (1983), added improvement in discrimination of frequency and intensity to the list of advantages. More recently Zelnick (1985), included better speech discrimination in reverberation and masking of tinnitus also as advantages of binaural hearing. Johnson (1987) supported these views in his reports on the advantages of binaural hearing.

Markides (1977) in his study on binaural hearing aid performance discusses the binaural advantages under (a) Binaural enhancement of speech intelligibility and (b) Directional hearing.

(a) Binaural Enhancement of Speech Intelligibility: Hearing with two ears improves speech intelligibility considerably. This improvement can be due to (i) binaural summation (ii) facilitation in noise and (iii) integration of incoming stimuli.

(i) Binaural summation: It is well established that at threshold pure tone binaural threshold of hearing is more sensitive that that of monaural, the difference being in the region of 3 dB (Keys, 1947; Shaw, Newman & Hirsh, 1947; Pollack 1948; Reynolds and Stevens 1960).

This binaural advantage of 3 dB, however, can be realized if the stimuli are presented to the two ears at the same loudness level not at the same SPL

When such "equating of the ears' was established, Keys (1947), Shaw, Newman and Hirsh (1947), Pollack (1948), Breaky and Davis (1949), Bocca (1955), Lochner and Burger (1961), found that the binaural threshold for speech in quiet was also around 3 dB more sensitive than the monaural threshold. Pollack and Pickett (1958), however, demonstrated that binaural summation of speech in noise can occur even when the signal levels at the two ears differ as much as 25-30 dB. Similarly, Coles (1968) stated that a 20 dB difference between the ears has little effect on binaural summation of speech and even with a 40 dB difference the weaker ear still contributes significant information.

Binaural summation also takes place at higher intensities, i.e., binaural summation of loudness at supra thresholds (Hirsh, 1950). Pure-tone measurements show that binaural sounds are louder than monaural ones with the difference increasing from 3 dB at threshold to a maximum of about 6 dB at a sensation level of 35 dB (Hirsh and Pollack, 1948, Reynolds and Stevens, 1960; Scharf, 1968).

Bocca (1955), Groen and Hellema (1960), Lochner and Burger (1961) using speech discrimination procedures, found the binaural and monaural curves to run parallel to each other, indicating that a higher level is required for monaural listening to achieve the same articulation score as for binaural listening. This shift was of the magnitude of 3 dB.

It is only when this 3 dB binaural advantage is looked at in terms of discrimination ability that its full impact can be appreciated. For speech material with an articulation function of 6% per dB, the binaural discrimination scores, for levels of presentation which are within, the linearly rising section of the articulation curve, will be 18% higher than the monaural one. A 6% per dB rising in discrimination score is, of course, associated with PB monosyllabic lists connected speech, however, has a much steeper articulation function; thus the difference between binaural and monaural discrimination ability of connected speech can be very substantial.

Markides (1980) and Ross (1980) also have reported similar findings with 3 dB at threshold, 6 dB approximately at 35 dB and 10-11 dB at 90 dB. The binaural summation advantage at higher sensation levels have greater relevance than binaural advantage at threshold (unless measuring improvement in spondee or speech detection thresholds) because aided listening typically occurs at levels far exceeding the listeners threshold.

Berger (1988), did a study to compare the gain settings on hearing aids of binaural and monaural hearing aid users, to see to what degree binaural hearing aid wearers set the gain of their hearing aids to match the gain prescribed. He found the 3 dB reduction in maximum gain with binaural fittings valid and a high correlation between the predicted and obtained aided responses of the binaural hearing aid users (this correlation also lends credence to prescriptive procedures). Therefore subtracting 3 dB from the monaural gain prescription approximates the functional gain with binaural users.

(ii) Facilitation of speech in Noise:

(i) Interaural Phase:

The difference in phase between signals presented to the two ears is known as interaural phase difference and it has long been known to have a substantial influence on the masked threshold of pure tones [Hirsh, (1948), Hirsh and Pollack (1948), Jeffress, Blodgett and Wood (1958)].

(ii) Squelch Effect:

Koenig (1950) observed that disturbing noises, like street sounds, multiple conservation, especially in reverberant environments, were considerably less evident during binaural than during monaural hearing. He also observed a remarkable binaural ability to select and attend at will at any single sound from a complex auditory environment. This ability of binaural listening to "tune in" to a wanted signal and at the same time to minimize the interfering effects of unwanted back-ground noise, was referred to by Koenig as "squelching".

From studies of speech intelligibility in noise with normally hearing people [Nordlund and Fritzell (1963), Harris (1965), Carhart (1965)], it has been found that binaural reception was improved over monaural near ear listening (i.e, listening with the ear on the same side as the speech source) as much as if the background noise in the near-ear had been reduced by about 3 dB, Carhart termed this reduction the "binaural squelch effects".

Olsen and Carhart (1967) observed 4 dB binaural squelch, with more recently Mac Keith and Coles (1971) reported that such an effect varied from 0 to 4 dB depending on the orientation of the speech and noise sources. The differences among different studies are rather small and they can easily be attributed to the different speech materials employed.

The above facts are supported by Kuyper (1972) in his study of the Cocktail Party Effect".

(iii) The Head - shadow Effect:

A signal coming from the right side of a person will be louder in his right ear than in his left and vice versa. This reduction in loudness that occurs in the far-ear due to the intervening head is called the head-shadow effect.

Weiner and Ross (1946), Weiner (1947), Nordlund and Linden (1963), Shaw (1966) reported decrease in interaural intensity and noted that these differences varied with frequency.

Similar results were reported when the effect of head-shadow on speech intelligibility was studied. Tillman, Kasten and Homer (1963), found that the head-shadow effect attenuated the sound field spondee threshold by 6.4 dB for normal listeners positioned between the two loud speakers located at 45° on either side of the midline of the head. Olsen (1965) reported head-shadow varying from 5 to 7 dB on the spondee thresholds of normal listeners.

Under difficult listening conditions, the binaural listener gains an advantage over a monaural listener of up to 16 dB, when the good ear or single hearing-aided ear in case of bilateral impairment is on the far side in relation to the wanted signal source. Secondly the squelch effect gives the binaural listener a further advantage of about 3 dB. When added binaural hearing offers up to. 19 dB release from monaural masking. Of course there are other instances when this release from masking is only 3 dB, or less when the noise and signal come from the same source.

When the maximum advantage is translated into speech discrimination performance it can be seen that under certain conditions a monaural listener could be totally handicapped with his binaural counterpart enjoying nearly full speech reception.

(iii) Cross-correlation of incoming stimuli:

Experimental evidence suggests that the incoming auditory information is first analysed separately by each ear and secondly cross-analysed as described by Cherry (1953,1959, 1961).

This cross-correlation facility enables the binaural listener to use interaural signal differences in temporal and intensity characteristics as increase efficiency in binaural reception especially in the presence of noise (Cherry and Sayers, 1956, 1957). Also this cross-correlation facility enhances the integration of incomplete auditory patterns impinging in each ear, thus bringing about improved intelligibility.

(b) Binaural Improvement of Directional Hearing:

Although it has been asserted on several occasions (Agnell and Fite, 1901, Jonykees and Veer, 1957; Vish weg and Campbell, 1960, Butler and Naunton, 1967; and Fisher and Freedman, 1968) that at least under certain conditions monaural localization can be as good as binaural localization, there is no doubt what so ever that two ears are better than one.

Since the beginning of this century many workers have studied the physical phenomena governing directional hearing. From a physical viewpoint, directional hearing can be explained by the effects of the interposing head and the distance between the two ears. This involves differences in intensity, differences in phase, differences in time of arrival, differences in spectral composition and multiple changes in the reflective properties of the environment. The interpretation of these differences are influenced by past experience and it is also effected by learning process (Pierce, 1901; Hirsh, 1952).

1. Intensity Differences:

It is obvious that if a sound originates on the left side of listener, for eg. the left ear will be stimulated at a higher intensity than the right ear because it is not in the "shadow" of the head, Rayleigh (1904) suggested that a listener by making use of these intensity differences localizes the sound source towards the side receiving the louder stimulus. Intensity differences, however, occur if the wave length is small compared with the dimension of the head. Sivian and White (1933) have proved experimentally that such differences are practically zero below 300 Hz. It seems, therefore, that intensity differences are important in the localization of frequencies over 300 Hz.

2. Phase Differences:

As the intensity differences do not explain low frequency directional hearing, Rayleigh (1907) suggested phase differences to account for this; the rationale being that when two continuous tones varying only in phase are fed to the ears the listener tends to lateralize the sound as coming from the side of leading phase. It seems that phase differences on their own do not explain directional hearing for high frequencies. In this view it has been suggested (Hartley and Fry 1922) that a combination of intensity and phase differences give reasonable coverage of the whole auditory spectrum. However, the time-of-arrival has displaced phase as a factor of directional hearing.

3. Time of arrival difference:

This refers to the difference in time of arrival at the two ears of the start of the sound or any of the transients of a complex sound. The observer tends to localize the sound as coming from the side of first arrival. Of course, when dealing with pure tones a difference between the time-of-arrival at the left and right ears also means that there is a phase difference between the two signals. In real situations, however, sounds do not consist of a single pure tone. They have complex wave forms with regularly placed transients and consisting of low as well as high frequency components. The various component frequencies of a complex sound, its envelope, and its transients will be diffracted by different amounts, they will be phase-shifted by different amounts; and also they will be delayed differentially at the two ears. Thus localization of a complex sound may depend upon a simultaneous effect of intensity and time-of-arrival differences. Consequently it can be stated that sound localization is based on a complex running cross correlation of intensity and time-of-arrival interaural differences each of which can be "treated" with the other, a feature known as the "precedence effect".

It is stressed, however, that intensity and time differences cannot by themselves account for directional hearing, they can only give right or left lateralization with in the head. For these externalisation of the source of sound other factors, especially head movements and frequency modifications of complex sounds by head and pinnae diffraction effects are operating.

4. Spectral composition Differences:

The ability to localize complex sounds also depends upon their short term interaural spectral differences brought about mainly by the diffraction effects of the head and pinnae, the reflective properties of the environment and the impedance mis-matching of sounds at the two ears depending on the angle of incidence. These multiple differences and their systematic changes due to head movement govern the quality or timbre of the sounds at the two ears.

5. The effects of Head movements:

There is no doubt that head movements increase the ability to localize sound sources both in the horizontal and in the vertical plane (Wallach, 1940; Dicarlo and Brown, 1960; Thurlow and Runge, 1967). Even very slight head movements provide a listener with systematic varying interaural differences which are used as additional cues for sound localization, especially in discriminating between signals from the front and from the back (Rayleigh, 1907, Burger, 1958).

Head movemetns, however, do not seem to give a complete explanation of front-rear discrimination for it is well known that localization both in horizontal and front-rear discrimination can be very accurate even with the head rigidly fixed. Also sounds to brief to be influenced by head movements can be localized quite accurately, so other factors must be involved, in view of this, several workers asserted that the pinna plays a role in auditory localization.

6. The role of the Pinna:

In 1932, Petri made a structural analysis of the pinna and concluded that it consists of a "set of inter secting, reflective, parabolic surfaces which direct sound ultimately towards the auditory meatus". Batteau (1967, 1968) was of the opinion that the pinna because of its three dimentional asymmetry, creates a set of delayed replications in response to a single acoustic transient of the incoming signal and feeds them into the auditory canal, thus creating both intensity, time and tonal quality differences with critical effect on front-rear discrimination. This role is thought to be more effective for complex sounds and also with high frequencies for which the pinna casts more of a "shadow effect".

7. Minimum Audible Angle:

All available information on the minimum audible angle on the horizontal plane relates solely for binaural hearing. Stevens and Newman's experiment (1936) carried out with normally-hearing people seated on an elevated perch on the roof of a building in order to minimise reflections, revealed that the minimum angle of audibility varied with frequency bring about 11° at 60 Hz., increasing to 20° at 3 KHz. And then diminishing to 13° at 10 KHz. Clicks were localized with an average error of 80 while a hiss could be localized even more accurately with only 5-6° of error.

Siegenthaler and Aungst (1968) asserted that localization ability for speech depends on age, stating that after testing 93 children varying in age from 3 to 13 years, they noted a corresponding dicrease ri average error from 18° to 5°. Lehn ihardt (1969) pointed out, however, that the ability of auditory localization only worsens by no more than 2° between the ages of 10 and 70 and therefore caution should be exercised before making generalizations on possible relationships between age and directional hearing.

8. Physiology of Directional Hearing:

From a physiological point of view it is known that both the cochlea are represented in each auditory cortical area and that binaural interaction may occur at all levels of the auditory system from superior olivary complex to auditory cortical projection areas (Rosenzweig, 1961).

It is obvious that in pathological cases where these central neural centres are impaired, they will bring about an interference with the interaction of the signals coming from the periphery. It is on this principle that tests of auditory localization and binaural audiometry suggested for ascertaining lesions of the central path ways are based today (Bocca, 1955, Groen and Hellema, 1960). As yet, however, our knowledge is incomplete even regarding the basic anatomy of the auditory pathways and centres, let alone their interaction and even less so the diagnostic value of tests based on such interactions.

Valente (1984) observed that arrangement with the loudspeaker presenting the signal at 0° azimuth. While loudspeakers at 75° to the left and 105° to the right of the listener presenting correlated noise resulted in the real binaural advantage. He says that the manner in which a clinician presents the signal and / or noise can have a significant effect upon the resulting binaural advantage and that this factor should not be taken lightly.

Subjective Evaluation of Binaural Hearing Aids:

So far the efficiency of binaural amplification has been based on improved sensitivity, improved discrimination and improved localization all responding to universal measurement.

Briskey and Cole (1983) undertook a consumer evaluation of binaural hearing aids. The results of the survey of descriptive terms indicate that those items that reflect a negative feeling concerning the binaural system represent a significantly small percentage of the responses. The words chosen by the clients reflect that the clients enjoy an easier lifestyle when wearing two aids.

Responses to the rating of binaural performance in various listening situations indicate that the highest rated is 'outside the house on a calm day' and the two most negative situations were "in group discussion in noise" and "outside the house on a windy day".

For the survey on "What is the attitude of your family and friends toward your wearing binaural aids?" Most respondents gave responses like 'Encouraging', 'Supportive' and a small percentage a response like "Indifferent" and about 3 in 515 responses were "Discouraging".

Clients rating of binaural system on scale 1-10, [1=unhappy and 10=completely satisfied], Briskey and Cole (1983) found that 95% of the respondents indicated they were satisfied.

In a final question "would you recommend a binaural hearing aid to another hearing-impaired person?" The responses were 97.4% "Yes" and 2.6% "No".

Mueller (1986) sent questionnaires to 120 patients out of 282 who had stated preference for using two hearing aids. These patients were retired military persons who were to be provided free hearing aids.

Their responses were in the form of the seven influencing factors in rank order according to their mean-influence ratings. It was seen that persons exposed to wearing binaural amplification are influenced by several factors and that most consider those factors to be strong influences. Factors such as "understand better", "more natural / balanced", "severity of loss", and "two sided hearing" were highly ranked and were cited as influential factor by more than 90% of the respondents. Some of the moderality influencing factors were "advice from medical professional", "observation or advice from other users" and "spare aid or always have a working aid".

Of the 282 patients given the questionnaire 162 stated a preference for monaural amplification. The seven factors influencing monaural preference in . rank order according to that mean influence ratings show that strong influence was rated by only 38% of the respondents. This group of people are less enthusiastic about amplification in general, not just binaural fitting.

"Hearing-loss not severe enough for two aids" received mild-influence from 82% of respondents other influencing factors were "no expected improvement in hearing / understanding with second aid", "Advice from medical professional". "Convenience / second aid too much bother", "Cosmetic aspects" and "appear less handicapped with one aid" received low-rankings comparitively.

In 1984, Valente listed the subjective evaluation of binaural amplification by the consumers. Tables 2.2 and 2.3 lists the advantages and disadvantages of binaural amplification as expressed in several articles in literature [Brooks and Blumer 1981, Dirks and Carhart 1962, Lewis and Green 1962, Markides 1980, Nielson 1974, Ross 1980].

1. Superior to one aid	11. Better spectral orientation
2. More helpful than one aid	12. Better overall hearing
3. Use of two aids easier to her in groups	13. More natural
4. Easy to use	14. Relief from tinnitus
5. Improved localization	15. Lower, volume control setting
6. Boosts confidence	16. Less output required

7. More relaxed 8. Family pleased with improved communication 9. Improved clarity in quic;tand noise 10. Improved stereo-effect	17. Have one aid if other is broken 18. Quicker responses 19. Easier to listen without visual cues

Table 2.2:Summary of advantages revealed by binaural amplification as reported in questionnaires and survey.

1. Difficult to balance volume controls 2. Embarrassing to have two aids 3. Difficult to use in noise 4. Uncomfortable 5. Tiresome 6. Difficult to manipulate 7. Inconvenient 8. Clumsy 9. Useless 10. Not worth the trouble	11. Noisy when used in automobile 12. Awkward when using the phone 13. Increased cost of a. 2 Hearing aids b. 2earmoulds c. Batteries d. Repair e. Insurance 14. Destroy residual hearing

Table 2.3: Summary of disadvantages of binaural amplification as reported in questionnaires and surveys.

Stearns (1982) reported that the left ear is dominant for reception applicable to language skills and analytical thinking, while the right ear is dominant for reception applicable to spatial relations and music. However, both the ears have a symbiotic relationship which results in one ear assisting the other, eg. the right ear aided can help left ear to understand speech better and the left ear aided can assist the right ear in its reception functions such as in music.

Hence, aiding both ears in cases of bilateral loss would help restore total hearing balance for both ear's optimal functioning according to him.

Berger (1984) reported that some hearing-impaired individuals performed better with binaural aids, some performed alike with monaural and binaural fitting and some worse with a binaural than a monaural fitting. Therefore, there is a need to separate the binaural from non-binaural candidates.

Hood (1990) found that speech discrimination at the unaided ear, of a group of monaurally aided subjects inferior to that at the aided ear, and also was inferior to that at the ears (selected at random) of subjects who were binaurally aided.

This deterioration was attributed to the deterioration that is brought about by auditory depravation or neglect. Another factor that might have played a role if the ears were bilaterally aided are the supposed advantages claimed for central binaural integration which would accrue from binaural amplification.

CHAPTER-3

METHODOLOGY

Aim: The study aimed at determining if the 5 dB decrease in the binaural most comfortable level (MCL BIN R/L) found in Mercon method was valid. If it was, then the utility of the Mercon method to determine candidacy for binaural amplification.

To verify this, two studies, study I and study II, were conducted involving two groups of subjects group I and group II respectively, with mean ages as shown in the Table 3.1.

Group I: Consisted of thirty normal subjects, fifteen males and fifteen females. The subjects were selected on the basis of the following criteria.

1. The subjects had no significant history of ear infection or exposure to loud noise.
2. The subjects had normal hearing [i.e., <15 dB HL] at octave frequencies from 250 Hz to 8000 Hz.
3. Immittance evaluation showed 'A' type tympanogram with reflexes present.

Group II: Consisted of thirty verbal, hearing-impaired male and female subjects, with either conductive, mixed or sensorineural hearing loss. The degree of loss ranged from mild to severe in the poorer ear. The difference between the pure tone overage [P.T.A.J of both ears ranged from 0 dB to 30 dB.

		Mean (Years)	Range (Yeas)
Gp-I	Males (N=15)	19	17-21
	Females (N=15)	21	19-22
Gp-II	Males (N=16)	54.68	18-90
	Females (N=14)	41.92	18-87

Table 3.1 : The mean and range of ages of subjects of Group I and Group II

Equipment used:

A calibrated two channel diagnostic audiometer [Madsen OB 822] with TDH 39 P earphones and facility to present speech live through both channels simultaneously was used. The audiometer was calibrated as specified in the instruction manual [according to ANSI S 3.6 - 1971, Rev/ISO - 389 1975/BS 2497 standards] prior to data collection.

Test Environment:

A two room sound treated suite was used for the study. The ambient noise levels in the test room was within permissible levels according to ANSI S3.1-1991.

Test Material:

1. Kannada monosyllabic list [re: Mayadevi, 1974. as in Appendix3-A, was used for speech discrimination (S.D.) testing.
2. A passage in Kannada [as in Appendix 3 - B] was used to obtain binaural most comfortable levels [MCLBIN R/L] Speech was presented simultaneously through both the earphones of the audiometer in live voice. While presenting speech stimuli the Vu meter deflection was monitored at zero.

Procedure:

The Mercon method put forward by Mercola and Mercola (1984) was used to determine candidacy for binaurai amplification for the two groups [i.e., group I, group II]. The procedure is given below:

1. To determine monaural most comfortable levels [MCL_R, MCL_L]

   The subject was instructed previously as I am going to present speech signal through the earphones, one ear at a time. You must tell me at what level the speech is clear and distinct as if you were at an important meeting or lecture where every word spoken is important to you. If the signal is too loud, it will jarr your ears, if it is soft you will miss out on important words, or will have to strain to hear well. So tell me when the signal is just right for you, where you can hear without any problems (difficulty or strain)".

If the subject did not understand or perform well the instruction and the procedure were repeated

The most comfortable level for each ear [MCLR, MCL_L] was obtained separately, using informal speech. The subject was asked questions like "Is the signal too loud / too soft / just right 7", "Do you want me to reduce it / increase it / or is it comfortable ?", were asked. Once the subject said 'it is comfortable' he was asked, "Can you hear the speech clearly and distinctly now?"

2. Determining the binaural most comfortable levels (MCL BIN R/L)-

a) Once the most comfortable levels were obtained for each ear [MCLR, MCL_L,] the audiometer was set so that live speech could be presented, simultaneously to both the ears. In the 'reference ear[1] i.e., the better ear, the signal level was set at 5 dB less than the reported most comfortable level of that ear. In the other ear, i.e., poorer ear, the signal was set at 20 dB less than that for the reference ear [If the MCLR and MCL_L were equal then the right ear, was chosen was the 'reference ear[1]].

The instruction given to the subject was, "I am going to read a passage to you, and after each sentence I will ask, "Where does the signal seem to come from? You will answer like this, "From my left / right ear, left / right eye or midline (i.e., centre of the head)".

A five point schema as given below in Figure 3.1 represents the response pattern.

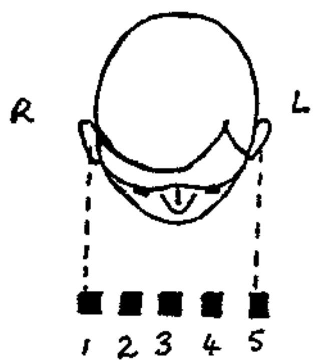


Fig.3.1 Five-point schema for responding

1 = right ear 2 = right eye 3 = nose/midline 4 = left eye 5 = left ear

The positions 1 to 5 shown above were used by the subject to indicate the position of the signal in the head.

b) The passage was read. After each sentence the subject was asked, "Where does the signal come from?". The subject answered in the manner described above. If a repetition of the trial was required, the sentence was repeated, or another sentence was read, at the same intensity level in each ear, so that the subject could make the required judgment to indicate the position of the signal.

c) After the subject had responded appropriately the intensity of the signal in the "POORER EAR" was increased by 5 dB and the level in the reference ear was kept constant. Through out the test procedure the intensity level at the 'reference ear' was maintained at the same level as that at the commencement (i.e., of step a), step (b) was then repeated.

d) Steps (b) and (c) repeated till the signal had crossed through all the 5 positions in the subjects head, or till the subject had failed to perform the task. The subject failed to perform the task if he reported no binaural fusion (indicated by no midline fusion). This implied that he was not a candidate for binaural amplification. If the subject reported midline fusion, then, the intensity in the 'poorer ear' was increased above and decreased below the level required for balance. This was to verify that the patient had understood all instructions for the procedure and that true binaural balance was achieved.

Then the binaural most comfortable level consisting of two levels [MCL $_{BIN-R}$ and MCL $_{BIN-L}$] were noted down.

e) The speech discrimination scores of the subject was then obtained at the binaural most comfortable levels [MCL $_{BIN-R}$ and MCL $_{BIN-L}$], when the speech material was presented binaurally to both the ears.

Study I:

The Mercon test procedure was used on the subjects of group I to find out the most comfortable level of each ear [MCLR, MCL_L,] the data was tabulated for each subject and subjected to statistical analysis to test the significance of difference between the most comfortable level of the better of the two ears (MCL MON BE) and binaural most comfortable level of the better of the two ear.

The results indicated that the difference (of 9 dB) between the monaural better ear most comfortable level and binaural better ear most comfortable level was significant at 0.05 level ($t = 6.899$).

Study II:

The same Mercon test procedure was repeated on subjects of group II to assess candidacy for binaural amplification.

Mercola and Mercola (1984), gave a new set of criteria for recommending a binaural hearing aid system.

1. No medical contra indications exists for either ear.
2. Binaural fusion is achieved.
3. Sufficient need for amplification exists in both ears.
4. Maximum improvement in achieved binaurally.

The Figure 3.2 given below is an illustration of localization of speech signal as the level in the right ear is changed to find binaural MCL.

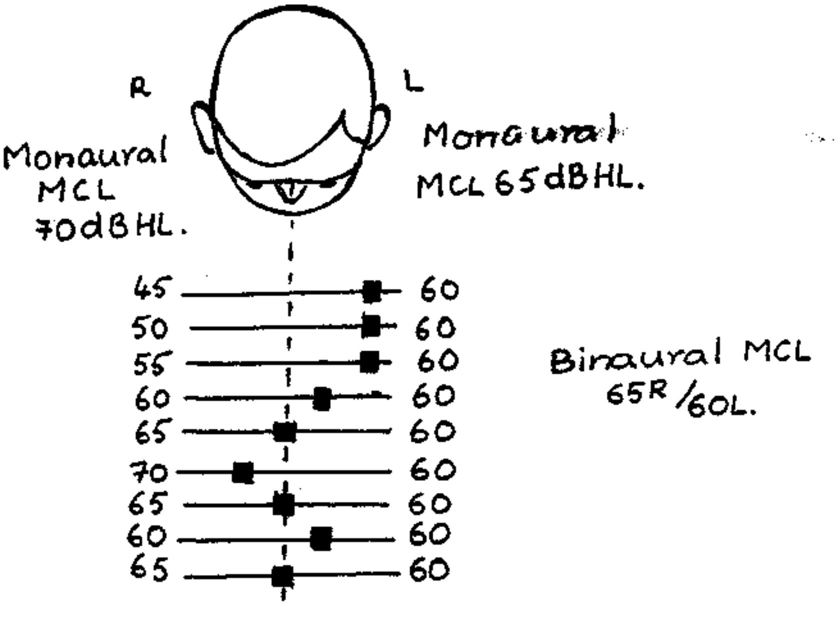


Fig.3.2 The Mercon Method schema for binaural MCL

Mercola and Mercola (1984) said, the binaural MCL consisted of two levels, one for each ear, which when applied to the two ears created a balanced, binaurally fused signal in the centre of the head and at the most comfortable level of listening. Examination of each of these two component levels of this binaural

MCL access to them provided considerable insight into the patient's amplification needs:

(1) If the components of the binaural MCL, both were substantially above normal, then binaural amplification was suggested and needed further evaluation.

(2) If neither MCL component was substantially above normal, then no amplification was required.

(3) If only one binaural MCL component was above normal, then only monaural amplification to that side was suggested.

If the binaural fusion could not be obtained, then binaural amplification had to be ruled out.

An ear exhibiting true binaural MCL of more than 10 dB above the normal MCL demonstrated a need for amplification, while an ear with a true MCL of less than 10 dB above the normal MCL required no amplification according to Mercola and Mercola (1984).

A monaural MCL of 55 dB HTL using speech was considered normal, and a binaural MCL of 50 dB HTL was like-wise considered normal by Mercola and Mercola (1984).

Therefore, when binaural MCL components were both substantially above normal, binaural amplification was suggested and the client had to be further evaluated. To know which system was best, comparative testing both monaurally and binaurally was required (Mercola and Mercola 1984).

Coarse as it may have been, improvement in speech discrimination scores was used as a measure of improvement of binaural hearing over monaural hearing. The levels of speech to each ear was presented in accordance with the binaural MCLs while doing binaural speech discrimination testing. This resulted in a balanced signal and allowed both the ears to participate in the discrimination process, which generally yielded the best binaural speech discrimination score. For monaural testing the level was inaccordance with the monaural MCL for that ear, and this generally produced the best monaural speech discrimination score comparison could then be made easily. Here it must be remembered that the benefits of binaural hearing are many and does not require to be demonstrated for each patient. For example, if binaural fusion exists, then it can be assumed that the patient can localize, if the binaural speech discrimination scores are comparable or better than monaural scores within the accuracy of speech discrimination testing then it can be said that because of all the added advantages of binaural hearing maximum improvement will be achieved binaurally.

But then there are instances where a patient is clearly a candidate for binaural amplification then the decision to fit with two hearing aids is tempered by other factors eg. physical limitation i.e., due to decreased manual sensitivity or emotional limitation. In such instances he should not be fitted binaurally. There are also patients who perform best binaurally but cannot afford a binaural system. Unfortunately, such patients are forced by economic reasons to choose the next - best system.

CHAPTER - 4

RESULTS AND DISCUSSION

The review of literature reveals that there is as yet no consensus regarding fitting procedures for binaural amplifications i.e., a procedure to identify a candidate for binaural amplification.

The present study aimed at finding out whether the 'Mercon Method' could be used as a procedure to identify candidates for binaural amplification. This was done by comparing the speech discrimination score, of the better of the two ears, at the most comfortable level when taken monaurally, and, the speech discrimination score, at the most comfortable level when taken binaurally.

The results obtained are given below:

Study I

The Table 4.1, gives the values of monaural most comfortable level and the binaural most comfortable level, for the better ear and the poorer ear, for the normal subjects.

Sl. No.	MCL BIN (dBHL)		Sl.No	MCLmon (dBHL)	
	Poorer Ear	Better Ear		Poorer Ear	Better Ear
1.	50	45	1.	60	55
2.	55	55	2.	60	60
3.	45	40	3.	55	50
4.	50	45	4.	55	55
5.	55	50	5.	55	55
6.	45	40	6.	60	50
7.	50	45	7.	60	55
8.	50	45	8.	60	55
9.	45	40	9.	50	50
10.	55	40	10.	60	60
11.	45	40	11.	60	50
12.	50	40	12.	60	55
13.	55	55	13.	60	60
14.	55	40	14.	60	60
15.	55	50	15.	55	55
16.	50	45	16.	60	50
17.	40	40	17.	45	45
18.	45	45	18.	60	50
19.	55	55	19.	60	60
20.	50	50	20.	50	50
21.	50	50	21.	60	55
22.	55	50	22.	60	60
23.	55	50	23.	60	60
24.	55	50	24.	60	60
25.	50	50	25.	55	55
26.	55	50	26.	60	60
27.	50	45	27.	55	55
28.	50	45	28.	60	55
29.	60	55	29.	60	60
30.	55	55	30.	65	60
		Mean = 46.83 dB Range = 15 (40-55) dB Std. Dev. = 5.24			Mean = 55.33 dB Range = 15 (45-60) dB Std. Dev. =4.26
		* 't' test = 6.899 (at 0.05) (* = Significant)			

Table 4.1 Values of monaural and binaural MCL values for the poorer ear and better ear (Study 1)

MCL BIN =Binaural Most Comfortable Level
MCL MON = Monaural Most Comfortable Level
Std.Dev. = Standard Deviation

(i) The mean of monaural MCL for the better ear was 55.33 dB with a range of 15 dB (45 to 60 dB) and standard deviation of 4.26.

The mean of binaural MCL for the better ear was 46.83 dB with a range of 15 dB (40 to 55 dB) and standard deviation of 5.24.

The results imply that the binaural MCL was about 9 dB better than the monaural MCL

The 't' test revealed this difference to be statistically significant at 0.05 level [t=6.899].

Study II

The Table 4.2 gives the values of monaural MCL and binaural MCL and the speech discrimination scores at these levels, for both ears, for the subjects with hearing loss.

Sl. No.	MCL MON				MCL BIN		SDat Binaural MCL
	BE MCL dBHL	SDof BE	PE MCL dBWL	SDof PE	BE MCL dBHL	PEMCL dBML	
1.	75	95%	85	95%	70	75	100%
2.	75	100%	80	100%	70	70	100%
3.	70	95%	75	90%	65	65	100%
4.	85	90%	90	85%	—	—	—
5.	80	80%	90	85%	75	75	100%
6.	75	90%	75	90%	—	—	—
7	80	60%	85	50%	75	70	90%
8.	80	60%	85	60%	—	—	—
9	85	75%	85	65%	80	80	100%
10.	70	85%	70	80%	65	60	95%
11.	85	60%	95				
12.	65	80%	65	80%	60	50	80%
13.	80	80%	85	65%	75	75	100%
14 .	75	90%	75	95%	60	70	100%
15.	70	85%	75	90%	65	60	95%
16.	70	100%	70	100%	60	65	100%
17.	75	95%	85	100%	70	65	100%
18 .	70	60%	80	50%			
19.	50	85%	65	85%	45	45	80%
20.	65	80%	90	90%	60	65	100%
21.	65	90%	70	90%			
22.	65	100%	70	100%	60	60	95%
	75	80%	80	70%	70	75	90%
24.	80	90%	90	90%	75	85	100%
25.	80	70%	85	65%	75	70	95%

Sl. No.	MCL MON BE MCL dBHL	SD of BE	PE MCL dBHL	SD of PE	MCL BIN BE MCL dBHL	PEMCL dBHL	SD at Binaural MCL
26.	80	70%	80	65%	75	75	90%
27.	95	50%	95	50%	85	90	85%
28.	75	100%	85	100%	70	80	100%
29.	90	65%	100	65%	85	90	100%
30.	80	70%	75	75%	75	85	100%
31.	75	80%	90	75%	70	80	100%
32.	80	30%	85	30%	70	75	80%
33.	55	85%	60	85%	40	50	90%
34.	90	75%	90	75%	85	85	85%
35.	90	75%	90	40%	85	85.	85%
36.	75	100%	75	100%	70	70	100%
37.	75	95%	75	80%	—	—	—
		Mean = 82% Range = 30% to 100% Std. Dev.=16					Mean = 94.5% Range = 80% to 100% Std.Sev.=6.99

Table 4.2 showing the values of monaural MCL and binaural MCL and speech discrimination scores at these levels (Study II)

MCL BIN = Binaural Most Comfortable Level
MCL MON = Monaural Most Comfortable Level
BE = Better Ear
PE = Poorer Ear
SD = Speech Discrimination
Std.Dev. = Standard Deviation

(i) The mean of speech discrimination scores of the better of the two ears at the most comfortable level, under monaural conditions was 82% with a range of 70 (30% to 100%) and a standard deviation of 16.

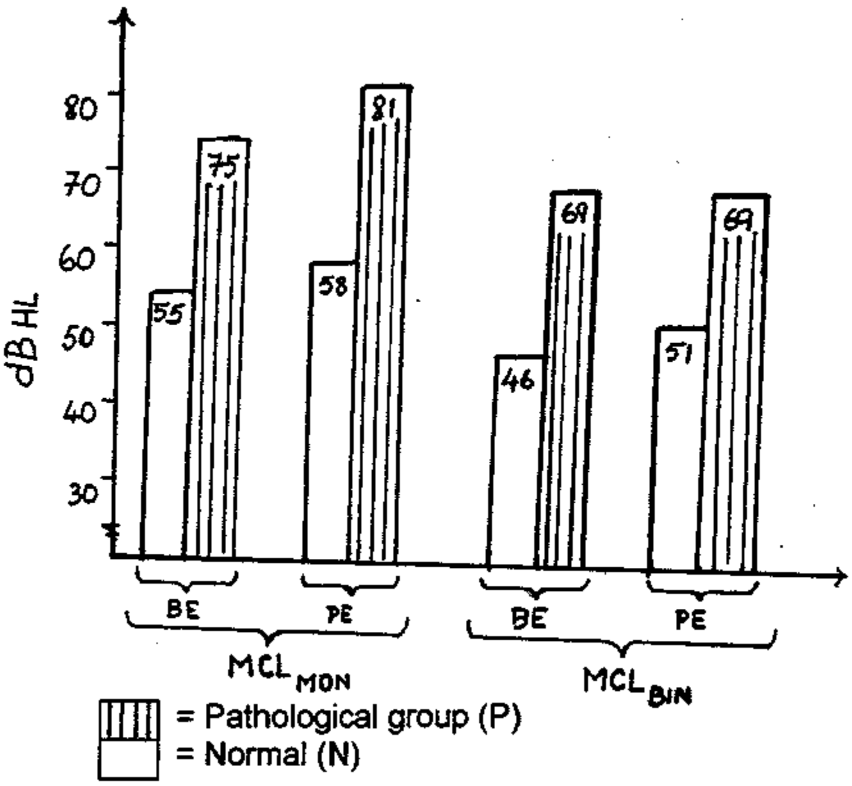
(ii) The mean of binaural speech discrimination scores, at the most comfortable level was 94.5%, ranging from 80% to 100% with a standard deviation of 6.99. The results show a smaller variability between the scores, and, when compared with the best monaural speech discrimination scores, these scores show an improvement for almost all the cases tested.

The 't' test revealed a statistically significant difference, at 0.05 level, between the means for the speech discrimination scores, for the better of the two ears, under monaural conditions, at the most comfortable level, and, the speech discrimination score, at the most comfortable level, under binaural conditions [t=2.83].

The results obtained in this study are consistent with those obtained in a similar study by Mercola and Mercoia (1984). That is, the binaural MCL obtained was 5 dB less than the monaural MCL, and, there was an improvement in the binaural speech discrimination scores over the monaural scores.

From the Table 4.2, it is observed that from among 37 subjects tested, 30 potential candidates for binaural amplification were identified and the remaining 7 were clearly identified as non-candidates for binaural amplification (even though the difference between the pure tone average of both ears ranged from 0 to 10 dB).

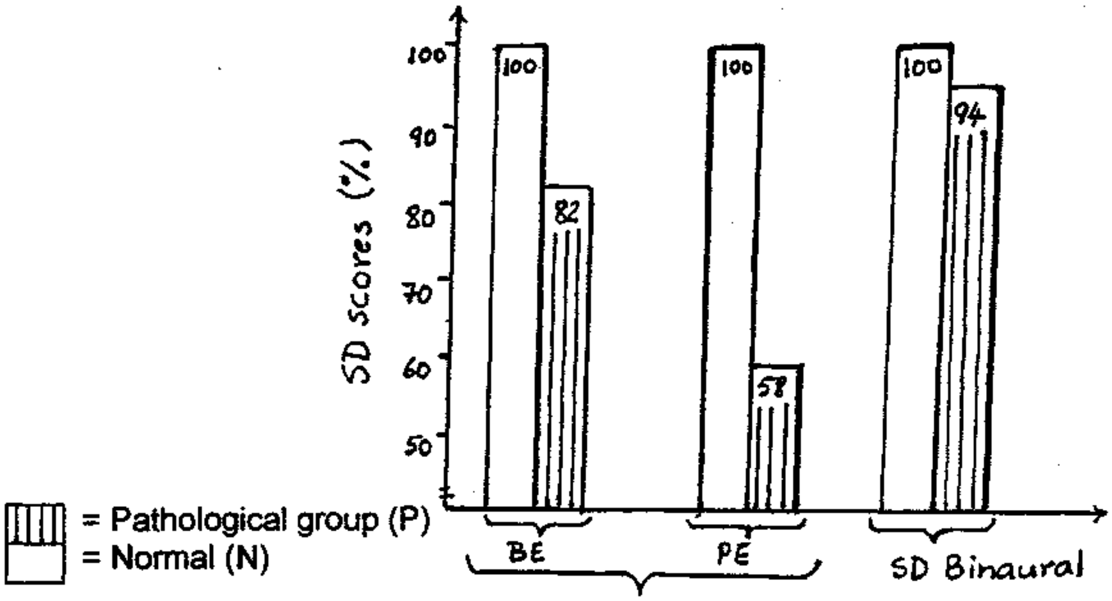
From Figure 4.1 we see that the monaural MCL values for the better ear (BE) and the poorer ear (PE) are poorer than those for binaural MCL for both normal and pathological groups.



MCL BIN = Binaural Most Comfortable Level
MCL MON = Monaural Most Comfortable Level
BE = Better Ear
PE = Poorer Ear

Fig 4.1: Comparing the monaural and binaural MCLs of normal and pathological groups, for the better ear and the poorer ear.

From Figure 4.2 we see that there is an improvement in speech discrimination (SD) scores, with values approaching 100%, in the binaural condition.



MCL BIN = Binaural Most Comfortable Level SD Monaural
MCL MON = Monaural Most Comfortable Level
BE = Better Ear
PE = Poorer Ear
SD = Speech Discrimination

Fig 4.2: Comparing the speech discrimination scores at MCLs for normal and pahtological groups, for the better ear and the poorer ear.

Thus the Mercon Method can be used to identify candidates for binaural amplification and to fit binaural hearing aids.

Recommendation:

1. As most of the cases tested had symmetrical hearing loss in the present study, cases with asymmetrical hearing loss or unilateral hearing loss may be included to decided about the type of hearing aid to be prescribed.

2. Majority of the cases had mixed hearing loss, it would be interesting, therefore, to study the response of other types of hearing loss eg., sensorineural and recruiting ears to the Mercon Method.

3. It is recommended to investigate if the binaural advantage is significant even when speech discrimination scores are tested in noise rather than in quiet alone. This would help in generalization of results for other situations.

Summary and Conclusions:

Two studies, Study I and Study II were conducted on two groups (Group I and Group II consisting of fifteen males and fifteen females, and, sixteen males and fourteen females, respectively) using the 'Mercon Method' with the two aims;

1. - of determining if the 5 dB decrease in binaural most comfortable level due to summation effect was valid, and

2. - if it was valid, to determine the utility of the 'Mercon Method[1] to determine candidacy for binaural amplification.

The results of the experiment reveal that the 5 dB decrease in binaural most comfortable level, due to summation effect, was valid, and that, the "Mercon Method' could be used as a procedure to determine candidacy for binaural amplification.

Conclusion:

The Mercon Method is a simple and valid test procedure in order to determine candidacy for binaural amplification.

APPENDIX - 3-A

Monosyllabic List [re: MayaDevi, (1974)]

List A	List B
ma	ča
t̪a	d̪a
sa	na
ča	ka
da	ba
t̪a	ra
ra	ga
ṇa	pa
pa	ma
va	va
na	da
ǰa	t̪a
ka	na
la	ha
ha	ya
la	sa
ga	t̪a
da	ʃa
ya	ǰa
ʃa	la

APPENDIX – 3-B

The Passage

ಬೆಂಗಳೂರು ನಮ್ಮ ರಾಜ್ಯದ ಒಂದು ದೊಡ್ಡ ಊರು. ಈ ಊರನ್ನು ನಮ್ಮ ರಾಜ್ಯದ 'ಬೊಂಬಾಯಿ' ಎನ್ನುವರು. ಇಂಡಿಯಾದ ದೊಡ್ಡ ನಗರಗಳಲ್ಲಿ ಇದೂ ಒಂದು. ಈ ಊರನ್ನು ನೋಡಲು ಜನರು ಬೇರೆ ಬೇರೆ ರಾಜ್ಯಗಳಿಂದ, ಬೇರೆ ಊರುಗಳಿಂದ ಬರುವರು. ಇದಲ್ಲದೇ ನಮ್ಮ ರಾಜ್ಯದಲ್ಲಿರುವ ಬೇಲೂರು, ಜೋಗ್, ನಂದಿ ಇವುಗಳನ್ನು ನೋಡಲು ಜನರು ಬರುವರು. ಈ ನಾಡಿನಲ್ಲಿ ರೇಷ್ಮೆಯನ್ನೂ ಬೆಳೆಯುವರು.

Bibliography

1. Agnell, J.R. and Fite, W. (1901). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

2. Batteau, D.W. (1967). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

3. Batteau, D.W. (1968). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

4. Berger, K.W. (1984). Is binaural for everyone ? Hearing Instruments, 35 (9), 24-26.

5. Berger, K.W. (1988). Predicted vs. actual gain usage by binaural hearing aid wearers. The Hearing Journal, 41 (9), 20-22.

6. Bergman, N. (1957). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

7. Bocca, E. (1955). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

8. Breaky, M.R. and Davis, H. (1949). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London: Academic Press Inc. Ltd.

9. Briskey, R.J. and Cole, P. (1983). Consumer evaluation of binaural hearing aids. The Hearing Journal, 36 (3), 29-31.

10. Brooks, D.N. and Bulmer, D. (1981). Cited in Valente, M. (1984). Binaural amplification. Audecibel, 33(1), 10-14-16

11. Burger, J.F. (1958). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

12. Butler, R.A and Naunton, R.F. (1967). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

13. Carhart, R. (1958). Cited in Johnson, E.W. (1987). Binaural amplification - naturally! Hearing Instruments, 38 (12), 19-23.

14. Carhart, R. (1965). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

15. Cherry, E.C. (1853). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

16. Cherry, E.C. and Sayers, B.M. (1956). Advantages of binaural monaural hearing. Cited in Markides, A. (1977). Binaural hearing a (pp. 1-13), London : Academic Press Inc. Ltd.

17. Cherry, E.C. (1959). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

18. Cherry, E.C. (1961). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

19. Coles, R.RA (1968). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

20. Day, A.G., Browning, G.G. and Gatehouse, S. (1988). Cited in Day, A.G., Browning, G.G. and Gatehouse, S. (1988). Benefit from binaural hearing aids in individuals with severe hearing impairment. British Journal of Audiology, 22, 273-277.

21. Day, A.G., Browning, G.G. and Gatehouse, S. (1988).. Benefit from binaural hearing aids in individual with a severe hearing impairment. British Journal of Audiology, 22, 273-277.

22. Di-Carlo, L.M. and Brown, W.J. (1960). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

23. Dirks, D. and Carhart, R. (1962). Cited in Valente, M. (1984). Binaural amplification. Audecibel, 33(1), 10-14,16.

24. Fisher, H.G. and Freedman, S.J. (1968). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

25. Fredriksen, E., Blegvad, B. and Rojskaer, C. (1974). Binaural hearing aid treatment of presbycusis patients aged 70 to 80 years. Scandinavian Audiology, 3: 83-86.

26. Gelfand, S.A., Silman, S. and Ross, L. (1987). Long-term effects of monaural, binaural and no amplification in subjects with bilateral hearing loss. Scandinavian Audiology, 16, 201-207.

27. Groen, J.J. and Hellema, A.C.M. (1960). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

28. Harris, J.D. (1965). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

29. Hartley, R. and Fry, T. (1922). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaurari hearing aids, (pp. 1-13), London: Academic Press Inc. Ltd.

30. Hirsh, I.J. (1948). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

31. Hirsh, I.J. and Pollak, I. (1948). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London: Academic Press Inc. Ltd.

32. Hirsh, I.J. (1950). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

33. Hirsh, I.J. (1952). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

34. Hood, J.D. and Prasher, D.K. (1990). Effect of simulated bilateral cochlear distortion on speech discrimination in normal subjects. Scandinavian Audiology, 19, 37-41.

35. Hood, J.D. (1990). Problems in central binaural integration in hearing loss cases. Hearing Instruments, 41 (4), 6-11.

36. Jeffress, L.A., Blodgett, H.C. and Wood, C.L. (1958). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

37. Johnson, E.W. (1987). Binaural amplification-naturally! Hearing Instruments, 38 (12), 19-23.

38. Jongkees, L and Veer, A.V.D. (1957). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

39. Keys, J.W. (1947). Advantages of binaural over monaural hearing. Cited In Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

40. Koenig, W. (1950). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

41. Kuyper, P. (1972). A cocktail party effect Audiology, 11, 277-282.

42. Lehnhardt, E. (1969). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

43. Lewis, D.N. and Green, R. (1962). Cited in Valente, M. (1984). Binaural amplification. Audecibel, 33 (1), 10-14,16.

44. Lochner, J.P.A. and Burger, J.F. (1961). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

45. Lundeen, C. (1988). Selecting binaural hearing aid candidates: A Moderate Approach. The Hearing Journal, 41 (1), 12-14.

46. Mac Keith, N.W. and Coles, R.R.A. (1971). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

47. Mac Keith, N.W. and Coles, R.R.A. (1971). Cited in Valente, M. (1984). Binaural amplification. Audecibel, 33 (1), 10-14,16.

48. Markides, A. (1977). Advantages of binaural over monaural hearing. Cited in Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

49. Markides, A. (1980). Cited in Valente, M. (1983). Binaural amplification. Audecibel, 32 (4), 16-24.

50. Markides, A. (1980). Cited in Valente, M. (1984). Binaural amplification. Audecibel, 33(1), 10-14,16.

51. Markides, A. (1982). Cited in Lundeen, C. (1988). Selecting binaural hearing aid candidates : A moderate approach. The Hearing Journal, 41 (1), 12-14.

52. Maya Devi. (1974). Development and standardization of a common speech discrimination test for Indians. Dissertation submitted to the University of Mysore.

53. Mercola, P. and Mercola, W. (1984). Cited in Mercola, P. and Mercola, C. (1985). A new test procedure for determining binaural candidacy. The Hearing Journal, 38 (3), 19-31.

54. Mercola, P. and Mercola, C. (1985). A new test procedure for determining binaural candidacy. The Hearing Journal, 38 (3), 19-31.

55. Moncur, J.P. and Dirks, D.D. (1967). Cited in Valente, M. (1984). Binaural amplification. Audecibel, 33 (1), 10-14,16.

56. Mueller, G.H. (1986). Binaural amplification attitudinal factors. The Hearing Journal, 39 (11), 7-10.

57. Mueller, G.H. (1988). On : Selecting binaural hearing aid candidates a moderate approach. The Hearing Journal, 41 (3), 20-26.

58. Neuman, A.C. (1996). Late-onset auditory deprivation. Ear and Hearing, 17(3suppl), 3S-13S.

59. Nielson, H.B. (1974). Cited in Valente, M. (1984). Binaural amplification. Audecibel, 33(1), 10-14,16.

60. Nordlund, B. and Fritzell, N. (1963). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

61. Nordlund, B. and Linden, G. (1963). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

62. Olsen, W.O. (1965). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

63. Olsen, W.O. and Carhart, R. (1967). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

64. Pascoe, D.P. (1985). Cited in Mueller, G.H. (1986). Binaural amplification attitudinal factors. The Hearing Journal, 39 (11), 7-10.

65. Petri, J. (1932). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

66. Pierce, A.R. (1901). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

67. Pollack, I. (1948). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

68. Pollack, I. And Pickett, J.M. (1958). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

69. Rayleigh, Lord (1904). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

70. Rayleigh, Lord (1907). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

71. Reynolds, G.S. and Stevens, S.S. (1960). Advantages of binaural over monaural hearing. Cited in Markides, A (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

72. Rosenzweig, M.R. (1961). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

73. Ross, M. (1980). Cited in Valente, M. (1983). Binaural amplification. Audecibel, 32 (4), 16-24,

74. Ross, M. (1980). Cited in Valente, M. (1984). Binaural amplification. Audecibel, 33(1), 10-14,16.

75. Scharf, B. (1968). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

76. Shaw, E.A.G. (1966). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

77. Shaw, W.A., Newman, E.B. and Hirsh, I.J. (1947). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

78. Siegenthaler, B.M. and Aungst, R.B. (1968). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

79. Silman, S., Gelfand, S.A. and Silverman, CA (1984). Cited in Gelfand, S.A., Silman, S. and Ross, L. (1987). Long-term effects of monaural, binaural and no amplification in subjects with bilateral hearing loss. Scandinavian Audiology, 16, 201-207.

80. Sivian, L.J. and White, S.D. (1933). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

81. Stearns, W.P. (1982). Monaural fittings : a prelude to failure ? Hearing Instruments, 33 (4), 9-11.

82. Stevens, S.S. and Newman, E.B. (1936). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids (pp. 1-13), London : Academic Press Inc. Ltd.

83. Thurlow, W.R. and Runge, P.H. (1967). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

84. Tillman, T.W., Kasten, R.N. and Homer, J.S. (1963). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London: Academic Press Inc. Ltd.

85. Valente, M. (1983). Binaural amplification. Audecibel, 32 (4), 16-24.

86. Valente, M. (1984). Binaural amplification. Audecibel, 33(1), 10-14,16.

87. Viehweg, W.A. and Campbell, R.A. (1960). Advantages of binaural overs monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London : Academic Press Inc. Ltd.

88. Wallach, H. (1940). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London Academic Press Inc. Ltd.

89. Wiener, F.N. and Ross, D.A (1946). Advantages of binaural over monaural hearing. Cited in Markides, A. (1977). Binaural hearing aids (pp. 1-13), London : Academic Press Inc. Ltd.

90. Wiener, F.N. (1947). Advantages of binaural over monaural hearing Cited in Markides, A. (1977). Binaural hearing aids, (pp. 1-13), London Academic Press Inc. Ltd.

91. Zelnick, E. (1985). Update on binaural hearing aid fitting. Audecibel, 34 *(3)* 16-19