BINAURAL AMPLIFICATION - A REVEIW OF LITERATURE

Reg. No.8805

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AN INDEPENDENT PROJECT SUBMITTED AS PART FULFILMENT FOR FIRST YEAR M.Sc. (SPEECH AND HEARING) TO THE UNIVERSITY OF MYSORE

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LOVING APPA, AMMA & RAJ

CERTIFICATE

This is to certify that the Independent project entitled: "Binaural Amplification" - A Review of Literature is the bonafide Work done in part fulfilment for First Year M.Sc. (Speech and hearing) of the student with Register Number. 8805

17/5/89

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CERTIFICATE

This is to certify that the Independent Project entitled: 'Binaural Amplification" - A Review of Literature has been prepared under my supervision and guidance.

Dr. M.N. Vyasamurthy

GUIDE

DECLARATION

This Independent Project entitled: "Binaural Amplification" - A Review of Literature is the result of my own review, undertaken under the guidance of Dr. M.N. Vyasmurthy, Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other Diploma or Degree.

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I N T R O D U C T I O N

" Epictetus the Stoic quoted to by Colin Cherry (1953), said that "God gave man two ears but only one mouth so that he might hear twice as much as he speaks". The wisdom of the "Almighty" was also recently referred to by Harris (1965) when he asserted that our creator would not "have simply hung a second ear on our heads purely as a mechanical safety factor in a chancy world". It may well be that this attitude expresses deep theological convictions but it does very little to throw light on the advantages of binaural interaction" Markides (1977).

(Hearing is based on the processing of information received through two ears. Binaural hearing is based on the ability of the total human system to detect two different signals, analyze their differences and perceive a single auditory imaged

In the normal auditory system, it is known that two ears have neural connections and the capacity to function as a binaural system. So binaural analysis, summation and fusion can occur, (in normal binaural (pertaining to two ears) hearing, one utilizes the dimensions of intensity, frequency and time to assist him in localisation and identifying a signal. The ability of an individual to Spatially place signals, as well as separate signals from noise, results from binaural hearing function.

Monaural (involving one ear only) listening is also possible. In normally hearing individuals monaural listening can be brought about by occluding one of the ears (artificially induced by earplugs).

Binaural hearing occurs when there is a balance between the two ears, as in normally hearing individuals. In individuals with hearing loss, this balance between the ears is distrubed and hence binaural hearing is precludedJ

The hearing impaired individuals seek medical line of management to rectify their hearing loss. But if permanent hearing impairment continues to exist following medical care, the first and most logical step in the aural rehabilitative process is a hearing aid evaluation (Tannahill, WalterJ Smoski, 1985). For some individuals, successful use of amplification resolves the

the communication Handicap; however, for many others the acquisition of a hearing aid is the first step in a long line of aural rehabilitation procedures (Tannahill, Walter J Smoski, 1985).

The hearing impaired individual, based on the number of ears involved can be classified as the unilateral hearing impaired and the bilateral hearing impaired.

The amplification system, if prescribed, for a unilateral hearing impaired individual is a monaural fitting. THe amplification systems generally advocated for a bilatterally hearing impaired individual include one hearing aid delivering sound to one ear (monaural), one hearing aid delivering sound to both ears (pseudobinaural or Y-cord), or two hearing aids (binaural). But there is a general disagreement regarding which system provides optimum amplification.

Historically, manufacturers and dispensers of hearing aids have strongly advocated binaural fittings, while audiologists are more reluctant to do so. A great deal of formal and informal research has been performed in an attempt to demonstrate the advantage of binaural amplification. Positive cases fill the report files, yet the disagreement continues(Pollack, 1975).

Binaural amplification has been defined by Konkle and Schwartz (1981)

"True dichotic or stereophonic stimulation of each ear independently is binaural amplification".

Wright (1959) (referred to by Pollack, 1975) points out that the purpose of binaural amplification is to create a sound environment for the listener that is a faithful reproduction of the original acoustic event so that he can take advantage of the intensity, time and spectrum differences of the auditory signal at each ear.

These differences, theoretically, provide the additionalcues necessary for a more reasonable approximation of the hearing experiences of the normal - hearing population.

A bi-lateral hearing - impaired individual is unable to use ofthe cues normally, hence by providing binaural amplification enable him to use the additional cues.)

Some investigators exclude the 2 complete body level aids to constitute a binaural amplification system while some do include them under this system.

(Ross (1969) indicates that until ear - level hearing aids developed, binaural aids were not practical for the hearing aid user. He adds that to obtain true binaural effect, two complete units must be situated in the vicinity of the ear. This is notso with body-borne hering aids.

The most important point is that the binaural amplification has two separate microphones, two amplifiers (onemic-to-one amplifier) and two receivers (one amplifier-to-one receiver only). They can be 2 body borne aids, 2 ear - level aids, two IROS aids (one each side) and BiFROS aids."

Not all handicapped individuals are bonn with a single handicap. They can have multiple handicaps. One such group constitute the deaf-blind. Heyes and Gazely (1975) gave a series of 3 chest - mounted binaural hearing aid systems, intended to aid auditory localisation for the hearing - impaired blind. They were of different complexity. The systems, which represent successive approximations to an ideal natural system are as follows:-

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System A'Crossed Stereo pair - A pair of high quality studio microphones, both with a cardioid polar response, were crused; each microphone making an angle of 45^0 to the straight ahead. In accordance with usual studio practice, the microphones were mounted with the diaphragm one above the other. This is a system which provides only intensity cues. However, a consideration of polar response shows that this arrangement provides an interaural intensity versus azimuth relationship, the magnitude of which is less than that experienced in normal hearing (Weiner, 1947) (referred to by Heyes and Gazely, 1975).

System B. Crossed Stereo Pair without Phase Cross-Talk

This system uses the crossed stereo pair (system A), but with the sterephonic sound image aritfically widened by feeding a proportion of the signal from each channel (18%) out of phase into the other channel.

This increased inter-channel intensity difference could also have been achieved by increasing the angle between the microphones.

System C: Crossed Stereo pair with Frequency Dependent Cross- Talk

This employed an arrangement which was identical to system 3 except that the stereophonic sound image was a function of frequency. The intensity/azimuth relationship obtained by Weiner was thus reproduced quite accurately, in - phase cross talk being provided at low frequencies to remove inter-channel differences and out-of-pnase corss-talk provided at high frequencies to artificially enhance, the inter-channel aeperation. This system was thus 'quasi-natural' in that the intensity/azimuth relationship was essentially correct for the two channels but the time difference information was absent.

The designs of these systems make successive approximations to the 'ideal', where the 'ideal' systems is defined as that which perfectly mimic the normally experienced inter-ear intensity and time differences for sound sources in the azimuth plane.

Bentzen (1968) indicates that majority of binaural treatments have been carried out by ear-level hearing aids, chiefly in the form of earhangers with external telephone, for presbyacusis. He points that this model which is the most robust uses a normal ear mould which for the old patient is quite simple to place in the external ear canal. The ear hangers having a maximum amplification of 46dB have been used by patients with hearing losses between 11 and 60 dB,

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but it is noteworthy, however, that this type of hearing aid can be used by patients having hearing losses in the 61 - to 80 dB range. Above this hearing loss these aids were not used instead body - type hearing aids with Y cord had been prescribed as standard treatment of presbyacusis.

Though actually binaural system involves considering independent amplification to each ear, Johnson (1975) established a design objective for a single system to aid two eared hearing. He says that this single system should provide as many acoustic cues as possible to compliment the two ears the system is designed to serve.

He says - "since little more can be done to selectively alter the frequency and intensity signal presentations, to add to the binaural function, the initial experimentation with hearing instruments involved the third dimension, basic phase considerations. Due to compact design of hearing aids with critical mechanical, electrical and acoustical considerations, phasing is an important design consideration. To intentionally upset an optimally phased hearing aid design and maintain performance integrity involved considerations beyond simple lead reversals to alter phase.

The second design consideration with specific attention to the right ear facilitation for language brings special emphasis in the frequency range above 2000 Hz to the right side unit of the system. With phase and high frequency changes in the right amplifier of the system, an 'unbalanced'presentation of acoustical information is made. The differendes in the signals from the dissimilar sides add the important difference cues in binaural amplification. The resulting system is called the Biphasic binaural hearing system.

Having had a glance as to what constitutes binaural amplification, it is imperative to determine whether this can restore binaural hearing to the bilateral hearing impaired individual.

This requires that one surveys the information regarding binaural hearing. This has been done under the chapter - 'Binaural Auditory Phenomena'. Further the consequences of binaural amplification have to be determined. This has been dealt under the chapter - 'Binaural Amplification - its Role'.

The next question that arises in whether all bilateal hearing impaired individuals are candidates for binaural amplification. This requires considering the audiological and nonaudiological factors related to it. This has been dealt in the chapter - 'Candidacy for Binaural Amplification".

Investigators have used different approaches to determine as to who can benefit from binaural amplification. Broadly, the approaches includes experimental studies and subjective reports. This has been reviewed in the chapter "Procedures to evaluate candidacy for Binaural Amplification".

A majority of hearing impaired persons who can benefit from amplification should be wearing a bindural hearing and Briskey (1983). This calls for precision in binaural hearing aid fittings. This has been dealt in the chapter - 'Binaural Hearing Aid Fittings And Its Eventual Use'.

Compilation is an essential aspect, from pieces of information. This has been given in the 'Summary and Conclusions'.

BINAURAL AUDITORY PHENOMENA

The concept of binaural amplification actually predated the introduction of electronics hearing aid by atleast fifty years when a manufacturer in Great Britain produced binaural ear trumpets connected by a headband (Berger, 1970; referred by Konkle and Schwartz, (1981) Literature points out that since that 'novel' invention, the term binaural amplification has been used to describe several different systems. But for the present purpose,'binaural amplification is defined as follows by Konkle and Schwartz (1981)

"True dichotic or sterephonic stimulation of each ear independently" is binaural amplification.

Langford (1970) (referred to by Pollack, 1975) has summarized the clinical and research observations and proposed five potential advantages of binaural amplifications - better sound localization, increased speech discrimination in noise, greater Case of listening, better spatial balance and improved sound quality.)

The practical advantages attributed to this binaural arrangement, given by Konkle and Schwartz (1981) include:

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(1) an improvement in the speech recognition ability under adverse listening conditions, often referred to as the 'Cocktail Party' effect;

(2) a reduction in the effects of unpleasant background noise or reverberation, frequently termed the 'squech' or 'Koenig' effect.

(3) enhanced sound localization

and (4) an avoidance or reduction of the hear shadow effect that occurs when the head is positioned between the source of a primary stimulus and the aided ear, especially in a background of noise.

In order to appreciate fully the implications associated with proposed binaural advantages, some important basic phenomena of binaural hearing have been reviewed.

1. The Summation of Acoustic Energy

Binaural summation of acoustic energy refers to an increase in perceived loudness of an acoustic signal when presented binaurally, rather than monaurally (Konkle and Schwartz, 198)). Example, binaural. thresholds of audibility for tonal as well as speech stimuli are approximately 3dB more sensitive than monaural counterparts (Keys, 1947; Shaw, Newman and Hirsh, 1947; Polladk, 1948; Breaky and Davis, 1949; Bocca 1955; Pollack and Pickett, 1958; Reynolds and Stevens, 1960; Lochner and Burger, 1961; Coles 1977 (referred by Konkle and Shwartz,1981).

It has been demonstrated by Pollack and Pickett (1958) (referred by Markldes, 1977) 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) (reffered- by Markides, 1977) 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.

For normally hearing people 3 dB gain at threshold can hardly be considered an advantage for they seldom need to listen to speech at threshold level . It is obvious, therefore, that "for such people, this few dB gain at threshold can be a very real advantage (Markides, 1977).

Having considered binaural summation at threshold, the next thing to be considered is binaural summation of loudness. Pure tone measurements reveal 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, 1950; Scharf, 1968) (referred by Markides, 1977). Further more, Reynolds and Stevens (1960) (referred vby Konkle and Schwartz have indicated that this loudness advantage increased to 10 dB when stimuli were presented at intensites above threshold.

Thus, while.binaural advantage is approximately 3 dB at threshold, it improves to approximately 6 DB at 35 dB SL and 10 - 11 dB at 90 dBSL (Markides, 1980; Ross,1980) (referred by Valente, l983). These latter findings seem to have greater relevance than binaural advantage at threshold (unless measuring improvement in Spondee or Speech Detection Thresholds) since aided listening occurs typically at levels for excluding the listener's threshold (Valente, 1983).

As pointed out earlier, 3 dB advantage at threshold for the hearing - impaired is a real advantage. This concept is illustrated by the performance - intensity (PI) functions as shown in the figure l below.

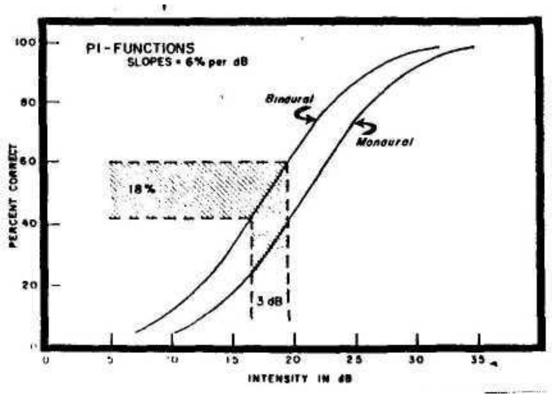

Figure:1 Word-recognition perfprmance - Intensity functions for monaural and binaural listening.

It can be noted that the Linear portion of each function rises at a rate of 6 percent per dB, as is characteristic of many commonly used monosyllabic word recognition tests, but that approximately 3 dB seperates the binaural function from the monaural function. Bocca (1955), Groen and Hellema (1960) and Lochner and Burger (1961) (referred by Konkle and Schwartz all have found that while monaural and binaural PI functions typically parallel each other, an additional 3 dB usually is necessary for the monaural percent correct score to approximate binaural performance. Thus, with a 6% per dB rise depicted for the linear slopes shown in the figure, a 3 dB binaural improvement will result in about 18% better than the monaural score

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obtained at an equal intensity. The difference would be magnified for continuous discourse because the linear portion of the slope for such stimuli is much steeper, about 12% per dB. Thus, it is entirely responsible for a minimal 3 dB advantage in binaural loudness to be reflected as more than 30% improvements in speech intelligibility for continuous discourse. (Konkle and Schwartz 1981)

2. Binaural Squelch:

One of the advantages of binaural hearing is that of the "Squelch' effect. Koenig (1950) (referred by Konkle and Schwartz described this phenomena as the ability of binaural hearing to "tune - in" to a wanted stimuli and at the same time minimise the competing effect of unwanted or disturbing background noise. A common procedure used by the investigators to quantify squelch effect is to assess word recognition ability in a sound field while the speech signal is presented in a background noise. The figure 2 shows an experimental arrangement that may be used to evaluate 'squelch' (Konkle and Schwartz, 1981).

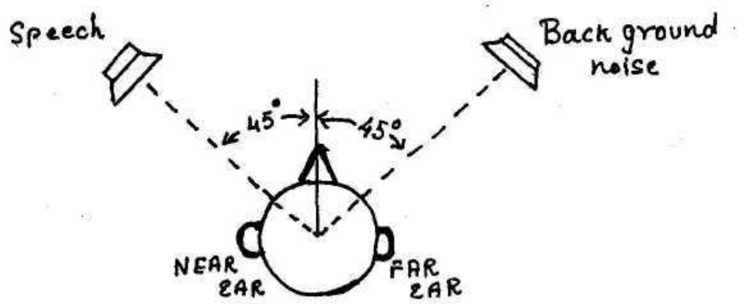

figure: 2 : Sound field listening condition depicting a spatial separation of speech and noise loudspeakers and showing the near ear and far ear designation relative to the speech source

Several investigators have used the protocol to examine word recognition performance of normal hearing individuals. From studies of speech intelligibility in noise with normally hearing people (Nordlund and Frtizell, 1963? Harris, 1965; Cayhart 1965) (refferred by Markides, 1977) results show that the binaural reception was improved over monaural near - ear listening (that is, 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. Cayhart (referred by Markides, 1977) termed this reduction as the 'binaural squelch effect".

Olsen and Cayhort (1967) (referred by Markides, 1977) found 4 dB binaural sqnelch while Mackeith and Coles (1971) (referred by Markides, 1977) report that such an effect varied from 0 to 4 dB depending on the orientation of speech and noise sources. Markides (1977) concludes that the differences reported between the different studies are rather small and can be easily attributed to the different speech materials employed.

Considering squelch effect, it refers to the condition when the favourably placed ear during monaural near-ear or direct listening is the same as the one during binaural listening and, moreover, this ear is subjected to the same signal - to noise (s/N) ratio whether or not the second ear is active. So any binaural advantage appearing must be attributed to interaural interactions that occur when the second ear participates, even though less favourably placed (Markides, 1977).

The 3dB binaural "squelch" advantage in speech-to-noise ratio may appear insignificant, translating it into a 12 to 18 percent improvement in monosyllablic word recognition, its effect can be substantial, (Konkle and Schwartz 1981).

Moreover, it must be remembered that an improved speech to - noise ratio generally is considered the essential factor in classroom amplification relative to that of personal hearing aids (Konkle and Schwart 1981).

3. Binaural Release From Masking

This is a factor which parallels binaural squelch and is Often referred to as Masking level Difference (MLD) or 'unmasking'. When the tone or speech signal is presented to one ear in the presence of a broad band noise, and the noise can just mask the tone or speech, the introduction of the noise by itself to the opposite ear will result in audibility of the previously masked tone or speech signal (Konkle and Schwartz 1981)'

Markides (1977) reports the same in terms of interaural phase. He points that a tone is more detactable when its interaural phase is different from interaural phase of the masking noise (heterophasic. condition) or opposite to it (antiphasic . condition while when the interaural phase of the tone and noise are the same (homophasic condition), detactability is reported to be poorer.

Literature shows that the results in this area vary considerably. For example, Hirsh and Webster (1949) (referred to by Markides, 1977) found an heterophasic advantage of 22 dB when a narrow band noise centering at 250 Hz was to be detected in a background of white noise. With pure tones as stimuli this average varied with frequency, ranging from 3 dB at higher frequencies to about 14 dB for lower frequencies (Hirsh, 1948; Jeffress, Blodgett and Wood, 1958) (referred by Markides, 1977).

Research using speech as stimuli has shown that a binaural release from making improves the threshold for speech by about 4 to 6 dB (Kaiser and David, 1960; Schubert and Schultz, 1962; Carhart, and Tillman, Johnson, 1967; Levitt and Rabiner, 1967; Levitt and Voroba, 1974; Novak, 1977) (referred by Konkle and Schwartz, 1981). It's possible that the variations in the results could be due to the different experiment procedures adopted by different investigators. None the less, even a 4 dB gain can bring a substantial 24% speech reception improvement with speech material havihg an articulation curve rising by 6% per dB (Markides, 1977).

Konkle and Schwatz referred that while it is recognized that the 4 to 6 dB improvement in speech thresholds associated with binaural release from masking are obtained only under earphones, and that in normal listening conditions where there are no earphones interaural phase differences occur together with interaural differences in intensity and frequency spectra, it remains that release from masking probably plays some role in enhancing binaural speech recognition.

MLD in Bilateral Sensorineural Impairment

a) Noise Induced Hearing Loss - (N1HL)

Literature reveals that detection measurements showed that most NIHL patients have MLDs in normal range for 500 Hz target tones, few subjects showed very small MLDs.

MLDs with spondees reduced relative to normal values (example, average MLD is approximately 2 dB smaller than normal) and a large percentage of patients show negligible MLDs in this case.

But some patients have normal MLDs but significantly elevated threehold at low frequencies. In these cases it becomes essential to consider the latter results, not MLDs alone.

b) Presbyacusis:-

Studies of MLDs in subjects with hearing losses due to aging have been reported.

MLDs reduced by 1 to 3 dB relative to normal listeners in these studies. This reduction takes place even though speech reception thresholds (SRTs) are only moderately impaired (never>40dBHL), and homophasic thresholds are themselves increased (so that the antiphasic threshold must be increased still more to have reduced MLD).

A single patient was reported in the frequency dependent study. This patient revealed a slight sloping loss starting at 50 dBHL at 250 Hz. In tests at octaves from 250 Hz to 4 KH this subject appeared to have and of binaural ability at 500 Hz. Interanal time and correlation discrimination were possible at 300 Hz, binaural detection results showed a maximum MLD of 5 dB at 500 He(with no MLD octave above or below), and best performance is interaural intensity discrimination at 500 and 1000 Hz.

It has been concluded that prebyacusis is not a specific condition best a category which includes several types of pathologies (example, sensory, neural, sterial atrophy and cochlear conductive as subcategories given by Schuknecht (1974) (referred by Arnst, 1985) and so there will be variability in binaural abilities as well.

MLD in Brain Stem Lesions

Most of the date reported include those from multiple sclerosis, through a variety of disorders of the brain stem are included.MLD tests have been frequently used in the evaluations of patients with known or suspected brain stem lesions by a number of investigators.

Literature reveals that inspite of the varied etiologies, the populations of patients with brain-stem lesion show some commonality. Their pure tone and speech MLDs are frequently small or absent.

4,The Head Shadow Effect

MaVkides (1977) explains what the head- shadow effect is. A signal coming from the right side of a person will be louder in his right ear than when compared in his left ear and vice versa. The reduction in loudness that occurs in the far-ear (that is, the ear on the far side of the head in relation to the signal source) is obviously due to the .head intervening. This reduction in intensity is termed as the head shadow effect.

Markides (1977) points out that Sivian and white (referred by Markides 1977) studied the effect of head shadow upon pure tone thresholds as early as 1933.

Tillman, Hasten and Horner (1963) (refferred by Markides 1977) found that the shadow effect attenuated the sound field spondee threshold by 6.4 dB for normal listeners positioned between two loudspeakers located at 45^0 on either side of the midline of the head. Olsen (1965) (referred by Markides, l977) reported that head - shadow effects vary from 5 to 7 dB on the spondee thresholds of normal listeners.

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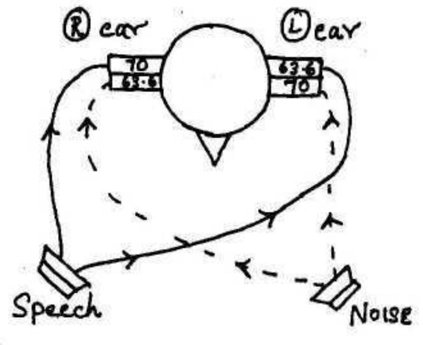
The following is an example of the head shadow effect given by Konkle and Schwartz (1981).

Figure 3: Illustration of Head-shadow effect for speech and noise source showing the appoximate 13dB signal to noise(S/N)ratio .



EAR	S/N RATIO
RIGHT	+6.4 dB
LEFT	-6.4 dB
MAX	13 dB

For the 70 dB speech stimulus, it is at 63.6 dB at the far ear. Competing noise is 6.4 dB intense than the primary signal at the left ear; or an unfavourable - 6.4 dB S/N ratio. Hence, maximum difference between the S/N ratios is about 13 dB

Thus, the head-shadow has a double effect whenever speech is listened to with a background of noise.

The unfavourable effects of headshadow are minimized during binaural listening because one of the two ears is always positioned to the side of the primary signal. The binaural squelchoccurs whenever the primary signal is located so that the active ear is nearest the source, and then the addition of a second ear results in an approximate 3 dB release from masking. In the reverse situation however, the addition of a 2nd ear combines with the effects of squelch and head shadow so that an approximate 14 to 16 dB reduction in masking occurs. Consequently binamal listening allows an individual never to be in the position of unfavourable listening situation where speech recognition depends upon far - ear listening (Konkle and Schwartz 1981.

The following is a review of Nordlund & Fritzell (1963) (referred by Valente 1983) study which documented the differences created by head diffraction and shadow effects.

They presented Swedish phonetically - balanced word lists and speech noise at 0^0, 30^0, 60^0, 90^0 135^0 and 180^0 azimuth to a dummy, head situated in a sound suite. The output from each ear was fed to two channels of a spectrograph for spectrographic analysis of the signals at the near and far ears.

Spectrographic analysis of the results revealed significant loss of spectral information at the far ear, as the loudspeaker moved from 0^0. Little difference was present when considering the vowel segments between the two ears. For the consonant energy, and significant loss of higher frequency consonant energy was seen at the far ear, especially the fricative sounds (f, s, o, v, z).

To measure the effect of the interanal spectral differences created by head diffraction and shadow, the output from the dummy head was fed to a set of earphones. They evaluated near, far and binaural discrimination, scores for 10 normal listener for the six treatment levels of azimuth. The following table 1 gives the result:-

Table: 1 Binaural Advantage (in percent) Between near and far ear for Swedish PB word lists embedded in speech noise under six conditions of Azimuth Presentation (Nordlund and Frtizell, 1963) (quoted by Valente (1983).

Azimuth	NE	FE	NE-FE
0	6		
30	12.0	29.0	17.0
60	10.0	43.0	33.0
90	11.0	41.0	30.0
135	88.0	31.0	23.0
180	7		

A small binaural sqelch (difference between the binaural score and the optimal monaural score The latter is referred to as 'near ear' (HE) Score), of 8% to 12%, a large difference between binaural and far-ear listening of 31% - to 43% and head shadow effects of 17% to 33% can be seen.

There is a small binaural advantage when the signals were delivered in front (O'azimuth) or behind (180* azimuth) due to the non existance of interaural differences of the signals. These differences occur naturally in the suite when a loudspeaker presents a signal at 90* azimuth. To the right of the listener, when the signal is presented the signal will take approximately - .65 msec longer to arrive at the far (left) ear if the signals is far from the head, or a.79 m sec longer if fairly close to the head. Thus the ears are stimulated at different times, with the left ear being stimulated later.

Due to the head shadow and diffraction, signal changes in frequency, changes in interural intensity and spectral differences develop. With increase in frequency, wavelength decreases. At the same point, the wavelength of the signal will be equal to or smaller than the distance between the two ears (circumference of the head). In an average adult male, this occurs for frequencies 2000 Hz, there will be interaural time difference present but little interaural frequency or spectral differences. At higher frequencies, however, less intensity and less high frequency spectrum is present at the far ear relative to the near ear. Valente (1983) states that it is due to this reason that Nordlund and Frtizell (1963) found little difference in the vowel segment (typically low frequency) between the ears, but large differences in the donsonant segment (especially the fricatives).

Because the far ear is receiving less high frequency information and reduced intensity in comparison to the near - ear, the socre in the far ear is 30 to 50% poorer than the near ear score. So, when the signal is at 90* to the right ear, the left ear receives the signal a little later/ a little weaker (in,the higher frequencies) and with less high - frequency information. It has been stated that at this time a binaural hearing aid arrangement will typically result in better performance than a monaural aid on either ear.

5. Cross - Correlation of incoming stimuli

Markides (1977) indicates that experimental evidence suggests that the incoming auditory information is first analyzed separately and secondly cross - analyzed as described by Cherry (1953, 1959 1961) (referred by Markides, 1977).

This corss - correlation enables the binaural listener to use interaural signal differences in temporal and intensity characteristics as cues to increase the effeciency in binaural reception particularly in the presence of noise (Cherry and Sayers, 1956, 1957) (referred by Markides 1977). This cross - correlation enhances the integration of incomplete auditory patterns impinging in each ear, thus bringing about improved intelligibility. This effect can be observed when the speech is split so that low frequencies are passed to one ear and high frequencies to the other ear (Fletcher, 1953;. Bocca, 1955) (referred by Markides 1977). But such an integration ability has its limits. Perrott and Burry (1969) (y referred by Markides 1977) found that the limits of binaural fusion of pure tones ranged from OHz difference at 250 Hz to 640 Hz at 8 KHz. This implies that binaural hearing is resistant to the adverse effects of a considerable dicholic frequency disparity (diplacusis) at higher frequencies, but it shows very little tolerance for any disparity at the lower frequencies. Another deduction from their study is that speech intelligibility may be enhanced by stimulating the second ear of the hearing - impaired people even if such people have made differences in hearing losses regarding freqenny distribution between their two ears (Markides, 1977)

6, **Directional Hearing**

Localisation of sound is a basic function of the auditory system, contributing directly to the survival by indicating the positions of mates, prey or enemies. In the day-to-day life directional hearing is used almost continually in monitoring environment.

Though it has been asserted on several occasions (Angell and Fite, 1901; Butler and Naunton, 1967; and Fisher and Freedman, 1968) (referred by Markides, 1977) that atleast under certain conditions monaural localization can be as good as binaural localization there is absolutely no doubt whatsoever that two ears are better than one.

The ability to localize sound depends upon a complex interaction among the variables which include peripheral and central auditory processing, coYtical and subcortical associations and the frequent motor skills involved in the head and body orientations. (Konkle and Schwartz, 1981). The physical differences present in the acoustic energy in the two years is brought about by the distance between the two ears as well as head, pinnae and ear canal sound diffractions. (Konkle and Schwartz) The auditory system measures the physical parameters of the signals at the two ears and the brain interprets these measured parameters in terms of possible locations of the sound. It is convenient to examine the differences in the sound stimuli which result from a transformation from free field to ear drum.

These include intensity differences, phase differences, time of arrival differences and spectral composition differences.

Intensity Differences

Example

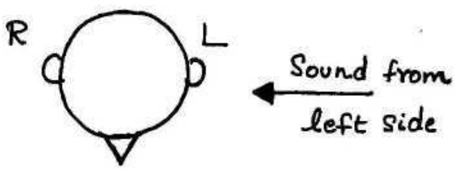


Figure 4: Left ear is stimulated at a higher intensity

Examining the figure4shows that since the sound originates from the left side, the left ear will be stimulated at a higher intensity than the right. Lord Rayleigh (1904) (referred by Markides, 1977) suggested that a listener localises the sound source towards the side receiving the louder stimulus using intensity differences. Intensity differences do occur if the wavelength of the sound is small compared With the dimension of the head. Sivian and White (1903) (referred by Markides, 1977) proved experimentally that intensity differences are practically zero below 300 Hz. Thus, it seems that intensity differences are important in localisation of frequencies over 300 Hz.

Binaural distance difference is an important variable. It refers to the distance of each ear from a sound source. This is an important variable because sound pressure decreases with propagation. In any particular instance,the significance of this variable depends on the azimuth and distance of the source. This difference is zero for sources in the median plane, regardless of the distance. When the source is away from the Median plane, but close to the head, the sound must travel a greater distance to reach the ear on the further side and the energy available becomes progressively less. If the source is further away from the head and is also away from the median plane, the binaural distance difference is small. The greater the distance of the source from the head, the less significant is the role played by binaural distance difference in the differential intensity at the

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two ears (Gulick, 1971).

Intensity is an important clue used in the judgement of distance. With distance constant, change in intensity brings about a change in the apparent distance of the source, even though direction remains constant (Stevens and Davis, 1938). Phase difference does not seem to offer as much help due to the reflections from the shoulder which makes the distance ambiguous. Stevens and Davis (1938) say that the judgement of distance is possible for familiar sounds, based on amplitude ratio, and that it is not possible to assess the distance of unfamiliar sound sources.

Phase Differences:

Difference in phase means that the cresh of one sound wave arrives either before or after the crest of the sound wave (Stevens and Davis, 1938) or that the crest arrives at one par before it arrives at the other ear.

As the intensity differences do not explain how low frequency directional hearing occurs, Rayleigh (1907) (referred by Markides 1977) has suggested phase differences to account for this; the rationale is 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 the leading phase.

There is a difference of opinion regarding the upper limit of the frequency range in which the phase difference operates. Jongkees and Groen 1946 (referred by Markides 1977) stated'that the phase differences operate with frequencies below 1000 Hz.Sandel, Teas, Fedderson and Jeffress(1955) (referred by Mackides 1977) place this frequency limit as high as 1500 Hz while Christian and Roser (1957) (referred by Markides 1977) considered the upper frequency limit to be about 800 Hz.

Therefore, it seems the phase differences on their own do not explain directional hearing for low freqnnecies (Markides 1977).

In this view, it has been suggested that a combination of intensity and phase differences give a reasonable coverage of the whole auditory spectrum (Hartley and Fry, 1922), (quoted by Markides, 1977).

Time of arrival differences

It 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. (Markides, 1977). The observer tends to localise the sound towards that side to which it arrives first. With regard to pure tones, the time - of arrival at the left and right ears also implies that a phase difference exists between the two signals. But real situations lack pure tones and have complex waveforms with irregularly spaced transients and consist 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 will be delayed differentially at the two ears. So intensity differences and time of arrival differences contribute simultaneously to localisation of a complex sound. Consequently it can be stated that sound localisation depends on a complex running cross - correlation of intensity and time of arrival interaural differenqes each of which can be traded with the other, a feature termed as the 'precedence effect' (Markides, 1977).

Markides (1977) adds that intensity and time differences cannot by themselves account for directional hearing; they can only give right or left laterilisation within the head. To truely externalise the source of sound, other factors expecially head movements and frequency modification of complex sounds by head and pinnae diffraction effects, are operating.

Spectral composition Differences

Diffraction effects of the head and pinnae the reflective properties of the environment and the impedance mismatching of the sounds at the two ears depending on the angle of incidence all bring about interaural spectral differences and in turn help localise complex sound (Markides, 1977).

These multiple differences and their systematic changes due to head movement govern the quality or timbre of the sounds at the two ears and, according to Pierce (1901) Angell and Fite (1901) and Steinberg and Show (1934) (referred by Markides 1977) this binaural information'acts to enhance auditory localisation.

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The effect of Head Movement

In actual listening situations, head movements help localization. IB is an integral part of sound localization. The head movements increase the ability to localise sound sources both in the horizontal and in the vertical plane (Wallack, 1940; Dicarlo and Brown, 1960; Thurlow and Runge 1967) (referred by Markides, 1977). It has been indicated that very slight head movements provides 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) (referred by Markides 1977).

But, it has been indicated that head movements do not give a complete explanation of front - rear discrimination because even with the head fixed, localization both in the horizontal and in front rear discrimination can be very accurate. Also sounds too brief to be influenced by head movements can be localised quite accurate, hence other factors must be involved. (Markides, 1977), Markides (1977) says that several workers asserted that the pinna plays a role in auditory localization.

The effect of the Pinna:

Petri (1932) (referred by Markides 1977) made a structural analysis of the Pinna, and concluded that it consists of a set of intersecting, reflective, parabolic surfaces which direct sound ultimately towards the auditory meatus". Batteau (1967, 1968) (referred by Markides, 1977) opined that the pinna, because of its three dimensional arymmetry, creates a set of delayed replications in response to a single acoustic transient of the oncoming signal and feeds them into the auditory canal, thus creating both intensity, time and tonal quality differences with critical effect on front - rear discrimination. Further, 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'.

Minimum Audible Angle

The physical parameter what is varied is the angular displacement of the solid source (loudspeaker) Minimum Audible Angle (MAA) is the smallest change in this parameter that can be descriminated reliably.

Most of the available informations of the MAA on the horizontal plane relates solely to binaural hearing (Markides, 1977), In 1921, Marx and Mark (referred to by Mills, 1958; referred by Markides 1977) indicated that normally - hearing people could localise a sound source with 1/3 to 1/2 from the actual source. King and Laird (1930) (refferred to by Markides, 1977) reported that the smallest change in direction which could be detected by normally hearing people on average 1.8 , range was from 1.5 to 2.0. Stevens and Newman's experiments (1936) (referred by Markides 1977) carried out with normally hearing people seated on an elevated perch on the roof of a building in order to minimise reflections, revealed the variation in minimum audible angle with frequency, being about 11^0 at 60 Hz, increasing to 20^0 at 3 KH and then diminishing to 3^0 at 10 KHz. His could be localized more accurately with a average error of 5 - 6^0 when compared to clicks which were localised with an average error of 8^0. De Boer (1940) (referred by Mackides, 1977) considered that 3^0 was the minimum angle of auidibility for complex sounds like speech. This assumption was verified in 1958 by Mills (referred by Markides 1977) and in 1950 by Hochberg (referred by Markides, 1977). Snow (1953) (referred by Markidis 1977) opined that impulsive sounds like speech or clicks could be perceived at smaller angles of 1 to 2^{0}. Gardener in 1968 (ref by Markides 1977) verified this who after studying localisation for speech found an average error of only 1.5^{0}.

Age influences localization. Siegenthaler and Aungst (1968) asserted that localisation ability for speech depends on age. After testing 93 children varying in age from 3 to 13 years, they noted a corresponding decrease in average error from 18^{0} to 5^{0}. But the study by Lehnhardt (1969) exercises a caution. They pointed out, however, that the ability of auditory localisation only worsens by no more than 2^{0} between the ages of 10 to 70 and hence caution should be exercised before making generalisations on on possible relationships between age and directional hearing.

Role of Stimulus Frequency in the Localisation Sound in Space.

Butler etal (1967) asked the listeners to locate tone bursts and differently filtered noise - bursts on the horizontal plane. The stimulus frequencies in the range of 2 - 4 kc/s appeared further towards the median plane than tones either higher or lower in frequency. The amount of displacement was also dependent on the azimuthal position of the sound source. It was greater for those sounds originating more peripherally. Even a noise burst was seen to be displaced towards the center if its frequency composition was restricted to a range of 2 to 4 kg/sm.

In one sub study, SPLs inside earcanal were measured. The data revealed that when a tone appars displaced towards the median plane, the interaural intensity difference provided by the stimulus is nearly the same as that provided by the same tone when it does indeed originate near the median plane.

Auditory localisation and Body Tilt

Body tilt produces a change in localisation of sounds. Analogous to the visual and haptic situations, Teuber and Liebert (1956) (referred by Altshuler and Comalli 1970) found that today tilt produced similarly consitent displacements in localisation of sounds. With adults tilted 28^0 L or R, they showed that an ambient sound from a single overhead source is displaced opposite the body tilt when the task is to localise the sound directly overhead. Altshuler and Comalli (1970) further investigated the effects of body tilt and auditory localisation when the body tilts were greater than 30^0 in an attempt to ascertain whether at larger body tilts 'A' or 'E' effects are obtained.

(The error occuring with large body tilt = A effect)

The error occuring with small body tilts = E effect)

Results revealed that with increase in body tilt from 30^0 to 60^0, a progressive displacement of the auditory mtdline in a direction opposite to the tilt of the body and the auditory midline is displaced to the same side as the initial placement of the sound source.

On the basis of this experiment, they concluded that with small body tilts analogous effects are found* for auditory, visual and haptis situations, but with large body tilts, effects for auditory localisation are move similar to effects found for tactual - Kines- the mode rather than the visual mode.

The above mentioned studies relating to directional hearing are primarily related to normally hearing individuals. It is essential to look at the relationship between directional hearing and hearing impairment.

Butler (1970) describes the effect of hearing impairment on locating sound in the vertical plane. The auditory stimuli used consisted of noise bursts repeated 6 times persecond. They originated from loudsepakers separated by 15^0 . Two groups of patients were studied. One group consisted of those with bilateral hearing impairment for frequencies in the region of 8000 Hz. The other group consisted of those with a unilateral hearing impairment. The performance of each group was Compared with each other as well as with that recorded for a group of normal hearing persons.

The results revealed that persons whose acuity for high tones was impaired severely were completely not able to locate vertically placed sounds. This total lack of proficiency, however, was peculiar to the vertical plane since special tests indicated that these patients could locate horizontally positioned sounds accurately. Persons with unilateral hearing impairment performed significantly more accurately than those with bilateral high tone impairment, but the form group failed to perform as accurately as the normal hearing persons.

The data demonstrated the definite role played by the high frequencies in locating sounds in the'vertical plane. The wave length of the higher frequencies correspond in size to the pinnae and the pinnae play an essential role in providing spectral cues associated with the elevation of the sound source.

To give an explanation to the better performance of the normal hearing parsons relative to that recorded for persons with monaural hearing, it was speculated that a slight degree of asymmetry between the two ears might exist. If so, this could provide binaural spectral cues for a sound emanating from the median plane. These cues, although minimal, could be utilised when locating vertically positioned sounds.

Thus, from this example, it can be concluded that hearing impairment influences directional hearing.

Having reviewed the binaural auditory phenomena, realising its advantages, it is essential that in the non medical management of the bilaterally hearing - impaired individuals efforts should be made to restore binaural hearing. Hence it can be concluded that binaural haring aids be prescribed. But is it really possible? This calls for determining the role played by binaural amplification, which will be dealt in the next chapter.

BINAURAL AMPLIFICATION: Its Role

A normal auditory system delivers binaural hearing. A disrupted auditory system destroys binaural hearing.

Binaural (pertaining to two ears) hearing, reviewed in the earlier chapter, shows many advantages which include summation of the acoustic energy, improved speech intelligibility and enhanced directional hearing.

Thus, the evidence is in. People can hear better with two ears rather than one (Wernick, 1985). This occurs in a normally hearing individual, who has a normal auditory layout.

In the hearing - impaired population, the auditory system is disrupted and hence binaural hearing cannot be realised. This requires management of the hearing impaired individual.

In the literature pertaining to the non medical management of individuals with bilateraly hearing losses, a major area of disagreement would be found among professionals with health care whether this bilaterally hearing - impaired individual should use one hearing aid delivering sound to one ear (monaural), one hearing and delivering sound to both ears (pseudobinaural) or two hearing aids (binaural) (Pollack, 1975).

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In other words, there is a controversy' regarding the type of amplification system to be fitted to the bilateral hearing impaired individual.

Most of researches do advocate binaural amplification. Binaural amplification, defined by Konkle and Schwartz (1981) is as follows:

"True dichotic or stereophonic stimulation of each independently" is binaural amplification. It precludes pseudo-binaural or 'Y' cord fitting.

There is a certain rationale behind advocating binaural amplification. Investigators, by fitting binaural hearing aid help to bring about a balanced hearing, which is disrupted in the hearing impaired individual. But it can be seen that literature, concerning binaural hearing of the hearing - impaired and binaural amplification has produced varying results, leading to the realisation that the advantages of two hearing aids over one must be viewed as equivocal (Pollack, 1975).

There are both subjective and objective reports in literature demonstrating superiority of binaural amplification.

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Watson and Tolan (1949) (referred by Harris, 1975) Credit Josephine and Timbulake (1945) with just demonstrating the advantage of binaural aid fitting as early as 1937, but they refer only two other persons who had publicly advocated binaural hearing aids, even on adults, by 1949.

Watson and Tolan (1949) (referred by Harris, 1975) indicate, "The effect (of 2 complete aids) on some cases of nerve impairment and word confusion is remarkable. Not only is the wearable to judge the direction and distance of sounds, but he often receives greatly improved ability to discriminate between different sounds and voices and can better understand speech in the presence of conflicting sounds and noises. It is regretabl that more cases of perceptive deafness do not consider the use of true binaural haring".

Bender (1960) (referred by Harris 1975) had hung body aids on young children in the early 1940s, but noted that the weight "noticeably pulled down growing little shoulders". She fitted binaural ear - level aids the very moment the transistor was available, to babies even with severe losses and even as young as 10 months old with the hope of even younger fitting. As she said (1960) - "The long tortuous process of building word on word, sometimes sound on sound, is hastened and eased for them and their teachers almost beyond belief".

Bender and Wiig (1960) have described their use of binaural hearing aids for very young 16 children with hearing losses, in 13 months to 12 years, their audiogram, showing an average loss for the speech frequencies ranging from 33 dB to 75 dB. Tests were administered to fifteen of the subjects. They reported an improvement in hearing with binaural amplification over no amplification. It ranged from 16 to 46 dB with an average of 34.33 decibels. Parents and teachers apswered a number of question regarding the advantages of using binaural hearing. They concluded that in every instance the parents expressed a decided preference- for the use of binaural aids because of the better response of children and because of greater convenience and economy.

Lewis and Green (1962) report of a one year study conducted by the New York League for the hard of hearing to compare language growth and academic achievement for twenty four children fitted with binaural hearing aids and twenty three children fitted with monaural aids. The results indicated a slight superiority of the binaural aids as measured by SRT, PB Scores, Verbal IQ and achievement tests. They felt that a larger study was necessary to justify this device for educational purposes.

Edith Whetnall (1964) (referred by Harris, 1975) felt that binaural aids were unquestionably superior for every child with residual hearing in both ears and further that such children learned more rapidly. They were more oral more social and happier.

Guttner (1964) (referred by Harris, 1975) argued for binaural fitting. He says, for example, "exploirting the stereophonic capacity of the ear markedly improves the reception of the hard of hearing in everyday complex sound fields - reverberation, continuous noige or impulsive sounds". He indicates that only on-the-ear aids can achieve the best results, when the directivity of the systems closely simulates the acoustic conditions at the eardrums of the unaided head.

Pollack (1964) (referred by Harris, 1975) reported that their greatest successes were achieved when babies were diagonised, and fitted with powerful binaual aids before six months'.

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The statement in 1967 regarding the position of ASHA on binaural hearing aids for children was given by Black and associates (1967)? (referred by Harris 1975) The one channel versus two-channel receiving system presents an argument that has not been resolved in terms of the impact of language and ease of listening for the person who wears one or the other system".

Devos (Audiology Center, Rotterdam) (referred by Harris, 1975) points out that the baby must be given the opportunity to learn the emotional value of words and background noises, which often lacks acoustic cueing than does simple intelligibility. Devos (1968) (refered by Haris 1975) always starts with binaual aids on a baby.

Ross (1969) indicates that clinical and experimental reports of binaural fittings with children have been almost unanimously positive. The children's responses are quicker and more certain and they demonstrate an accelerated growth in speech and language.

Kuyper and deBoer (1969) compared stereophonic hearing aids with monaural aids with respected to directional hearing. Improved directional hearing was found using stereophonic hearing aids in fourty two out of fifty five children. Among the remaining thirteen, only one did better with a single aid while the others had an overall difficulty in determining directionality.

Luteeman (1970) compared seventeen pre-school hard of hearing children (age range 34 to 57 months) using monaural and binaural amplification following two weeks experience with each dondition of amplification to a 1000 Hz tone and to a speech signal. Parents of the child were also required to complete an observation form on the child's auditory behaviour under both conditions. Results indicated a statically significant improvement in SDT and 1000 Hz tone for binaural condition as compared to the monaural condition. Almost twice as many definite responses were noted by the parents under the binaural condition as under monaural observations. Finally, no child failed to accept the second aid.

It has been condluded that binaural hearing aids appear to have merit for pre-school hard of hearing children.

Ewertson (referred by Hariris 1975) says "we find the early fitting of hearing aids to the babies of paramount importance in order, to give the baby a feedback of its own babbling. Through the perception of voices from the family members, the baby starts to build up a passive language. He adds that 30% of his cases in 1970 got binaural aids (29,000 aids to 21,000 patients) but also admits that they had very few methods of objective examinations to determine this is too many or too few.

Kuyper (1972) indicated significant improvement of speech discrimination both in noise and in 'babble', in 19 out of twenty five patients (8-16 years of age) fitted with a stereophonic hearing aid in a normal environment.

Beebe went fully binaural in 1966, with great success(1974) (referred.by Harris, 1975). She created an impact on her pupils with powerful binaural aids and can be seen through the initial astonishing of an Assistant, Mary A Burns (1974), when first meeting these five year olds with audiometric losses of 80 - 100 dB, yet with good speech and language in very natural voices... living normal lives at home and attending regular public schools with hearing Children".

3yrne and Deumody (1975) state that the N.A.L. Binaural Hearing And Project commenced in 1971 following numerous and increasing demands for binaural fittings from parents of hearing impaired children. It was decided that fora a trial period of two years - three months all hearing impaired children under eleven years of age would be fitted binauraly except in small proportion of cases where there was definite medical or audiological contraindications. But they soon realised that their aim could not be ralised while the project was restricted to children. Comparing with results of adults, their favourable reaction was consistent with reports redeived from parents and teachears that most of the children who had been fitted binaurally liked wearing binaural aids and appeared to receive additional benefit. However, a survey of the teachers of the deaf showed a great diversity of opinion concerning the particular kinds of benefits received from binaural fitting and the types of children who were most, atleast, liable to benefit.

Pollack (1975) gives a tabulation of results of two cases and indicates that binaural hearing rarely improves the SRT (which is usually the same as the aided threshold of the better ear) but in almost every case, brings about a significant change in the discrimination score. Table 2 shows the results

Table 2

	250 Hz	500 Hz	1 K	2 K	4 K	Aided SRT	Unaided Discrin
Case:1 Congenital deafness, etiology unknown							
R Ear	85	90	110	110		40dB	52% at 70 dE
L Ear	85	95	105			35dB	48% at 70 dB
Binaural						35dB	68% at 70 dB
Case 2: Congenital deafness, etiology: Rubella							
R Ear	75	90	85	80	75	45 dB	60% at 60 dB
L Ear	90	90	95	90	80	45 dB	65% at 60 dB
Binaural						WIPI =	96% at 60 dB

Zelnick (1985) says that there is evidence that suggests that early auditory deprivation in the form of prelingual sensorineural hearing loss results in later problems of auditory perception. He adds that reports say that use of hearing aids by children improves the unaided tonal hearing sensitivity. So it appears that the use of electro acoustic amplification by the children suffering from SN hearing losses may offset some of the disturbances of auditory perception caused by sensory deprivation of auditory stimuli.

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He points out that there is evidence that auditory sensory deprivation can affect binaural function. Beggs and Foreman (1980) (referred by Zelnick, 1985) report that the critical period for binaural stimulation may be over between four and eight years of age. So it is imperative that youngsters with bilateral hearing losses be fitted with binaural hearing aids as soon as the loss has been definitely determined. -

Thus, a review in the chronological order reveals that binaural amplification plays an important role in the habilitation/rehabilitation of a hearing impaired youngster. In a nutshell, it overcomes the disturbances due to sensory deprivation, enhances speech and language, elicits better responses and causes case of listening.

But there are studies which do not demonstrate any binaural superiority over other amplification systems One such study is that of Rice (1963) (referred by Markides 1977). Using a questionnaire method, he selected 70 children from three schools for the deaf and after an experimental period of 9 months tried to find out benefits due to binaural haring usage. Body worn hearing aids were used in the different ways.31 of the children tried both 'Y' lead and two hearing aids,

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and the remaining 32 children tried 'Y' lead only. He concluded that 65% of children could benefit by making use of both ears. Findings revealed that both systems were equally effective in making the child more alert, eager to co-operate, and suffer his strain. His conclusion was that provided the hearing loss was symmetrical in both ears the method by which they were stimulated was of secondary importance.

It is also possible that binaural hearing aids can deteriorate hearing, rather than enhancing balance between the ears. As example of this is given by the study of Jerger and Lewis (1 9 7 5) .

They report of a nine years old girl with bilateral SN hearing loss due to rubella who suffered apparently permanent damage to residual hearing by powerful hearing aids.

It has been concluded that 'Uncritical advocacy of powerful binaural aids is challenged as a potentially dangerous practice" (Jeger and Lewis,1915).

Thus, binaural amplification in youngsters has both advantages and disadvantages.

Studies to evaluate superiority of binaural amplification are more extensively carried out with adults.

(One of the advantages of binaural hearing is improved speech discrimination in the presence of noise. Numerous studies which involve experimental study or subjective reports have been performed to realise this binaural advantage in the hearing - impaired with binaural amplification.

Experimenting with an artificial head, two microphones and twoearphones, Koenig (1950) (referred by Markides 1977) reported that binaural hearing improved 'directionality' 'squelched' reverberation and markedly increased speech intelligibility. He also observed that the above effects could not be achieved with a 'Y' lead arrangement, that is one mic feeding two earphones. Similarly Knudesen (1929), and Keys (1947) (referred by Markides, 1977) reported improved intelligibility with binaural systems. These pioneers, Markides (1977) says, have laid the foundation for more serious work on monaural hearing aids.

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Hedgecock and Sheets (1958) (referred by Markides, 1977), compared speech comprehension with binaural hearing aids of spectacle type as opposed to monaural aids and found no significant difference in the performance of 30 hearing - impaired adults. They recommended that the fitting of binaural hearing aids should be an individual matter and any benefits occuring from binaural hearing aids should be weighted against the considerations like initial cost and relative discomfort of wearing two hearing aids. A tentative scanning of their test procedures, however, reveals that their results would hardly have been different. Their assumed monaural conditions could have been a binaural one as no magking was Employed in the non-test ear. Further, their tests were carried out in a quiet surroundings with both speech and noise coming from the loudspeaker. Under these circumstances one could hardly expect a second ear to aid speech discrimination.

Markle and Aber (1958) (referred to Markides 1977) clinically evaluating monaural and binaural hearing aids, with ten otoscherotic patients arrived at different conclusions. They found no significant differences between the speech reception thresholds obtained with monaural and binaural hearing aids. With respect to speech descrimination abilities of the subjects, they showed significant differences in favour of binaural hearing aids in the order of 11 and 29% at signal to noise ratios of 0 and 10 dB, respectively.

Belzile and Markle (1959) referred to by Markides, 1977) reported 5 clear superiority of binaural over monaural hearing aids in discrimination abilities. Using PB word lists they measured the discrimination abilities of 30 subjects half with conductive and half perceptive bilateral moderate hearing impairments. Results revealed that for both the conductive and perceptive deafness groups there were no significant differences between binaural and monaural listening in quiet, but that 50% discrimination level could be achieved in the presence of 10 d3 more noise when wearing two hearing aids than when wearing a single hearing aid.

Evaluating the studies of Belzile and Markle (1958) and Markle and Aber (1909) (referred to by Markides 1977) reveals that monaural aid was worn on the chest while binaural aids were placed on the head. So it is impossible to know whether the differences observed in favour of binaural haring aids were due to two ears or to headworn pickups, or to a combination of the two.

Dicarlo and Brown (1960) (referred to by Markides 1977) reported no advantage for a headworn binaural hearing aid system over a preudo-binaural or a headoworn monaural aid with respect to speech intelligibility in noise. They found this conclusion to be true for subjects with normal hearing and patients with either conductive, mixed and nenral hearing impairments. They also stated that although there was a unanimous agreement among subjects that binaural listening rounded chearer, all of them consistenly preferred monaural to either binaural or pseudo binaural hearing aid systems. Their speech discrimination tests was carried out in the presence of a constant 70 dB noise. It is pointed out that if these tests were administered at several signal to noise ratios their results might have been different They also paid scant attention to their results of SRT in which they found that the binaural thresholds was lower than the better monaural thresholds by 3.9 dB for the conductive group, 3.4 dB for the mixed and 2.4 for their sensour neural.

Jerger and Dirks (1961) undertook to replicated Belzile and Markles experiment as closely as possible to confirm their findings, but results failed to do so. This was because their original belief that they had carried out a true replication of Belzile and Markle's

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st6dy turned out to be false.

Harris (1965) (referred by Markides, 1977) evaluat-ting the above studies pointed out that important factors like head movements head shadow effects and/or presenting both speech and noise from the same loudspeaker were not properly taken into consideration there by rendeiing test results uninterpretable or even insensitive to binaural improvement.

Harris (1965) (referred to by Markides, 1977), in his study tested 89 normal and 36 symmetrical hearing defective subjects and concluded that the improvement in intelligibility of dichotic over monotic listening was in the order of 25 - 33% or about 4 to 5 dB in signal to noise ratio.

Wright (1959) after revewing the previous experiments and clinical reports on binaural hearing revealed that there was little evidence to support a final conclusion about the efficiency of one hearing aid system over Another. After this report Wright and Carhart (1960) performed a study with a view to exploring the relative merits of binaural hearing aids. They used spondees and PB words in quiet and in the presence of saw-tooth noise with each of three types of system: monaural, diotic (pseudolinaural) and binaural hearing aids. Results revealed that no difference in performance was seen when diotic or pseudobinaural system was compared with the monaural system, binaural thresholds tended to be better than monaural both in quiet and noise and finally, the binaural h&aring aids werex superior only under some circumstances and only for some subjects.

Olsen and Carhart (1967) reported little differences between monaural and binauralin quiet but these differences increased considerably when they introduced competing sounds. They also stated that a binaural listener almost always has one ear favourably located with reference to the wanted signal and in their opinion this constitutes the most dramatic advantage of binaural hearing. The test materials used in the study were spondee words presented with no background noise; monosyllables with no bakcground noise; monosyllables presented with competing speech and monosyllables presented with speech spectrum background noise.

Zelnick (1970) (referred by Zelnick, 1985) reported the results of his research with hearing impaired listeners suffering from approximately bilateral symmetrical SN hearing disorders. He found that on scoring speech discrimination with phonemic method suggested by Duffy (1967), the binaural system proved significantly superior for speech intelligibility to the monaural mode.

Markides (1977) indicated that individuals with symmetrical and symmetrical hearing impairments showed significant binaural advantages for speech perception.

Ross (1977) (referred to by Cherhak reviewing the earlier studies points out that majority of studies comparing speech discrimination scores obtained with binaural and monaural hearing aids with hearing impaindsubjects revealed binaural superiority.),

Gelfand and Hochberg (1973) (referred by Chermak;1981) suggested that the squelch effect (the apparent decrease in ambient background noise intensity and disruption when listening with the two ears in a noisy environment, is responsible for better speech discrimination under reverberant conditions with binaural amplification.

Vaselek and Pickett (1974) (referred by Zelnick, 1985) reported better speech discrimination with the binaural over the monaural mode of listening for both normals and hearing impaired listeners in backgrounds of noise at different reverberation times.

Nabelek (1982) Preferred by Zelnick 1985) performed a study on speech perception in noise and never berations with hearing impaired subjects. The conclusion of the study was that hearing impaired listeners indicated a significant advantage for speech intelligibility for the binaural over the monaural mode of listening. The binaural advantage that was indicated was not reduced or influenced by the introduction of hearing aids.

(Hawkins and Yacullo (1984) conducted a study to determine the signal-to-Noise Ratio (S/N) ratio necessary for a constant performance level for 12 normally hearing adults and 11 hearing - impaired subjects (bileterally symmetrical mild-to moderate sloping SN hearing losses) under 3 levels of reverberation (0.3, 0.5 and 1.2 sec) with monaural and binaural hearing

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hearing aids having directional and omnidirectional microphones. Results indicated that " a) a significant binaural advantage (2-3 dB) which was independent of hearing aid arrangement (monaural or binaural) but dependent upon level of severberation, c) a significant reverberation effect which was larger than either the binaural or directional microphone effect, and d) additive binaural and directional microphone advantages". The results obtained suggested the S/N ratio is optimised when binaural hearing aids with dimentional microphones are used in rooms with short reverberation times.

Schreurs and Olsen (1985) had thirty hearing impaired patients compare monaural and binaural hearing aid use for a period fourty weeks. The tableggives the number of better responses obtained when comparing monaural and binaural hearing aid use in various listening situations for the thirty subjects.

Table 3 : No. of better responses when compraising monaural and binaural hearing aid use in various listening situations for 30 subjects (given by ScheuerS and Olsen, 1985)

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Listening Situation	Better Monaural	Better Binaural	No difference	No Response
Conversation in quiet room		16	6	1
Converssion while other talking nearby	18	11	1	0
Quiet restaurant	5	19	5	1
Noisy restaurant	20	8	1	1
Listening to TV	5	16	9	0
Listening to Radio or TV while others are talking nearby	14	11	4	1
When listening in Church, Theatre, or other large room	10	15	3	2
When driving or riding in a car	14	11	5	3
When listening via a telephone	17	1	5	0
When typing to locate source of sound	5	14	11	0

(The table 4 shows the composite of better response for comparisons of monaural and binaural hearing aid use in four quiet and four noisy situations.

Table 4-: Composite of better response for comparison of monaural and binaural hearing aid use in 4 quiet and 4 noise situations.

	Better		NO Difference	No Response
	Monaural	Binaural		
Quiet	27	66	23	4
Noisy	66	41	11	2

It was found that after a 4 week trial period of monaural and binaural hearing aid use and Considerations of their own personal circumstances, seventeen of them purchased a single hearing aid and eight purchased binaural hearing aids. Those individuals who chose monaural haring aid use reported binaural hearing aids to be better in some situations but apparently judged that they did not derive sufficient additional benefit in a satisfactory number of their every day activities or listening situations to warrant the purchase of a second aid.

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(Thus this study reveals that binaural amplification seems to be of little benefit in a noisy situation.

Bergman (1957) (referred by Markides 1977) reported that in a study of hearing impaired blind people many subjects commented that they experienced an ease of listening when hearing with both ears rather than with one.

Carhart (1958) points out that 'less effort is required for comfortable listening when this (binaural) is used. Langford (1970) (referred to by Pollack, 1975) reported that a binaural arrangement when compared to a monaural aid provides greater intensity to the auditory system - this allows the user to hear faint sounds with greater ease. He has described situations in which binaural users turn up the gain of the remaining aid considerably if one aid is turned off. They appear to do this to maintain the signal intensity achieved with both'aids on.

Kodman (1961) (referred to by Pollack, 1975) summarized this aspect of the binaural use of hearing aids by suggesting that 'another way of viewing the binaural effect is that the patient hears easier or with less effort, even though the intelligibility score is comparable, or even identical with the monaural score. It is suggested that hearing promotes an interaural effedt which is reflected in better sound balance and ease of perception".

Zelnick (1985) in his experience found that many hearing impaired showed more relaxation and less tension in the listening situation when using the dichotic mode of amplification rather than monotes.

Haskins and Hardy (1960) (referred to by Mackides, 1977) state that routine clinical tests are not effective measures of the improvement of the function. All the cases studied with binaural hearing profited sufficiently to choose it. They enjoyed the quality, and like others who enjoy the effect, they report that events in sound are more natural and not so thin with'both sides of the head alive'.

Kodman (1961) (referred So by Markides 1977) selected 50 successful binaural hearing aid users and issued a questionnaire to them they reported both advantages and disadvantages of binaural hearing aids improved their personality (less nervousness, less strain, improved social life). Other advantages mentioned include better sound balance, better localisation and better hearing in a group. The disadvantages that were mentioned are too expensive, too heavy and more repairs needed.

Killion (1982) (referred by Zelnick 1985) Suggests that the main reason for hearing aid users accepting the binaural hearing aids even though increased speech intelligibility could not be demonstrated, was simply that the sound quality of the two hearing aids, was much better than the sound quality of one and such improved quality of amplified sound is very important for many users.

Thus most subjective reports indicate improved listening abilities that the objective or experimental studies.

But, two extensive investigations, one by Dirks and Carhart (1962) and another by Siegenthaler(1979) give a different view of the speech discrimination abilities using binaural hearing aids.

Dirks and Cachart (1962) in a Survey of the reactions of the users of binaural and monaural hearing aids reveal that both groups reported relatively poor performance in conditions with strong background noise.

Siegenthaler (1979) (referred to by Yanick, 1979) reports of a field test of the hypothesis that two ear hearing is better than one ear hearing. The data indicate that while most persons have essentially the same binaural test scores for SRT and for maximum speech intelligibility as they have for the better of the two ears, some have discrepancies greater than errors of test measurement between the better ear and binaural hearing test scores. The discrepancies are not always in the direction of better binaural than monaural test scores. The discrepancies are not always in the direction of better binaural than monaural test scores. In the present data approximately three times as many persons (28.5 percent) had better binaural SRT scores compared to better ear SRT scores, than had worse binaural SRT scores (8.4%).
The situation is reversed for speech intelligibility about five times as many persons (4.5%) have worse binaural than monaural better ear speech intelligibility

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about five times as many persons (4.5) have worse binaural than monaural better - ear speech intelligibility than have better binaural speech intelligibility (.9%).

The findings are consistent for subjects with worse binaural than monaural test scores, with the hypothesis that for some listeners when the two ears each feed a distorted signal into the CNS the auditory pathway is less able to handle the possibly conflicting information (produces poor SRT and worse maximum intelligibility test scores) than when only one ear is functioning. That this should be so for an intelligibility test than for a threshold test is likely in view of greater redundancy in spondee words used in threshold tests, than the single syllable intelligibility test words.

For subjects with better binaural than monaural test scores, the hypothesis of binaural summation may be a valid explanation of the finding.

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Some investigations have performed both subjective and some objective investigations to determine the status of the binaural amplification. Example to this is the study by Byrne and Dermody (1975). Speech discrimination performance testing was determined with a speech signal and a background noise presented from seperate loudspeakers to a group of 61 hearing impaired adults underaided binaural and monaural conditions. A biaural squech averaginy about 7% and a headshadow effect of about 1% was found. But concluded that the speech in noise test used by them would give group trends but not satisfactory binnural advantages in individual cases.

Other points to considered here, with regards to improved intelligibility include head shadow effect and binaural squdch. Valente (1984) in his summary of the advantages of binaural amplification, reviewing the earlier research, indicates that a range of 1.1 to 5.3 dB for squelch effect (NE) and a range of 1.0 to 11.2 dB for the binaural advantage over monaural for ear (Fc) listening. The literature reports of an average squlch effect of 30 dB and as much as 16 d3 when comparing binaural to monaural far ear (Olsen and Carhart 1967) binaural to monaural far ear (Olsen and Carhart 1967) (referred to by Valente 1983). Thus with binaural listening, head shadow, effect is removed and squelch effect is seen. Table 5 gives the summary of selected studies investigating the binaural gain (in dB) in comparison to near and far ear listening.

Table:5 Summary of selected studies investigating Binaural Gain (in dB) in comparison to Near and Far Ear, listening (given by Valente, 1983).

Authors	Near Ear	Binaural Advantage Far Ear	Signal/ Competition
Dirks and Wilson (1969)	2.7 - 4.2	7.7 -- 11.2	SRT,SSI/Speech noise Connected discourse
Cox DiChicchis and Wark (1981)	1.9 5.3	-	'N U-6/Six Talker Babble
Markides (1980)	2.0 3.0	6.0 - 7.0	P3/Speech Noise
Mackeith & Coles (1971)	1.1 - 4.0	1.0 - 8.7	PB/Speech Noise
Luterman (1969)	3.5 - 4.1	-	Connected discourse and 1000 Hz
Wright and Caroart (1960)	2.0	6.0	Spondee/Saw Tooth Noise
Nabelek,& Pickett(l974)	3.0 - 5.0	-	MRT/Babble:Clicks

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In terms of percentage Valente (1983) summarising from the past research, reveals a range of 0.0 to 30% for the Squelch effect (NE) and a range of 1.0 to 57.0% for the binaurd advantage over monaural for ear (Fe) listening.

(Valente (1983) says that the literature typically suggests an average 10% advantage of binaural listening over near ear listening and 40 to 50% over far'ear listening. He adds that the variability revealed in the binaural gain in Table 5 may be probably related to the different types of signals, noises, S/N ratios, loudspeaker arrangements, subject selection, as well as care taken by the authors to control and account for possible extraneous variables.

To the statement posed by some clinicians, that is 3 dB improvement reported in the literature is hardly worth the cost of the second hearing aid, Valente (1983) answers as follows:-

1) He says - "It is my opinion that professionals should not be making decisions relative to what is most beneficial for the patient based on the cost. The decision should be left to the patient after he has been counseled on the potential advantages of binaural amplification.

2. He says - A Clinician with normal hearing should be very cautious in predicting what is or not beneficial for a hearing - impaired individual. It is my Experience that the actual benefit a patient receives from a hearing aid based on the audiogram and hearing and evaluation is very unpredictable. As professionals, we are trained (sightly or wrongly) to judge significant differences in spondee. Thresholds and word discrimination scores in quiet and noise. We are involved with number, statistics, and the accuracy of calibration. On the other hand, the patient is involved with his impression of improvement, which is usually entirely different from our training as to what constitutes significant improvement. As professionals, we talk about decibels, functional gain and improved percentages while the patient talks about greater ease in his listening,greater confidence, and improved family life. We normal hearing clinicians have little appreciation for what a hearing impaired individual can get out of each additional decibel.

3. He says that, there is tremendous variability in group data and hence can expect tremendous variability in individual data. Few patiats will achieve far more than 3 dB improvement while others may achieve

none or perform poorly with binaural amplification. The lesson here is that we should be careful about generalizing from the group to the individual.

4) Lastly he says that 3 dB represents the least beneficial binaural comparison. It is essential to look at the range of binaural enhancement.

If the clinic has a sound suite in which two loud speakers are spatially seperated by 45* to an individual seated at one meter's distance, with one loud speaker emitting the signal while the other emits the competition. Then during monaural near ear listening the addition of the second hearing aid will provide only about 3 dB release from marking. During monaural for ear listening,-however, the addition of the second aid will combine the squelch effect (3 dB) with a 13 dB (6.5 + 6.5) release from head shadow. Therefore momentarily, binaural amplification will provide as much as 16 dB release from marking (Valente, 1983)

The table 6 shows the potential binaural advantage relative to the monaural near and monaural for ear for the W-22 and Rush - Hughes recording of the PAL Wordlists.

Table 6: Potential 3inaural Relative to the Monaural Near and Monaural Far Ear for the W-22 and Rush - Hughes Recording of the PAL word lists. For each stimulus, the percent improvement I & B is given at two different segments of the articulation curve (10 - 90% ; 20 - 80%) Also provided is the potential difference between monaural near ear and far ear conditions (given by Valente, 1983)

Effect	W-22		Rush Hughes	
	3.2%/dB (10-90%)	3.3%/dB (20-80%)	2.0%/dB (10-90%	2.5%/dB (20-80%)
A. Binaural NE-3dB (Sqelch effect)	9.6%	9.9%	6.0%	7.5%
B. NE/FE=6.5 dB (Head Shadow Effect)	20.8%	21,5%	13.0%	16.3%
C. Binaural FE=16DB (Squelch & Head Shadow effect)	51.2%	52.8%	32.0%	40.0%

For each stimulus and segment of the articulation curve the predicted word discrimination is,,provided for the average squelch effect (3dB)HSE (6.5 dB) and binaural far ear listening (16 dB)

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A look at the table 6 reveals several points (Valente 1983).

He says!"The magnitude of benefit one may expect to receive binaurally is dependent upon the stimulus used to measure the binaural - monaural having aids. Use of the W-22 as a stimulus would be expected to reveal greater benefit than Rush Hughes for all three comparisons because the acticulation curve is steeper, that is, easier message, for the W-22 then for Rush Hughes. This is important because a quick look at the articulation curve for 'everyday sentences' is significantly steeper than for even the W-22 lists. This implies that benefits from binaural amplification in the 'real world' where sentences are. The typical stimuli may reveal even greater benefit from binaural amplification than reported in the clinic.

2. The benefit of binaural amplification can range from as little as 6.0% (Rush Hughes) or 9.9,4 (W-22) to as great as 40.0% (Rush Hughes)or.52.8% (W-22), depending upon whether one is referring to the least or more favourable binaural advantage".

A glance at the Table 5 reveals that these predicted scores, based upon the articulation curves of these two stimuli, are not significantly different than reported in the literature. Thus it is apparently important for the clinician to counsel the patient concerning the range of potential binaural advantage and the conditions under which these advantages may arise (Valente, 1983).

Another factor related to binaural amplification is the loudness summation. Due to binaural hearing, loudness summation at threshold (Hirsh, 1950; Tempest et al, 1968) (referred to by Dermody and Byrne, 1975) and summation in loudness growth (Reynold and Stevens, 1960) (referred to by Dermody and Byrne, 1975) occur. Dermody and Byrne (1975) attempted to study if this potential advantage of binaural hearing that is binaural loudness summation, can be obtained by the hearing impaired through the use of binaural hearing aids.

Keys (1947) (referred to by Dermody and Byrne 1975) found about 30 dB., summation at threshold for 500 Hz and 1000 Hz pure tones thresholds.

In a preliminary investigation, Dermody and Byrne (1975) in their lab, using a certain technique, indicated that thirty seven subjects with mixed hearing losses and wearing ear - level hearing aids obtained an average of 3 dB summation at 20 dB above threshold for frequencies 500, 1000 and 2000 Hz.

In their present study, this effect was investigated further. So adult males well considered with mixed hearing loss. There is a tendency for summation to increase at higher intensity levels. But over all, this trend is statiscally significant at only one of the three test frequencies, namely thousand Hz. Due to distortion in the bone conductor at levels above 40 dBBSL for majority of cases, it was not possible, to determine whether loudness growth was maintained at higher.SL. Overall- thse results support the conclusion that their subjects, through wearing binaural aids obtained a similar growth in binaural loudness summation as that reported for normal hearing persons. The specific advantages include l) use lower gain hearing aids ot lower volume control settings and thereby reduce the risk of acorstic feed back and harmonic distortion often associated with high gain monaural fittings.

2) reduce in the amount of threshold shift arising from loud sounds and production of less distortion in the auditory system owing to Cochlear overload. In other words, because of binaural summation a binaural fitting would allow the same dynamic range to be obtained with less power. Also, where the amount of residual heading is small there would be a better change of providing adequate amplification and of providing effective hearing over a greater distance.

Integration is the ability of the auditory mechanism to perceive dissimilar portions of the same speech sample presented to the two ears as a fused image rather than as two separate stimuli. Tobias (1972) (referred to by Zelnick, 1985) stated that any similarity between two sounds mary lead to their fusion, if the similar factors fall below 1500 Hz and come close to coinciding in time. It appears that temporal similarities in waveform envelopes are relatively easy to detect, as are commonalities of fundamental frequency.

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Franklin (1975) (referred to by Zelnick, 1985) proposed that the SN hearing impairment could take advantage of the integration or fusion effect by having binaural aids designed that would have high frequency components of speech going into the right ear and low-frequency components of the right ear and low-frequency components of speech going into the left ear. By this method the masking effect of the low frequencies on the high frequencies could be avoided.

She did a study in which a 1020 Hz to 2040 Hz passband filter together with a second passband of 240 Hz to 480 Hz was presented first to the same ear and then to the opposite ear. She reported that the addition of the low-frequency, band, significantly imporved speech discrimination only in the binaural condition. It has been pointed out that it would appear logical that instead of using passband filters, the low frequencies components of speech could beattenuated through a hearing aid fitted to the right ear and an extended bandwidth of lows and highs in the other ear for limiting the masking effect of low-frequency speech on the high frequency consonant clues.

One other potential of binaural amplification is improved localisation.

Tonning (1971) found that these calculations in no case revealed significantly worse DTI (Directional Threshold of Intelligibilty) Values with binaural hearing and treatment than with monaural. Their experimental conditions diverge considerably from listening situation in everyday life. The results therefore do not prove but suggest binaural hearing aid treatment is advantageous.

Byrne and Dermody (1975) in a series of studies found that localisation of sound with binaural body worn hearing aids was fast superior to localisation with monaura body-work. aids. Four severely deaf and four normal hearing individuals served as subjects. Optimum localisation was achieved when the mycrophones of the two aids were seperated by a distance of seven to ten inches and there was limited evidence that a seperation of eight or nine inches is ideal. The optimum seperation for localising sounds in the horizontal plane did not appear to be influenced by stimulus frequency or whether the sound was presented from behind or in front of the subject.

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Heyes and Ferris (1975) compared the auditory localisation ability of deaf subjects using chest mounted and post-aural hearing aids both monophonically and stereophonically, the results enabled the various systems to be ranked: binaural postaural being the best. A single chest mounted aid is so poor that for those hearing aid users for whom sound localisation is important, for example the blind, it's provisions should be regarded as a last resort. Sound localisation by hard of hearing subjects, is best if they are able to use a pair of post-aural aids although it is still much inferior to the ability of the subjects having good hearing. Should the severity of the hearing loss preclude the use of two postaural aids then either a single postaural aid or a pair of chest mounted aids would be the next best solution. They also point out that these work had not revealed much difference between these two alternatives but obviously there would be a cosmetic preference for the post-aural aid.

Ross (1980) (referred to by Valente, 1983) reviewed five studies that examined binaural verses monaural localisations skills. All of these reported significant binaural advantages.

Ross (1980) (referred to by Valente, 1983) opines - "This is one area in the binaural - monaural debate where there seems to be almost total agreement.

That is biaaural amplification is superior to monaural amplification, as long as the signal is in the horizontal plane and delivered at a relatively low sensatic level. As the signal moves to the vertical plane and/ or is delivered at relatively higher sensation levels, the binaural advantage disappears. The cues for localization seem to be interaural time and phase differences for frequencies, below approximately 1500 Hz, while interaural intensity differences seem to be the cues to correct localization for stimuli above 1500 Hz.

Zelnick (1985) points out there are skeptics who have argued that such binaural localization effect is not possible with the use of hearing aids by the hearing impaired. Westmann and Tepholm (1985) (referred to by Zelnick 1985) concluded that with the use of ITEs there was increased directional hearing, especially after a week's use.

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Jerger and Dirks (1961) (referred to by Tonning, 1971 b) and Jerger etal 1961 (referred to by Tonning, 1971 b) did not find binaural hearing aids better than monaural. In their experiments the head was allowed free movement, so the experimental subjeet -could move the head into the most favourable subject could move the head into the most favourable position, something the deaf do almost as a reilex.

Thus, with respect to localisation, both advantages and no advantages have been reported in literature.

Briskey and Core (1983) report of an extensive questionnaire survey. There was a 75% response. The responses reflected a good balance by sex: Male 220; Female 165; not indicated 35. The age range was 16 to 93 years. The data, in general was treated as responses from a single population.With reference to prior awareness, which involved the level of information about binaural hearing aids prior to purchase, 54% were aware of binaural amplification prior to purchase. Regarding wearer's initial reaction their answers reflected an acceptance. The distribution of awareness was that i4% were surprises; 8% were unconcerned; 24% concerned, 39% pleased and 15% skeptical. Information was gathered regarding the adjustment period to amplification. 66% of the subjects rapidly adjusted themselves to amplification. The period was less than one months, to adjust to the binaural fitting were experiencing various difficulties with such problems as balance, localisation, manipulating difficulty in a crowd, and an uncomfortable feeling when wearing the aid. The hours of use of the binaural fittings was also questionned. It was found that 89% of them used binaural aids for more than 8 hours a day. The clients were asked to rate the binaural. Performance in various listening situations ranging from excellent to very poor. The different listening situations included a) in person to person conversation, b) in group discussion in quiet, c) in group discussion in noise d) listening to one speaker e) listening to radio/TV news, f) listening to radio/TV special shows, g) regular shows, h) listening to music, l) outside the house on a clam day and j) outside the house on a windy day. The last two situation were found to be difficult. The survey reflects the practical application of amplification in real life situations through a direct application by the person using the aids.

Thus the survey report by Briskey and Core (1983) speaks more in favour of binaural amplification.

Zelnick (1985) points out that there is evidence that suggests that early auditory deprivation in the form of prelingual sensory neural hearing loss results in later problems of auditory perception. Studies have been reported with respect to this in children. The question of the effects of auditory depreviation in adults with bilateral, SN hearing losses has been investigated only recently. Silman, Gelfand and Silverman (1984) (referred to by Zeilnick, 1985) conducted a study with fourty four adults with bilateral SN hearing loss who were fitted with binaural hearing aids. Performance prior to the use of hearing aids was compared to performance after four - fife years of hearing aid use. The results showed that the speech recognition difference scores of the binaurally fitted subjects remained stable over time whereas they increased for the monaurally fitted subjects. Their findings also indicated an auditory deprivation effect for the unfitted ears of the subjects with monaural hearing aids. They add that it would be interesting to determine whether the diminishment in auditory discrimination in the unfitted of the group wearing monaural hearing aids could be reverside through the introduction of amplification.

In patients with tinnitus binaural amplification seems to be helpful. Zelnick (1985) indicates that the best masker for tinnitus sufferers complain of noise in both ears. Where the individual suffers bilateral tinnitus, in his experience, binaural hearing aids will often effectively mask it out.

Johnson (1987) also has the same opinion. He opines that the use of binaural hearing instruments in tinnitus masker. His experience has shown that many patients with severe tinnitus problems could be helped with hearing instruments. In many cases, amplifying sound slightly overcomes the subjective perception of tinnitus. Whether the patients impairment is symmetrical or not, binaural fitting, he says, usually is more effective in controlling the patients tinnitus.

Thus, from the reports of the several authors, from questionnaires and surveys as well as clinical impressions, Valente (1984) provides the advantages and disadvantages in a concise tabulation.

The table 7 and 8 give the advantages and disadvantages of binaural amplification as expressed in several articles in literature by the authors (Brooks and 3ulmer, 1981; Dirks and Cavhart, 1962; Lewis and Green, 1962; Markides 1980; Nielsen, 1974 - referred to by Valente 1984) and Ross 1980 (referred to by Valente, 1984) as well as himself.

Table 7: Summary of Advantages Revealed by Binaural Amplification as Reported in Ouestionnairer and Surveys (given by Valente, 1984)

1. Superior to one aid
2. More helpful than 1 aid
3. Use of 2 aids easier to hear in groups
4. Easy to use
5. Improved localisation
6. Better Spatial orientation

72. Better Overall hearing

8.. More natural

94. Relief from tinnitus

10. Lower Volume Control Setting

11. Boosts Confidence

12. More relaxed

13. Family pleased with improved Communication

14. Improved Clarity in quiet and noise

15. Improved stereo effect

16. Less gain required

17. Less 0/P required

18. Have one aid if other broken

19. Quicker responses

20. Easier to listen without visual clues

Table 8: Summary of disadvantages of binaural amplification as reported in questionnaires and surveys (given by Valente, 1984)

1. Difficult to balance volume control

2. Embarassing to have two aids

3. Difficult to use in noise

4. Clumsy

5. Uncomfortable

6. Tiresome.

7. Difficult to manipulate

8. Inconvenient

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. 2 earmoulds

c. Batteries

d. Repairs

e. Insurance

14. Destroy residual hearings

Erdman and Sedge (1986) in an earlier investigation found an overwhelming preference (90%) for binaural amplification among subjects who evaluated both monaural and binaural fittings for controlled periods of time. They also found that the preferences for binaural amplification tended to be consistent overtime, and the self report advantages and disadvantages of monaural and binaural amplification were similar for all subjects.

Table 9 show the advantages and disadvantages of binaural amplification given by Erdman and Sedge (1986).

Table 9 showing advantages and disadvantages of binaural amplification.

Advantages	Disadvantages
Improved Speech Clarity	Difficulty balancing
Stereo effect	Volume
Balanced hearing	Increased ambient noise
3ettu overall hearing	(Cosmetic Concerns
Released listening	Noisy driving automobile
Bettu speech clarity in noise	Awkward using telephones
Natural quality	
Tennitus relief	
Lower Volume settings	
Enhanced localisation ability	

They also did a further evaluation of binaural preferences. They list the preference patterns for individuals comparing binaural and monaural amplification (shown in Table 10).

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Table 10: Preference patterns for individuals comparing binaural and monaural amplification.

	Binaural	Monaural	No aid	Total
Group I				
New Hearing Aid Users (Mean age: 39 yrs)	27	2	1	30
Group II				
Experienced Monaural Hearing Aid Users	27	3	—	30
(Mean Age: 44 yrs)				
Group III				
Purchasers (Mean age 58 years)	30		4	34
Total	84	5	5	94
%	89.4	5.3%	5.3%	

Considering binaural amplification, it is essential to determine which pair, chest mounted or post aural aids provide greater benefit to binaural hearing aid user. In the study by Heyes and Ferris (1975), they made a comparison between the auditory localisation ability of deaf subjects using chest mounted and post aural hearing aids, both monophonically and stereophonically. The results enabled them to rank the various systems: binaural post aural being the best. A single chest mounted aid is so poor that for those hearing aid users for whom sound localisation is important, for example, the blind, its provision should be regarded as a last resort. They also point out that sound localisation ability for the hard of hearing subject is best if they are able to use a pair of postaural aids although it is still much inferior to the ability of the subjects having good hearing.

Orton and Preves (1979) (refered by Cherleck 1981) indicated that localisation ability was generally better with a ITE and as compared to a BTE aid and microphone placement.

Literature points out that binaural amplification provides advantages even to the blind persons. They include better improved localisation of the sound source, selective listening and superior sound quality.

Binaural amplification has been provided to the geriatric patients. Bentzen (1968) indicates that in presbycusis binaural hearing aid treatment is the standard treatment in every case, it is a treatment which first and foremost, should be attemtpted with ear level hearing aids. In his study of fifty persons with presbyeusis (averaging 82 years) full time utilisation of binaural hearing aids was in 28, instance and part time utilisation in 10 and it was necessary to give up the treatment in 12. Frederiksen et al (1974) attempted binaural treatment using ear-level hearing aids in 172 (18%) out of 972 prebycusis patients aged 70 to 80 years, selection being based on the patients motivation to carry through the binaural treatment, their hearing requirements, mental and physical state. 100 patients were followed up after a period of half-two years. It revealed that only one-quarter used both hearing aids from morning till evening, half of the patients used two hearing aids part of the day,

while the remaining quarter had stopped using binaural amplification. 2% had given up using hearing aids. In almost 60% of the patients who had stopped using binaural amplification full time, the reason given was that the inconvenience was too great. In not quite 40% the inadequate use was due mainly to acoustic reasons. Many found that Binaural amplification was unpleasantly strong and noisy. The patients received treatment at a time when open mould fittings were not yet introduced as standard for slight and moderate hearing impairment in the treble, which may have influenced the results negatively. However the most important complaint from their patients was that they had no benefit from using 2 hearing aids, as they felt themselves bombarded by meaningless clatter. They also indicate that there are a number of anatomical and experimental studies which suggest that prebycusis is due to degeneration of the central acoustic tracts rather than to changes in the peripheral sense organs. (Example Hansen (1973 and Jerger 1973-referred to by Frederiksen et al, 1974).

Integration is the ability of the auditory mechanism to perceive this similar portions of the same speech sample presented to the two years as a fused image rather than two seperate stimuli (Zelnick, 1985). However Haas (1982) (referred to by Zelnick, 1985) reported that using binaural amplification the split signal presentation neither increases nor decreases word recognition scores a,t relatively, high levels in quit an older population. Therefore, with geriatric clients caution must be exerted in the recommendations of split band binaural hearing aids as their integration or fussionability probably deminishes with age.

All the studies mentioned earlier, demonstrating advantages/disadvantages of binaural amplification, have been done after fitting binaural hearing aids to the hearing-impaired individuals.

Mueller (1986) performed a pre-fitting study to determine the prospective user's attitudes towards binaural amplification. A patient's existing bias towards either a binaural or monaural fitting, for example might outweighs whatever performance differences he or she might observe during the trial-use period Mueller (1986).

Considering this aspect, questionnaires were sent to 300 persons who were waiting to befitted with hearing aids. A preliminary report was constructed based on the first 282 responses. All respondents were males, ranging in age from mid-40's to mid-90's with majority falling between 60 and 70. Every respondent had undergone an audiologic evaluation at which time it had been decided that he should be feferred for a hearinq aid fitting.

On the questionnaire, each one was asked to state his preference for using one or two hearing aids and then rate the degree to which each of the seven factors influenced that preference. Example."strong influence".

"moderate influence", "no influence". Those factors, which differed for monaural and binaural preferences, were selected from a pilot study as representative of the most common reasons given by the patients for choosing a monaural or a binaural fitting. All patients included in this study were retired members of the military, their hearing aids were to be provided at no cost to them. Hence factors relating to cost were not included in the questionnaire. The patients were informed that their responses were not binding and the ultimate decision regarding fitting one or two aids would be made at the time of their hearing aid evaluation.

120 out of 282 (43%) patients who returned the questionnaire preferred using two hearing aids. 91 out of 120 who favoured binaural fittings completed the influence-rating portion of the questionnaire. Table 11 lists the 7 influence factors in rank order according to their mean influences ratings and summarizes their distribution among respondents.

Table 11: Summary of the responses. Mean rating, obtained by assigning 3=strong influence, 2.0=moderate influence, l=mild influence and 0=no influence.

Reasons for preferring binaural amplification	Mean in= fluence Rating	Distribution		
		Strong influ- ence	Mild or Moderate influe- nce	No in- fluence
Hear (understand) better	2.74	83	15	2
Mostnatural/ balanced	2.48	70	23	7
Severity of loss	2.41	63	31	
Two-sided hearing	2.31	58	34	a
Advice from medical professional	1.73	50	15	35
Observation/advice from the users	1.34	30	27	43
Spare aid/always have one working aid	1.14	19	38	43

134 respondents, that is 57% preferred monaural amplification. Table 12 lists 7 factors influencing monaural preference in rank order accroding to their mean influence ratings and summarized their distribution among respondents.

Table 12 :

Reasons for preferring Monaural amplification	Mean influence Ratings	Distribution		
		Strong influence	Mild or Moderate influence	No influence
Hearing loss not severe enough to use two aids	1.86	38	44	18
No expected improvement in hearing (understanding) with second aid	1.45	27	41	32
Observation/advice from other users	1.29	31	20	49
Advice from medical professional	1.19	26	23	51
Convenience/2nd aid too much bother	1.10	23	27	50

Cosmetic aspects	0.81	16	25	59
Appeal less handicapped with one aid	0.58	11	22	67

It has been concluded that many people view monaural amplification as the next logical step after having made their decision to obtain a hearing aid. going directly from no to two hearing aids is viewed as an out-of-sequence event.

Overall, binaural amplification is beneficial as review of literature points out that it provides improved localisation, better speech intelligibility in quiet than in noisy situations), better quality of sound and ease of listening. Binaural amplification is beneficial for the bilateral hearing impaired population - be it a baby, a child, an adult or an older person. But in each case caution should be executed while prescribing binaural hearing aids. Binaural amplification provided in the form of ear - level aids are more advantageous than body-word aids.

CANDIDACY FOR BINAURAL AMPLIFICATION

Berger (1984) Comments that a great deal of literature exists on the subject of binaural hearing. For normal listners the overwhelming evidence is for a binaural advantage in most listening tasks. Evidence in reference to hearing - impaired individuals in particular to binaural hearing aid use, is less plentiful or convincing. Evidence of binaural aided superiority comes primarily from two sources:

1) Experimental reports of binaural to monaural comparisons under assorted audiometric test conditions and
2) Surveys of binaural hearing and users.

A review of these approaches, which are used in evaluating binaural amplification and hence determine who can benefit from binaural amplification, is presented in the next.

BeYger (1984) also adds that the experimental results generally, but not invariably, show binaural aided- superiority. One weakness of such reports is that they rarely present other than the averaged data. Therefore, if a percentage of subjects does not show a binaural advantage, this is obscured in group data. Loudspeaker arrangements for speech and noise also often represent an unrealistic situation. Regarding questionnaires or surveys from binaural users, the weakness is that they do not ±ule out placebo effect.

BeYger (1984) observes that over the past 20 years the hearing health care professionals, have been reluctant to recommend to recommend binaural fittings because it was difficult, if not impossible, to produce objective evidence of aided binaural superiority. But more recently these professionals have become increasingly and vocally in favour of binaural fittings. Their reasoning, again reduced to a generalization is like this, since binaural hearing is the natural condition, binaural aids should be recommended unless it can be shown that a monaural fitting is better. In other words, these professionals were previously unable to objectively demonstrate a binaural advantage, but that should now be the recommendation unless a monaural fitting can be objectively demonstrated to be superior. He indicates that this is merely a reversal of arguments and, from a scientific standpoint, does not constitute progress.

Considering the hearing-impaired individuals, it seems obvious that 1) some hearing impaired individuals perform better with binaural aids, 2) some perform alike with monaural and binaural fitting and 3) some worse with a binaural than a monaural fitting. It also seems obvious that a large percentage of hearing aid candidates fall into the first group and that the second and the third groups do not warrant a binaural fitting (BeYger 1984).

But question arises as who comprise the first group of the above mentioned categories. Does every bilateral hearing - impaired individual fit into that group or there are only a few candidates who can benefit from binaural amplification. ?

There are many answers which plaque this question and many factors which plaque the answer. Audiological,Psycho-logical and social factors are the ones pointed out in literature.

Valente (1983) points that, in 1958, carhart (quoted by Valente.(1983)) called for the creation of the cri-teria to recognise those members of the hearing impaired population that could potentially benefit from binaural ampli-fication and to identify test procedures which may be used to demonstrate the superiority of binaural amplification.

Hahlbrock and Schmidt (1960) after examining the direc-tional hearing of twenty -seven normal subjects, twenty five with bilateral and twenty with unilateral deafness, postuala-ted that near normal directional hearing may be achieved by means of binaural hearing aids of the spectacle type, espe-cially with patients with bilateral symmetrical hearing loss.

Ross (1969) viewed that the best candidates for binaural hearing aids are those with moderate, bilateral, symmetrical hearing lows because they can utilise ear level aids to great advantage. Those with severe hearing loss are not favourable. for ear level binaural amplification because of occurence of acourtic feedback when high gain hearing aids are used.

Valente (1984) points out that, to the question of who is a candidate for binaural amplification, the spectrum of answers provided is wide. He reveals that 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 afairly wide dynamic range, a symmetrical hearing loss (+ 10 - 15dB).

Gatehouse and Haggard (1986) points out that many authors have suggested that maximum success with binaural hearing aids is most likely among patients with relatively symmetrical hearing losses. They says that this suggestion is based on two assumptions.

The first, only with relatively similar and minimally impaired auditory characteristics in the two ears could subtle differences in the two inputs be exploited.

The second, localization tasks and speech reception against spatially separated noise interference are the circumstances in which this ability ought to be specifically advantageous, and thus they should be emphasized heavily in the, clinical evaluation (whether report - or performance-based).

" Advantages " could be construed in terms of decibles in relation (as in Psycho-acoustic enviornment) to similar presentation levels at the better-hearing ear, the major determinant of auditory disability.

Lundeen (1988) selects binaural hearing aid candidates based on the audiogram using the following criteria: with respect to degree of loss in each ear, he considers two frequency average (average of 1000 Hz and 2000 Hz). This two frequency average of 40dBHL forms the "lowfence" for fitting binaural hearingaids. Considering the upper limit, he points out that if the loss is greater than 90dBHL, then binaural fittings are inappropriate. With regard to symmetry,he views that the threshold difference between ears should be 15dB or less and the difference in speech discrimination scores between the right ear and the left should not be greater than 20%

Thus, several investigators opine that symmetrical hearing loss is an indicator of binaural amplification as a rehabilitation strategy (provided medical care does not help). There are several other investigators who have reported of asymmetrical hearing impairment as a contraindication for binaural amplification.

Pollack (1975) reports that binaural aids are not recommended or are of questionable value for most asymmetrical losses (than a 15 - dB difference between ears through speech range) for two reasons. They are:

a) either the better ear (if a mild loss) can compenrate satisfactorily or b) the worse ears many cause the performance of better ear to degenerate through the increased distortion in the auditory system.

BeYger (1984) - "This clinics guide lines for binaural fitting, where deemed feasible are as follows:

1) If the average hearing threshold level in the worse ear is 40dB 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 UCL of each ear is similar (within 15dB is suggested) if at the same sensation level word discrimination scores are not significantly different and if the pure tone thresholds by bone conduction differ by no more than 15dB at any of the speech frequenciens and are roughly parallel.

A scan through the studies and reports presented above reveal that a hearing impaired individual with symmetrical loss is a candidate while ' a hearing - impaired individual with asymmetrical hearing loss is not a candidate for binaural amplification. There are a number of studies and reports - which challenge this concept.

Jorden etal (1967) conducted a follow-up study of over 1000 patients, They noted no difference in hearing aid usage for patients with asymmetrical losses versus those with symmetrical losses. About 31% used both aids all the time and appiorimately 47% used them part of the time.

Byrne and Dermody (1974) indicate that a good reason to fit arymmetrlcal losses binaurally is what they term "crossover" effect that is,when each ear has a different range of frequencies that it responds to better, a binaural fitting may result in a wider range of frequencies being presented to the auditory system then would be presented by either ear alone, and thus, a more effective fitting may result.

Doreen Pollack (1975) reports that approximately 70 to 78% of the youngsters in the Denver Acoupedic Programe have losses more than 85dB, and a significant number of them suffer from additional problems, such as percetptomotor dysjuctions. With very few exceptions, they have been fitted binarally from an early age and received annual audiologic re-assessments over a period of sever years. Quastiohing-should the ears with asymmetric thresholds be fitted binaurally, reports of performance improvement in the binaural scores.

While it is true that the wearer has the sensation of hearing only in the better ear, auditory information is entering the other ear and being used, as demonstrated by the improvement in the binaurai scores :-

Table-13

	250 Hz	500 Hz	1K	2K	4K	Aided S.R.T.	Aided discrimination
(R) Ear	80	80	80	75	75	25d B	56% at 60dB
(L) Ear	70	90	110			60dB	40% at 60dB
Binaural						25dB	76% at 60dB
(R) Ear	70	90				50dB	16% at 70dB
(L) Ear	50	85	100			60dB	16% at 70dB
Binaural						50dB	32% at 70dB
						WIPI =	64% at 70dB

It is shown that the experience mentioned confirm the findings of Bentzen (quoted by Pollack D.(1975) who reported fitting binaurally fifty children, one to 15 years of age. 50 out of 64 cases had symmetrical losses and 14 had arymmetric, that is a difference of 20dB or greater. The latter wove earlevel aids successfully. All the children with profound losses wore body aids.

Mecham (quoted by Pollack D.1975) indicates that, however, in reporting on the affect of training on better and poorer ears, stated that improvement was negligible, but all subjects favoured binaural fitting and showed little interest in returning to one aid.

Byrne and Dermody (1975) suggest that most persons who have two ears suitable for aid fitting will probably obtain binaural advantage provided the aids are appro-priately selected and adjusted. A close examination at the data for few adult cases who did not react favourably to blnaural hearing aids revealed that they were unable to find any characteristic which reliably distinguished their cases from the remainder of the cases. In one case, it appeared that a large inter-aural difference in speech discrimination might be the problem but it was noted that there were similar cases who received benefit from binural fitting.Several persons had quite large inter-aural differences in hearing thresholds, but of thefe, some received binaural advantages while others did not with regard to this point, it has been reported elsewhere, that monaural aided localization improves at higher SLs and this begins to occur whenever the unaided ear receives sound above threshold Thus, even when sound is received considerably more loudly in one ear than the other some degree of binaural advantage is possible.

Ross and Giolas*, (1978) (referred to by Chamaik,1981)Indicate that asymmetry of threshold configurations and jrupfa threshold functions in the two ears do not contraindicate binaural amplification. The advent sand successful use of split-band binaural hearing aids implies that threshold symmetry is not a pre-requisite for binaural superiority (Ross and Giolass 1978).

Cauyey and Bender (1980) (quoted by Wernick (1985)), in a study evaluation the speech diserimination in the presence of competing signals found a binaural advantage both for subjects with symmetrical and arymmetrical hearing losses. They concluded that "lack of symmetry did not have a deliterious effect upon performance with binaural amplification".

Pollack (1980) (quoted by Wernick, 1985) and Johnson (1980) (quoted by Wernick, 1985) both indicate that they have been using binaural amplification, on individuals with arymmetrical losses, successfully, and present some sample cases exhibiting binaural advantage with arymmetrlc loss.

Chung and Stephens (1986), in a questionnaire survey, of 200 patients, who had been fitted with bihural aids, to determine the factors which would influence the use of binaural aids revealed that : 1) a significantly greater proportion of male patients, 2) a significantly greater proportion of patients with a different hearing loss configuration in the two ears used binaural hearing aids as compared with those with ^Asymmetrical hearing loss : 3) The frequent users of binaural hearing aids were males, who had additional help to reduce their hearing disability and had a more severe hearing loss in the better ear.

Erdman and Sedge (1986) in an earlier investigation found an overwhelming, preference (90%) for binaural amplification among subjects who evaluated both monaural and binaural fittings for controlled periods of time. Preferences for binaural amplification tended to be consistent over-time, the self report advantages and disadvantages of monaural and binaural amplification were similar for all subjects. Then, in their further evaluation of binaural preferences Erdman and Sedge (1986) wanted to determine whether this same preference for binaural amplification be evident among a population of former users of monaural hearing aids. This one the first part of their investigation. Reports displayed that out of 84 individuals, 47 had a Symmetrical hearing losses and 37 had varying degrees of asymmetry. Asymmetry in hearing - impairment, therefore, at least to some degree does not appear to preclude succesful binaural hearing aid fittings.

Table 14 shows the preference patterns for individuals comparing binaural and monaural amplifications (Erdman and Sedge, 1986).

	Binaural	Monaural	Noaid	Total
Group I New Hearing Aid users (Mean Age: 39 years)	27	2		30
Group II Experienced Monaural Hearing Aid users (Mean Age: 44 years)	27	3		30
Group III Purchasers (Mean Age 58 years)	30	-	4	34
Total	84	5	5	94
%	89.4	5.3	5.3	

The clinical implifications of the study are that patients age, degree of loss, symmetry of loss and attitude towards amplification do not indicate that optimum fitting is monaural or contraindicate blnaural aids.

Johnson (1987) points out that in the past; many articles suggested that symmetrical hearing configuration is the only eriteria for using binaural hearing Instruments,

He concludes that asymmetrical losses should be fit with binaural hearing instruments, then

may be used even with markedly arymmetrical patterns, with good discrimination one side and marked discrimination impairment on the other side.

He sites two cases as examples.

The first individual had essentially normal hearing in one ear with more than a 50dB loss on the impaired side (Figure 5). She could tolerate a hearing instrument well. Even with a 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 was fitted 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 on the left ear. The asymmetry in the hearing impairment is noted in the figures. She initially was fit with a mild gain, high frequency impairment for her right ear, bit no fitting was attempted on the 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.

figure: 5

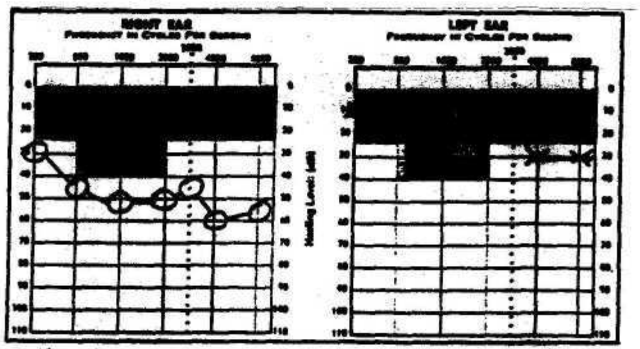

Fig. 5 In addition to the instrument worn on the right (poorer) ear, a mild gain instrument on the left (better) ear, which primarily boosted the higher frequencies, helped this individual to better cope with an asymetrical hearing loss.

figure: 6

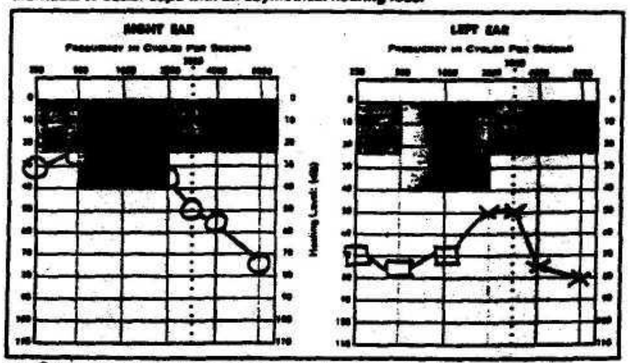

Fig. 6 A binaural fit for this person made her feel like a "whole" person.

Mueller (1988) comments on the "moderate approach" to select candidates for blnaural hearing aids given by Lundeen (1988). Mueller disagrees with Lundeen and says that establishing arbitary numerical cut-off points for determining who can benefit from binaural hearing aids only hinders the effectiveness of the professional tasked with determining the optimum hearing aid fitting arrangement.

Thus one can see that conflict continues whether to fit or not to fit a candidate with asyntmmetrical hearing loss with binaural hearing aids.

Though most investigators wither support or refrain support to fit asymmetrical hearing losses, a few investigators make a comprise (Markides, 1977, Gatehouse and Haggard, 1986).

Markides (1977) gives who a binaural hearing aid candidate is and gives exceptions to the rule. Binaural hearing aid candidature:

1) Subjects with symmetrical or asymmetrical conductive or sensorineural hearing Impairment with average hearing levels falling between 40-50dB to 9OdB (averaged across 500,1000 and 2000 Hz). The severity of hearing loss can ofcourse, be higher than 900dB, provided the patient can accept amplification which is around 20dB (10dB for localization) above his/her speech Detectability threshold (SDT) at each ear.

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

He also gives the exceptions:-

1) Subjects with relatively flat impairment in their better ear and with a steeply falling pure tone audiogram configuration in their worse sear.

2) Subjects exhibiting diplacusis binauralis (The average degree of diplacusis binauralis found to affect binaural hearing aid use;a combination of ± 30% at 500Hz, ± 10%, at 1000Hz and ± 10% at 2000 Hz.). *

*These figures are approximate. More research is required to identify the minimum degree of diplacusisbinauralis which interferes with binaural hearing aid use.

3) Subjects with severe fine manipulation problems (mainly elderly people).

4) Subjects with predominantly retroccochlearperipheral neural) lessons, as it is universally accepted that such people have poor speech discrimination ability and many of them benefit very little from amplification.

5) Subjects with unilateral hearing impairment.

Thus, Markides (1977) indicates that individuals with Symmetrical as well as asymmetrical hearing impairment showed significant binaural advantages for speech perception But subjects with relatively flat hearing impairment in their better ear and with a steeply falling pure tone audiogram configuration in their worse ear are exceptions.

Gatehouse and Maggard (1986) give a discussion and also comment on Chung and Stephens findings. In the discussion they point out that the diotes advantages support the contention of Haggard and Hall (quoted by Gatehouse and Haggard that a substantial part of the advantage of binaural amplification derives not from stereophonic signal separation, but from summation across the slightly different distortions introduced by the two impaired ears. In diotes listening, asymmetric subjects receive substantially lower diotic advantage than do symmetric subjects. This finding confirms with an appropriate monaural baseline, the interference that Davis and Hagggard(quoted by Gatehouse and Haggard 1986) made from obsolute diotic scores. The benefits from monaural amplification in the better ear in diotic listening are similar to those from binaural amplification. In dichotic listening conditions for symmetric subjects, the optimum configuration for monaural amplification varies slightly with signal orientation, but binaural amplification is always, best - reinforcing the arguments for binaurals aidprovision. In asymmetric subjects, the amount of benefit from different amplification patterns is highly dependent on signal orin- tation. So benefit is greatest when speech is presented to the worse ear. For monaural amplification - the obtained interaction between side - of - presentation and side - of - amplification is due almost entirely to non- benefit from amplification in the better ear when speech is presented to the worse. In their present subjects, binaural amplifi- cation and amplification to the worse ear were virtually indistinguishlable in performance terms, if condition of better and worse - side presentation are averaged.

Commenting on Chung and Stephens' (quoted by Gatehouse and Haggard 1986) findings and for previous claims that arymmetrity is a contra indication for binaural aiding, they point out that the apparent conflict can be without in- voking any systematic discrepancies between patients self report and results obtained with performance tasks, It would seem to lie partly in the uncontrolled outcome for those of their patients who did not continue with bina- ural aids - that is, lack of an explicit comparison with better - ear monaural, worse - ear monaural, or noaid at all. According to their (Gatehouse and Haggard 1986) data, if a choice is conceived before the asymmetrics as in effect a choice between 2 aids or one in an unspecified ear, 2 would be the better choice Chung and Stephens (quoted by Gatehouse and Hag- gord 1986) give no details of any advice to patients concerning the more appropriate single ear to aid in the event that binaural aids were not continued, as their objective was to whether binaural provision had a gross effect on continual hearing aid use.

Gatehouse and Haggard 1986, their data showed that specified appropriate monaural fitting provides no less benefits than binaural in asymmetries. They say that Chung and Stephens' data therefore should not be taken as implying that binaural aiding is generally the best provision strategy for patients with arymmetric losses. Certainly against economic and other contradindications, their (Gatehouse and Haggard 1986) data would agree that binaural Aids should not be provided in asymmetric losses, except in the presence of favourable values on other strong prognostic factos (yet to be formulated).

Although they report of no directly relevant dat a, the above conclusion further leads them to an interpretation of Chung and Stephens findings of an actually greater use of binaural aids in those with asymmetric configurations of the audiogram. With this interpretation Gatehouse and Haggard (1986) give an explanator of Chungs and Stephens null finding on asymmetric impaitment levels. With an unspecified monaural alternative and no advice given, binaural aids would ensure that the most aid - favouring is always aided, even if there is no advantage for binaural hearing as such. Such coverage of the more aid favouring ear by over provision, rather than by determination could be the basis for Chung and

Stephen's findings. Infact, Gatehouse and Haggard (1986) believe there is a good cape for specifically differential binaural aiding where there are d ifferences of audiogram configuration between the ears,. They offer this above argument only as an indication of the appropirate baseline for a formal trial of that approach. They add that the choice for both Symmetric and arymmetric patients is ultimately health-related and economic are, but with definite prior auditory bearing factors in the asymmetries. They conclude that they know of no audiologic evidence that asymmetry should be discarded as contraindicator, given that in their present subject sample it statistically delimits a subgroup of 2/3rds who obtain additional benefit.$ The present results agree that for such prognortic purposes, the appropriate boundary of "arymmetry" lies in the 12-dB to 15dB region.

There are other investigators who have used a slightly different criteria for binarual aid candidature.

Mercola & Mercola (1985) recommended the use of MCL is determining hearing aid candidacy, both monauraliy and binaurally. No one will disagree with the notion that the patient must exhibit the need for amplification before it is provided to him, the question arises as to what, level of hearing loss constitutes sufficient need. This question - "When is a loss a loss?" - has been repeatedly questioned. They do not debate over this issue. But, in their experience, MCL is a much more accurate predictor of hearing aid need than the traditionally used threshold measurement far too often threshold measurements have been misleading. Examples are patients whose thresholds remain within normal limits, still manifest all other symptoms of hearing loss; patients whose thresholds have been outside these same limits while manifesting no other symptoms of hearing loss and requiring no amplification to functions adequately. So they therefore strongly recommended the use of MCL in determining hearing aid candidancy, both monaurally and binaurally.

In their experience an ear exhibiting a true MCL of more than 10dB above the normal MCL demonstrates a need for amplification?, while an ear with a true MCL of less than 10dB above the normal MCL requires no amplification A monaural MCL of 50 dBHTL using speech is considered normal and a binaural MCL of 45R/45L is likewise considered normal. It should be noted that for certain losses such as precipitous high frequency loss the magnitude of the MCL obtained using a speech circuit having a flat response does not accurately reflect amplification needs. When the MCL is measured using the appropriate response slope, such as 6dB or 12dB/octave rise the result provides a more accurate indication of amplification needs.

As stated, when the binaural MCL components are both substantially above normal, binaural amplification is suggested and the client should be evaluated further. The procedure used to determine binaural candidature is called- "The Mercon method for Binaural MCL". The procedure is indeed powerful and its results arefar reaching. The reasons for the procedures effectiveners are as follows:

1) It is based on actual binaural measurements rather than on extrapolation from monaural measurements.

2) The measurements are made directly at the "use" level (MCL) rather than at threshold.

3) The procedure produces equal aided levels rather than requiring symmetrical unaided losses.

Based on this procedure, they suggest a new set of creteria for recommending a binaurai hearing aid system they are:

1) No medical contradindications exists for either ear
2) Binaurai fusion is achieved
3) Sufficient need for amplification exists in both ears
4) Maximum improvement is achieved binaurally.

The first criterion merely requires that the patient is able to wear a 2 aids without causing or interfering with any medical conditions. Any questionable cases should be referred to a medical ear specialist.

The second criterion requires that the patient is able to achieve binaural fusion, so that the advantages, of binaural healing can be obtained. Without binaural fusion, there is generally more confusion and a corresponding reduction in performance with 2 ears rathers than one (stroke victims are often unable to achieve binaural fusion).

The third criterion relates to the binaural MCL. Each of the binaural MCL components should be atleast 1OdB above the normal MCL to demonstrate sufficient need for binaural amplification.

The fourth criterion requires that patient perform best with binaural hearingaids as compared with all other systems that could be provided. Speech discrimination testing provides a means of comparative evaluation among the various hearingaid system, although other methods of comparison may prove to be good or better.

Zelnick (1985) in the discussion of many of the binaural advantages to be derived by hearing impaired through the use of binaural hearing aid, realises that every bilateral SN hearing impaired individual is not a suitable candidate for the dichotic mode of amplifications. In the hearing aid evaluation the subject must be carefully tested to be certain there is no degradation effect resulting from the placement of a hearing aid in the poorer discriminating ear. Ears with very small dynamic ranges and ears with very low thresholds of discomfort are often indications that a monaural fitting may be more desirable in a particular case.

Certain other investigators object to binaural amplification due to some reasons. They include

1) the greater posibility of NIHL.
2) the occiursion of both ears may be uncomfortable
3) added cost and increase in hardware associated with a second aid.
4) degradation in binaural hearing (binaural fusion) due to ear asymmetries (Chermak, 1981).

It is essential also to determine whether candidates with minimal hearing loss and those with high frequency Impairment be benefitted with binaural amplification.Johnson (1987) discusses on these.

Assumptions are often made that the patient with minimal or mild loss needs just or little hearing help and therefore, one instrument should suffice, but binaural instruments do benefit them. Johnson (1987) gives an example. This individual was a librarian who had difficulty communicating in the quiet enviornment of the library. Her supervisor asked her to"do something"about her hearing. She agreed to try binaural instruments. Her audiogram (figurey)shows that she was within what is normally classified as "serviceable" hearing, both for pure tones and speech. Mild gain instruments with IROS earmolds 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 theatre,meetings and conferences and to a certain extent, in her home.

Figure : 7

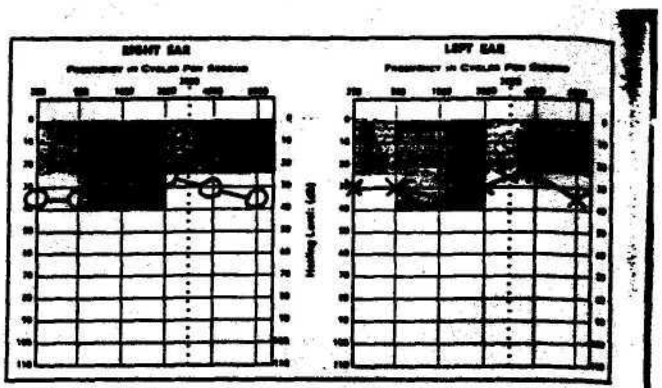

Fig.7. Even a minimal hearing loss can benefit from binaural amplification. Binaural, mild gain instruments with IROS earmolds were recommended for this case.

With regard to patients with high frequency impairment, Johnson (1987) indicates that earlier, patients with normal speech reception threshold, 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 reading. He concludes that patients with high frequency impairments rarely can, if ever be satisfactoruly fit with noaaural instrumentation. Both ears have to be fitted. He gives two examples, in the first case shown in figure 8 the audiogram illustrates a patient with essentially normal responses when tested in a quiet enviornment. His threshold for speech is 15dB or better bilaterally, and his right ear discrimination score is 100% and the left ear has a α score of 8 92%, in quiet. Testing with one syllable, phonetically balanced (PB) words in background noise illustrated his difficulty. His discrimination score dropped to 80% on the right and 64% on the left ear. The use of high frequency instruments with IROS type vents shifted his discrimination ability from 60% in noise unaided to better than 80% innoise when binaurally aided. The aptient was highly inotivated and felt that the hearing instruments were of inertimable value in conducting his business.

A second example (figure 8)involved a man in the number business with normal hearing with respect to speech reception threshold (SPT) and with reasonably good disdrimination ability in quiet. He too had difficulty in noise. Unaided in noise, he could distinguish only 18% of the PB Words. Properly aided binaurally, his discrimination ability in noise shifted to over 90%.

figure:8

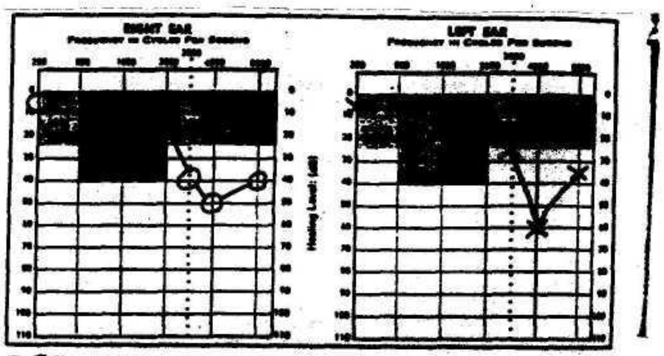

Fig. 8 Binaural, high frequency instruments with IROS type vents shifted this individual's speech discrimination ability from 60% in noise unaided to better than 80% in noise when binaurally aided.

figure:9

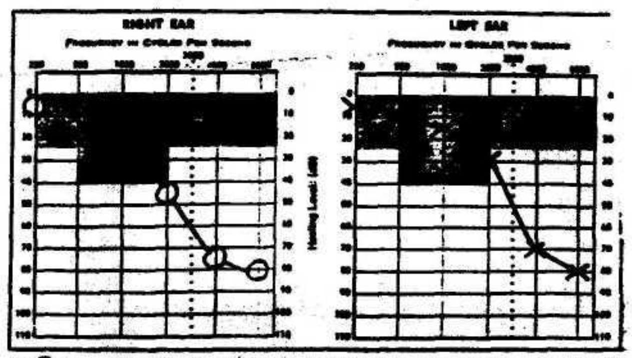

Fig. 9 Binaural amplification shifted this individual's speech discrimination ability in noise to over 90%.

Thus the review of literature, in general, gives the creteria used by the investigators and factors that influence the criteria. Though the main area of controversy is to fit or not to asymmetric hearing losses with binaural amplification, other factors like type of hearing loss, severity of the hearing loss, diplacusis binauralis, binaural fusion influence the final hearing aid system recommendation.

Special considerations are required while determining- "who is a candidate for binaural ampiification?"-in the paediatric and gaiatric population.

Babies :-

The case for Binaural Aid Fittings on Babies (quoted by Harris 1975).

Edith Whetnall (1964) felt that binaural aids were unquestionably superior for every child with residual hearing in both ears and that such children learned more rapidly. They were more oral, more social and happier.

Whatnall and Fry (1964) state that binaural fitting should be done as soon as possible after birth, preferably at 3-6 month They reported that st'nce 1961, they had adopted this practice as against monaural fitting, with auditory training going on continuously. The infant wore the aid even when asleep.

Guttner (1964) surveyed the problem and argued strongly for binaural fitting. He says for example, "exploiting the stereophonic capacity of the ear markedly improves the reception of the hard of hearing in everyday complex sould fields-reverberation, continuous noise or impulsive sounds". He points out that only on-the-ear aids canachieve the best results, when the directivity of the system

Closely Simulates the acoustic conditions at the ears drums of the unaided head.

Bentzen et al (1965) offered bilaterous fittings to 301 patients following some weeks of monoural experience 82% came to use two aids some or all (42% of the time), Of the 301 patients, all but 8 had on-the-head models with which a binaual fitting was said to be especially appropriates.

Harris (1975) adds that even yet, there was no general surge of effect to seek out those children and even infants who might benefit from binaual aids. In 1967, the position of ASHA on binaual aids for children was stated by Black and associates (1967) (quoted by Harris, 1975): The one-channel versus two-channel receiving system presents an argument that has not been resolved in terms of the impact of language and ears of listening for the person who wears one or the other system".

Clinical Experience Since 1967 With Binaual Aids For Babies. (Quoted by Harris, 1975).

Luterman (1969) compared monaural/binauaral aid performance on 17 children of 35 to 57 months by having trained parents make observations on certain types on their children. Two weeks in each mode were compared. All children were experienced aid wearers, two of them in binaural mode. Parents and child accepted this mode. Then, thirteen families purchased the second aid and three were saving up to do so.

Kayber and deBoer (1969) proved statistically in the Clinic with an array of loudspeakers at 30^0 intervals, that 42 out of 55 had significantly better directional hearing with two aids thap with only one.

The above study reports that binaural advantage can be achieved with two aids, thus babies are candidates for binaural amplification.

Rogs (1970) (referred to by Harris, 1975) points out that he would fit an infant as young as possible, but would used Y-cord until such time as a clear notion should be available 6f the audiogram of each ear, so that the later correct binaural fitting, upon which he would insist, could be accomplished.

Beisalski (1971) (quoted by Harris, 1975) tries h hard to fit children with binaural aids. He has constructed a test device with seven loudspeakers in the front semicircle at 30^0 intervals. He says, "If despite, careful fitting no effect of binaural therapy can be verified, special training must be instituted. Mostly, however, the failure is caused by: improper fitting. In some cases of cerebral defect, it may also be due to fusion results at the beginning. But we think that this merely a problem of training".

Devos (1968) (quoted by Harris, 1975) always starts with binaural aids on a baby. He points out that first the infant is adcustomed for 5-20 days to the earmolds, then aids are fitted. "Only if it turns out Sooner or later that the two ears disturb each other, we change the monaural". In this way he fitted hundreds of babies from 6 months - 3 years old.

Berg (1973)[referred to by Harris, 1975] tells of fitting over 1000 children, some as young as 4 months, with recommendation of ear level binaural aids whenever possible.

Case Reports :

In one account (Guercia, 1973; quoted by Harris 1975), a 9 - month girl was tested in 1969 and was found "profoundly deaf". This child, little Lori, with binaural aids from a Los Angles Clinic, and a program of home training, is now at 5 years of age, a healthy outgoing, hearing and talking youngster.'

The story of Lisa, now ten (Stambler, 1973; quoted by Harris 1975) is equally heart-warming, though through the in adequated and even incorrect advice of an audiologist cases of cerebral defect, it may also be due to fusion results at the beginning. But we think that this merely a problem of training".

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The story of Lisa, now ten (Stambler, 1973; quoted by Harris 1975) is equally heart-warming, though through the in adequate and even incorrect advice of an audiologist her acquiring binaural aids was near - tragically deferred till she was live.

Children :-

Ross (1969) Considers that children with severe hearing loss can use two body borne hearing aids, one to each ear; although this is not true binaural amplification, children so fitted make more progress than those fitted with first one hearing aid. With older children and adults with severe hearing loss, CRISCROS can be used. Clinical and experimental reports of binaural fittings with children have been almost unanimously positive.

Ross (1971), in the hearing aid selection for the young hearing impaired, recommends binaural amplification but does not fittttimmediately.

This is because of frequent occurence of vartly asymmetrical thresholds in the two ears of many of the children and so the gain and other electro-acoustic adjustments cannot be made appropriately.

The shift to binaural amplification occurs after establishing thresholds for the two ears because unless the auditory neural system is provided with dichotic stimulation early in life, the individual may be forever deficient in his capacity to develop full binaural auditory functioning. Perhaps it will be less of a detrimental effect in blindly fitting binaurally than in using a "Y" cord or rotating an aid between the ears. A kind of binaural sensory deprivation occurring which is analogous to auditory sensory deprevation in general, occurs. A "Y" cord or a monaural aid does not provide the uniquely patterened time and intensity differences to the central auditory mechanisms necessary as raw material for the construction of a full binaural system. He points that presently, this is a hypothetical consideration.

If is preferable to err on the side of commission, than on the side of omission as there is no direct clinical evidence to support or refute this hypothesis.

If loss is severe-to-profound, recommends two body-woen aids side by side on the chest. This is not the same kind of binaural amplification which would occur were hearing aids at ear level; that is, the time and intensity differences which occur when the microphones are on the chest are not the same as would result were the microphones at ear level.' It is not that no binaural advantage at all is forthcoming. Ross (1971) and others (Lotterman, 19698 quoted by Ross 1971) have found in their clinical world that children so fitted appear to make more rapid progress in their speech and language and in their responses to auditory stimuli, than they did immediately prior to the fitting and than children who are not so fitted.

If the loss is of moderate to severe type and the degree of loss in the two ears is fairly similar, he (Ross 1971) recommends binaural ear-level rather than binaural body worn hearing aids. There is no unequivocal dB hearing level which can be given to seperate those children who are body-worn as opposed to ear-level hearing candidates. A number of children who demonstrated relatively flat 80dB losses in both ears were fitted with binaural ear-level instruments. CRISCROS arrangement was used in several of these cases. This arrangement permitted maximum gain from the instruments without producing feedback as had occurred with the ipsilateral fittings. For the most part, bilateral flat losses of 70dB or less appear to be good candidates for ear-level binaural aids. Bilateral Symmetrical hearing levels between 70 and 80dB fall into the range of uncertainity; for these and other individuals where there is a deubt whether binaural ear-level instruments can be helpful, he recommends a supervisedtrial program.

As long as the degree is similar, he has not found that differences in configuration containdicate Binaural ear-level amplification because appropriate response changes can be made in each of the aids. He points out that binaural amplification is seldom successful when the average acurity of the two ears differ by 2OdB or more with the loss in the better ear approximately 60dB. In these cases the poorer ear is not suitable for ear level amplification while the better ear is. In a few cases, where body- worn aid was tried on the poorer ear, with an ear-level aid on the better side, observation indicated that children did poorer with this arrangement than with just a monaural ear-level aid. In these instances BICROS hearing aid showed a fair amount of success.

Zelnick (1985) - indicates that early auditory deprivation in the form of prelingual sensoriveural hearing loss results in later problems of auditory perception. H e adds that there is evidence that auditory sensory deprivation cdr affect binaural function. Beggs and Foreman (1980) (quoted by Zelnick, 1985) reported that the critical period for binaural stimulation may be over between 4 and 8 years of age. It is therefore imperative that youngsters with bilateral hearing losses be fitted with binaural hearing aids.

Elderly population :-

Aging produces deficits In pure - tone thresholds, the speech Reception Threshold and Speech, Discrimination but not all losses can be 'corrected' with a hearing aid. Binaural (stereophonic) devices are psycho-acoustically superior to monaural devices but behavioural and personality changes in the older patient influence adoption to the binaural aid, fitting of the aid and learning to use it (corso 1977).
In 48 out of 50 patients over 65 years of age, it was found (Bentzen and Hartrup, 1968; quoted by Corso 1977) that a significant improvement in speech discrimination was produced with the use of binaural (stereophonic) aid. Three months after initiation of treatment, 28 patients were using both aids at all times; 10 patients were using one hearing aid at all times and both aids about 25% of the time; four patients gave up the binaural treatment and used one aid at all times and two patients discontinued both aids completely.

While it neasy be concluded that stereophonic hearing aids are significantly better than monaural aids in improving deteriorated heating, care should be exercised in their prescription. Jensen and Funch(1968) (quoted by Corso, 1977) noted that elderly people have trouble enough using one aid and that they do not want two.

Aging produces both degenerative changes in the peripheral auditory organ and deterioration of the central acoutic tracts and brain. So part of the reason for the cessation of use of bin hearing aids in preebyacusis,lies in the inability of the patient with a central hearing impairment to integrate the acoustic information arriving from the two ears; It is estimated that about 1/3rd of the hard-of-hearing population over 65 years of age cannot be treated effectively with an ear-level binaural (stereophonic) hearing aid (Jorden, 1968,referred to by corso,1977).

Thus review of literature with regard to binaural candidacy in elderly indiciduals several that in general, they show binaural advantage using binaural aid but there are exceptions, that is, not all of them candidates for binaural amplification.

Elderly adults with suspected or confirmed central auditory aging deficits:-

In general, if a patient has a central auditory system problem, it would seem plavsible that he might have difficulty integrating the information coming in from two ears, and thus, binaural amplification might cause added confusion and distortion (Wernick, 1985) A study by Haskins and Hardy (1960) (quoted by wernick,1985) did demonstrate that some individuals with Central dysfunctions were unable to binaural hearing.

Rough (1985) (quoted by Arnst, 1986) reviewed several reports that demonstrated binaural resistances to distortion and binaural superiority using a modified binaural fusion task. The observation was that differences between elderly and younger groups of adult subjects could not be determined statistically; the only potentially age-related deficit that emerged was a binaural figure-ground separation problem.

Antonelli (1978) stressed the superiority of binaural over monaural fittings on a thoretical basis with order adults.

Though many studies confirm binaural advantages, it is essential to keep in mind that in a given patient, a reduction in auditory processing brought about by central aging effects must be identified before an appropriate amplification is selected (Arnst, 1986).

Thus, in considering an elderly individual with central auditory deficit as a candidate for binaural amplification he must be evaluated carefully.

Though, formally the binaurai candidature is determined using Audiological Reports and Age factors; there seem to be a few other factors which influence this. They include health, adjustment to amplification and finance.

Gatehouse and Haggard (1986) indicate that the choice, for both asymmetric and Symmetric patients is ultimately health-related and economic one.

While asking the patient to report subjective ability with binaurai amplification after fitting binaurai hearing aids, he may require some time to get adjusted to amplification. This time should especially be provided to the geriatric population and the paeditric population. Otherwise a hasty conclusion can be made, regarding "Who is a candidate for Binaurai Amplification".

This chapter concludes giving three major reports. One is by Stephens (1984) another by Valente (1984) and the third by Chung and Stephens (1986).

Stephens (1984), regarding fitting binaurally points out that it is been argued elsewhere (Stephens,

1983) (referred to by Stephens, 1984) that a Binaural hearing - aid fitting should be first considered with the question then being posed as to whether there is a good reason not to fit binaurally. To answer this question, he calls stores S. the patient's auditory needs and problems are particularly important, involving factors such as his need to localise and to discriminate signals in a difficult listening environment. His auditory sensitivity will have an important hearing on the decision- obviously binaural aids would not be fitted to a patient with a unilatual hearing loss. Poor aided visual acuity enhances the need for auditory localisation of information and hence the importance of binaural fitting, as do particulars vocational needs. He points out that probably the most important factors precluding a binaural approach are negative attitude towards it by the patient and limited upper-limb function so that a single aid required considerable effort on the part of the patient. Recurrent gtorrhoea militates against a binaural approach but tinnitus may work in both directions. He indicates that in most patients amplification of extraneous sounds inhibits tinnitus so that bilateral tennitus may be a further indication for a binaural approach. He concludes that in a minority of sufferers, however, even careful and appropriate hearing aid fittings can aggravate the symptom so contraindicating binaural aids.

Table :: 13 Factors in binaural aid fitting decision

Stores	Binaural ?
1A.1.1	Nature ofhearing problem
1A.1.2.1	Auditory sensitvity - unilateral asymmetrical
1A.2.2	Visual acruity
1A.5.a	Previous wearable instrument
1B.1	Prychological-attitude towards binaural
1B.2	Sociological - availability
1B.3	Vocational - need to localise
1C.1	Mobility
1C.2	U pper limb function
1C.3	Related acural pathology-tinnitus, Otorrhoea.

Valente (1984) gives a summary ofcommencements appearing In the Literature concerning who is a candidate for Binaural Amplification. The following table 16 given 1this summary.

Table:16 Summary of comments appearing in the literature concerning who is a candidate for Binuaral Amplification -

CANDIDATE	for Binuaral Amplification - **NON-CANDIDATE**
1. Good fine motor control	1. Problem 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 considerations	7. III or elderly
a. Symmetrical Hearing Loss	a. Asymmetrical
1. Threshold	b. Severe-profound
2. WOS	c. Retro cochlear lessons
3. MCL	d. Central lessons
4. LDL	e. Excersive Recruitment
5. DR	f. Poor word discrimination score
b. Magnitude	g. Flat configuration in better ear, falling configuration in poorer ear.
1. Mild	
2. Moderate	
c. Ttpe of Hearing loss	h.Binaural diplacusis
1. Conductive	>15%
2. Mixed 3.cochlear pathology	

d. Miscellaneous

1. Little Recruitment

8. Bicaural scores greater than monaural scores by 6, 9, or 10%

9. Electro acousitic characteristics of hearing aids should be similar.

i. Unilateral hearing loss

g. Binaural score poorer than monaural score.

Chung and Stephens (1986) state 8 factors indicated by various authors (example, Markides, 1977; Berger and Millin, 1980; Briskey, 1980; Davis and Haggard, 1982) which contra indicate binaural amplification:- They include;

1) A significant asymmetry of hearing loss between the ears (in excels of 15dB).

2) A significant differencer in speech discrimination (in excess of 8%)

3) A substantial difference in MCL, UCL Levels, or DR.

4) Unilateral hearing impairment.

5) Relatively flat hearing impairment in the better ear and a steeply falling pure-tone audiogram.

6) Diplacusis binauralis

7) Predominantly retrocochlear (peripheral neural)

leyioos, as such people have poor speech discrimination ability and many of them benefit little from amplification.

8) Severe fine manipulation problems (mainly elderly people) or low activity index.

From the two tables 15, 16 and studies a lot a commonalities can be visualised regarding criteria for binaural candidature. This includes that an Individual with asymmetric hearing loss is not a candidate for binaural amplification; But what about those studies which indicate binaural amplification for asymmetric losses?

Thus, it can be concluded that creteria for binaural candidature is highly idiosyncratic.

* ** **

PROCEDURES TO EVALUATE CANDIDACY FOR BINAURAL AMPLIFICATION

If permanent hearing impairment exists following medical care, the first and most logical step in the aural rehabilitation process is a hearing aid evaluation. Successful hearing aid use in dependent on competent hearing aid evaluation, selection of an appropriate aid and supervision of the, adjustment period. Based on the hearing aid evaluation, the audiologist will determine the potential benefit to be derived from amplification and often which aid is most appropriate (Tannahill, Walter J. Smoski.(1985)

The different kinds of amplification available include monaural, pseudobinaural, binaural, CROS (contralateral routing of signals) and its variation BICROS (bilateral CROS). and its variations.

The goal in hearing aid selection is to achieve normal, or near normal, hearing response as possible for the hearing impaired through appropriate electroacoustic amplification. Normal hearing people achieve normal listening response through the use of both ears (Zelnick, 1985).

It has been pointed out that hearing binaurally involves the integration of the signals from each of the two ears into a single hearing sensation. This is referred to as binaural fusion and for normal hearing persons occurs simply and automatically, because the signal from each ear are in proper proportion to each other and are combined into a single image by the central auditory system. The advantages of loudness summation, localization and discrimination enhancement in noise occrue as a natural result of this binaural integration. But, when signals from each ear are disproportionate with each other, the binaural integration process is less effective and the binaural advantages are correspondingly diminished or even lost. Such is the case or for an unaided asymmetrical bilateral hearing loss. (Mercola and Mercola, 1985).

Carhart (1958) called for the creation of criteria to recognize those members of the hearing impaired population that could potentially,benefit from binaural amplification and to identify test procedures which may be used to demonstrate the superiority of binaural amplification.

The previous chapter discusses on - "who is a candidate for binaural amplifications, by providing the criteria and comments appearing in the literature on binaural hearing aid candidature. One of the summary of comments, given by Valente (1983), is putforth below in Table A.

Table A: Summary of comments Appearing in the literature concerning who is a candidate for Binaural Amplification. (Valente, 1984).

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. Audiologic considerations	7. 111 or elderly.
8. Symmetrical hearing	8. Audiologic considerations
a) 1. Threshold	a) Asymmetrical
2. W 0 S	b) Severe - Profound
3. M C L	c) Retrocochlear lesions
4. L D L	d) Central lesions
5. D R	e) Poor word discrimination scores.

b. Magnitude	f) Excessive recruitment
1. Mild	g) Flat configuration in better ear, falling configuration in poorer ear.
2. Moderate	
-	
c. Type of hearing loss	h) Binaural diplacusis 15%
1. Conductive	i) Unilateral hearing loss
2. Mixed	
3. Cochllar Pathology	
d. Miscellaneous	
1. Little Recruitment.	
8. Binaural scores greater than monaural scores by 6, 8 or 10%	
9. Electroacoustic characteristics of hearing aids should be similar.	9. Binaural scores poorer than monaral score.

A glance at there criteria and the comments reveal that audiogram, speech audiometric tests; subjective reports including past experience with hearing aids, present experience with binaural hearing aids, adjustment ability, financial status; and objective clinical techniques showing the binaural advantages were the procedures used to delineate the binaural candidacy criteria.

A variety of procedures have been used by different investigators. Some have used audiogram reports and clinical techniques showing the binaural advantages to determine as to who can benefit from binaural amplification while some have used objective clinical techniques and subjective reports.

Kodman (1961) (quoted by Harris (1975))states that fifty binaural eyeglass wearers reported a number of subjective advantages over the monaural case, but the clinical techniques were unable to quantify that matter. Decroix and DeHaussey (1962 a,b) (quoted by Harris (1975)). however, were able to provide a quantitative estimate, of the binaural advantage by comparing complete articulation functions for monaural versus binaural hearing aid fitting.

Dirks and Carhart (1962) studied the reactions of hearing aid users and found that those who had binaural instruments expressed strong belief in their superiority. Though the reasons given by many binaural users to support their attitudes were vague and general, the beliefs remained firm. But no clinical test battery had been able to demonstrate this superiority on the basis of measurements.

Heffler and Schdltz (1964) point out that the clinical audiologists are generally agreed that the index of significance in the comparison of monaural and binaural amplification is the improvement in discrimination score when binaural hearing aids are used. So the requirement is a measurement of increase in intelligibility made by the addition of the second ear.

Heffler and Schultz (1964) list the several parameters that the clinical experimental literature reveal, which contribute to the design of an appropriate test : -

1. Competing Stimuli :- A primary requirement in the testing of binaurality is the use of second stimulus in competition with the speech signal. Studies evaluating binaural hearing aids in thequiet have repeatedly failed to yield significant differences between monaural and binaural listening scores (Dicarlo and Sheets, (1958) (referred to by Heffler and Schultz, (1964). Wright and Carhart (1960) (quoted by/Heffler and Schultz (1964)) compared discrimination scores both in the quiet and with a competing noise. Their results revealed that, though not all subjects heard better with binaural amplification, some differences appeared in the noise situation which were undetectable under the quiet listening conditions. In explanation of there findings, it appears that the single, aided ear, working in a quiet environment, is able to achieve nearly these almost - ideal conditions. What ever contribution the second ear might make cannot be expressed by increased discri-

mination unless procedures measure that contribution in the presence of competing sound.

2. Signal - to - Noise Ratios : The relative levels of such competing sounds is a matter of significance when discrimination for speech is measured. This relationship, usually designated signal - to - Noise (S/N) has no standard operational definition and different investigates have established it in different ways. Most of the commonly - used S/N definitions either attempt to equate or approach the level of the signal with the noise. It is well-known, however, that intelligibility remains reasonably high until the noise far exceeds the signal. It may be, therefore, that the S/N commonly used in comparing monaural and binaural discrimination scores permitted the monaural system to obtain so high a score that a binaural improvement could not be demonstrated.

Applying the concept of threshold, defined as a 50% point, one could set that level of noise which permits only 50% discrimination as another and equally valid definition of zero dB S/N. If one operates around zero dB S/N, thus defined,the discrimination scores for all listening conditions will be artificially depressed but the possibility of measuring an improvement in the functioning of the auditory system under experimental condition exists.

3. Localization Effects. It is pointed out here that one problem arising when competing stimuli are used is that localization tends to contaminate scores. One cannot separate the contribution to.intelligibility by the second ear from the contribution due to localization. When the scores of the signal and the noise are separa-ted in space, additional clues such as inter intensity difference's and differences in S/N at the two ears obscure the particular discrimination gain which is the focus of interest in the test. Such obscuring influences were observed by Wright and Carhart (1960) (quoted by Heffler and Schultz, 1964) who found a "sidedness effect" related to the intelligibility scores obtained by their subjects. The elimination of locall-zation of sidedness effects in a clinical test is clearly necessary.

4. Type of Signal : One of the notable advantages of binaural listening is the so-called " squelch capacity reported by Kbenig (1950) (referred to by Heffler and Schultz, 1964). He noted a marked reduction in the masking effects of a noise, without any change of physical sound levels, some few seconds after switchihg from monaural to binaural amplification part of the relatively long delay in realizing the full benefits

of this capacity may be due to the necessity of recognizing the presence of a particularly desired signal and identifying its characteristics so that it can then successfully be followed. This suggests that serious consideration be given to the type of signal to be used in testing binaural aided discrimination in noise. (A signal of short duration, such as a word from the PB lists, might well be gone before this proceisis complete. This may explain the finding by Jerger, Carhart and Dirks (1961) of no difference between monaural and binaural performance for their NC # 2 Test using these words. Test NU #3 used by the same investigation employed a signal of longer duration (sentence - length instructions or questions) but it is entirely possible that the nature of this stimulus requires an "all - or - none" type of discrimination by the subject. That is to say, a single word incorrectly interpreted or missed altogether might make it impossible for the subject to provide the correct response and thus deny him credit when, infact, he had correctly heard the major part of the sentence. A long duration stimulus in which fcactional credit for fractional discrimination is given might reveal this "auditory focusing" ability which seems to be a component of the binaural "Squelch capctcity. Summarizing these points, they point out that a procedure for comparing monaural and binaural aided discrimination should indude the following characteristics.

1. The presence of a competing noise
2. S/N which permits improvement due to the second ear to be measured.
3. elimination of localization and sidedness factors.
4. long-duration-speech signals with partial credit possible.

Effects of phase relationships on intelligibility— Among the properties of the auditory system is its use of interaural phase differences to improve discrimination of speech in noise. (Heffler and Schultz, 1964). Licklider (1948) (quoted by Heffler and Schultz, 1964) showed that if one of two binaural competing stimuli reaches the ears 180^0 out-of-phase interaurally while the other is in-phase, discrimination is better than when both sounds reach the ears either in-phase or out-of-phase. of the two possibilities, the antiphasic - + (speech out-of-phase; noise-in-phase), yields better discrimination scores than does the reverse. Significantly, this superiority tends to disappear as S/N increases. That is, when given a relatively easy listening task, the auditory system does sufficiently well. But, its ability to function under highly adverse auditions, as demonstrated by the superiority of antiphasic over homophasic listening is hidden. Licklider's findings (quoted by Heffler and Schultz, 1964) have been substantiated by Tobias and Curtis (1959) (quoted by Heffler and Schultz, 1964), among others, who found that their subjects were better able to discriminate speech in noise under this - + antiphasic condition.

The above mentioned properties of the binaural system were exploited in construction of a clinically useful test by Heffler and Schultz (1964). The test eliminated localization as a factor in speech discrimination yet permitted the above - listed desirable properties to be employed. The criterion measure was the growth of intelligibility for masked speech as a function of S/N and interaural phase relationships under two types of binaural listening conditions in a sound field. They do not suggest that tests for ability to localize with binaural amplification be abandoned rather, they opine that the procedure discribed by them should be added to the battery of tests used in hearing aid evaluation. The following is the procedure.

Experimental subjects and Environment - 36 normal hearing adults were chosen for the study as listners. The normal hearing was determined by an audiometric 10 dBHL sweep check. The subject was seated in a sound - treated room flanked by two loudspeakers at head height. Each speaker was located at a distance of about 30 inches and aimed at him. Each delivered both signal and noise, with the noise always in-phase interaurally and the speech varied experimentally in either an in-phase or out-of-phase condition.

The advantage of using a speaker at either side of the subject and reversing polarity of the speech wave from one speaker is that the procedure nullifies any effect of head movements by the subject. An interaural intensity difference for the total auditory stimulus will result from a head movement, but it will exist in exactly the same proportions for both component stimuli. In any head movement, S/N at each ear remains the same. Only phase difference, when presented, is useful for Separating the signal from the noise.

Speech stimuli : A pool of 103 sentences, selected from the Harvard PAL tests were distributing among 12 lists of 20 sentences each. No sentence appeared more than once in any test nor more than three times in the entire test. Each test of 20 sentences preceded by a 1000 cycle Calibration tone, was recorded on magnetic tape and inserted into an endless loop tape cartridge.

Masking Stimuli : The masking noise used in the study was the recorded sound of 16 simultaneous talkers. The use of a voice babble was judged sufficiently similar to an actual listening situation to offset the variability in level it occasioned.

Experimental Procedure : In the major experiment, 36 subjects listened to the lists under two interaural phase conditions and two binaural listening conditions at three S/N. The interaural phase conditions were homophasic ++ with both signal and noise in-phase, and antiphasic - +, wherein speech was out-of-phase and noise in-phase. The two binaural conditions were Balanced Binaural, with both ears unoccluded, and unbalanced Binaural, with one ear occluded where the one ear was filled with fresh earmold impression material and covered by a dummy earphone, which was filled with vaseline petroleum jelly and encased in a CZW-6 semi-plastic earphone socket; This occlurion offered - a shift on the order 23 dB in a preliminary study; Zwislocki's published attestation data (1955) (quoted by Heffler and Schultz, 1964) indicate that this average shift in SRT probably was conservative. Fifty percent intelligibility, determined previously in a preliminary study, was defined as zero dBS/N and the masking noise was varied around a constant signal level to produce S/N of -4, -1 and 2 dB. All subjects listened under all permutation of experimental conditions. The following table 17 shows the permutations of binaural listening conditions.

Tablei7: Permutations of binaural listening conditions.

Binaural Condition	Interaural Phase Condition	S/N ratios		
Balanced	Homophasic	-4	-1	2
	Antiphasic	-4	-1	2
Unbalanced	Homophasic	—4	-1	2
	Antiphasic	-4	-1	2

Each subject listened to six consecutive lists in the balanced condition and in the unbalanced condition. The order of presentation was randomly determined for each subject, as was the choice of earto be concluded. The order and sequence of interaural phase conditions and S/N were counterbalanced independently for each group of 12 subjects using a series of 6 x 6 Latin squares (Fisher and Yates, 1938); (quoted by Heffler and Schultz, 1964). The order of presentation of the test was randomized independently for each subject each heard every test once.

The means for the subjects at each of the S/N and listening conditions are graphically represented with S/N along the abscissa and percentage intelligibility along the ordinate.

The results of this study indicate that the normal binaural auditory system is able to extract more information from a given stimulus complex if it is presented with anti-phasic - + rather than homophasic listening conditions. Since the only difference is thatthe stimulus patterns at one ear changes relative to that at the other, the increase in intelligibility must be due to the change in binaural pattern. Thus it becomes possible to measure the contribution of the second ear independent of localization, and using hompphasic listening as a control. In order to observe this contribution, however, signal - to - noise ratios must be comparatively poor so that neither the monaural nor homophasic system obtains the score of which it is capable under favourable —listening conditions. They also add that this listening situation is a highly aritificial one and does not occur except under these experimental conditions.

They give two clinical applications of their study. One clinical application mightbe in the assessment of binaural versus monaural hearing aids. The clinical technique would follow much the same course as did the testing of subjects for this study. The patient, weaving binaural hearing aids, would be tested for intelligibility in both the homophasic and antiphasic interaural conditions

In addition, a test under monaural amplification would be taken. Differences in discrimination scores would guide, the audiologist in making a decision on amplification with more security than he has been enjoying.

Tests for potential gains in intelligibility by this method might find greatest value as a quickly administered prognostic test at the time of initial contact with the clinical patient. The procedure for the suggested test would be to determine the masked threshold for spondaic words presented homophasically either in a sound field or binaurally under earphones. The level of the speech signal should be held constant at about 40 dB SL relative to the better ear. Once the masked theshold has been established the audiologist should reverse the phase of the speech signal at one of the transducers and note whether a marked change occurs in intelligibility at the same S/N. If the subject is then able to respond correctly to a greater number of test words, thus indicating that the phase reversal has improved his masked threshold, the clinician can conclude that amplification the second ear will contribute to his useful hearing.

Another clinical application which may be derived from this study might prove useful in auditory rehabilitation programs.

Olsen and Carhart (1967) (referredto by valente. (1983)) in the second part of their study Utilized thirty three hearing impaired subjects (conductive, sensory neural and sensory neural secondary to presbyacusis). They listened to NU - 6 word tests embedded in the two types of maskers (speech noise and sentence) through a high fidelity listening device and three types of hearing aids. The spatial separation of the loudspeaker was the same as the first experiment. That is, the loudspeakers were placed at 45* azimuth to the right and left of the listeners. In this study, the binaural monaural comparisons were completed in quiet, as well as + 12 dB S/N ratio (actually + 18-to +6 dB due to head shadow effect at the two ears). The stimuli were presented in sound field to a dummy head wearing one of the three hearing aid arrangements or no hearing aid (high fidelity). The signals (NU-6 plus competition) were then presented to the listener via head sets. Hearing aid A had the widest frequency response, largest amount of harmonic distoition, and the least amount of intermodulation distoiton. Hearing aid C has the narrowest frequency response, least harmonic distoition and greatest intermodulation distoition. The electroacoustic characteristics of hearing aid B were somewhere between these extreames.

The following table lBshows the binaural advantage for 33 hearing - Impaired listeners (in percent) for NU-6 words embedded in sentences or speech noise and listening through four types of listening devices (olsen and Carhart, 1967, quoted by volente (1983))

TABLE: 18

Device	Quiet	NU-6/Speech Noise			Quiet	NU-6/sentences		
		NE	FF	NE-FE		NE	FE	NE-FE
HiFl	-0.6	2.1	24.1	22.0	0.5	1.9	19.3	17.4
Hearing Aid A	-3.7	2.3	29.1	26.8	-1.1	0.7	27.2	26.5
Hearing Aid B	-5.4	1.9	34.1	32.2	-0.8	1.8	29.0	27.2
Hearing Aid C	-9.5	2.3	37.1	34.8	-2.9	1.2	32.7	31.5

The results of second part of study of Olsen and carhart (1967) (quoted by valente (1983)) point out that under conditions of quiet, the binaural scores were poorer than monaural scores (binaural inhibition). The findings also revealed that the greatest binaural advantage occurred when speech noise was the masker and this finding appears to be in agreement with other investigation who report speech noise to be an efficient masker than sentences. It also reveals another possible cause of the wide variability of findings reported in the literature. It appears not only as if the type of signal and loudspeaker arrangement are important variables, but also the type of masker intielized in the study is significant.

Dirks and Wilson (1969) (Quoted by valente (1983)) determined binaural advantages over near and far listening for three subjects with normal hearing and three hearing - impaired subjects with presbyacusis. The signals used were spondaic words and synthetic sentences embedded in either speech noise or connected, discourse. When the signals were presented at 0* azimuth, there was no significant differences between binaural or either monaural listening situation. Then the signals were emitted at 90*, while the noise was emitted at 0*. Table 19 gives the results of this study.

Table 19 : Binaural advantage (in dB) for normal and hearing impaired listners for spondees and synthetic sentence identification (SSI) embedded in two types of noise. NE refers to Near Ear and FE refers to far Ear (Dirks and Wilson, 1969 (quoted by valente, 1983)

Ear	Normal (N-3)			Hearing Imparied (N=3)		
	SRT	SSI/Speech- Noise	SSI1/4Conti Discover	SRT	SSI/speech noise	SSI/ Continous Discover
NE	2.7	4.2	3.5	3.8	2.5	3.0
FE	10.8	8.7	9.2	11.2	7.7	10.7

The findings revealed essentially equivalent binaural advantages for both groups. A greater binaural advantage was reported when connected discourse wasthe competition. This is in direct contrast to the results reported by Olsen and Carhart (1967) (quoted by Valente (1983)). This may be due to differences in sample size, signals, arrangement of the loudspeakers, as well as the fact that the Olsen and Carhart (1967) (quoted by valente (1983) study used short sentences as competition and not cold running speech.

Kuyper and deBoer (1969) state that the main advantages that can be derived from having two ears are:

1. Cocktail Party effect (CPE) = better understanding of speech in a noisy environment.

2. fast and accurate detection of the direction of the sound source (directional hearing).

They add that if it is possible to use directional hearing or cocktail party effect to prove the superiority of stereophonic fitting of the hearing aids, of the two, directional hearing is a better tool. It easily yields an index that can be used to predict actual performance with two hearing aids. "If one deprives the cocktail party effect from its prychological factors, it is not very well suited for our purposes" - Kuyper and De Boer (1969.),

Byrne and Dermody (1975) fitted 101 hearing - impaired adults, who had worn monaural aids for many years, with binaural aids and were subsequently reviewed. 80 of the binaural fitting were in-the-ear aids and 21 were body-worn aids. Reports were obtained from all subjects and selected cases were allocated to smaller groups who were given particular types of tests. These tests were : binaural loudness summation measured at several suprathreshold levels, binaural 'squelch' and head - shadow as indicated by speech-in-noise tests, and localization under various aided and unaided conditions. Reviewing the adult cases 6 - 8 weeks after binaural fitting, about 85% reported that the favoured binaural aids. Approxeimately 60% said that they wished to continue wearing binaural aids for part of the time. This favourable reaction was consistent with reports received from parents and teachers that most of the children who had been fitted binaurally liked wearing binaural aids and appeared to receive additional benefits. However, they point out that, a survey of teachers of the deaf showed a great diversity of opinion concerning the particular kinds of children who were most, or atleast, liable to benefit. So, ther impression is that this difference of opinion demonstrates that the benefits of binaural fitting are not always obvious and consequently that objective measurements are important.

By testing binaural loudnerssmation at several sensation levels with a variety of narrow band noise stimuli, Byrne and Dermody (1975) confirmed that this advantage could be obtained by hearing impaired subjects when wearing binaural in-the-ear hearing aids.

They performed, speech discrimination testing, with a speech signal and a background noise presented from separate loudspeakers, for a group of 61 hearing - impaired adults under aided binaural 'squelch' averaging about 7% and a head shadow effect of about 1% The striking feature of this study was the high variability of performances and the numerous inconsistencies between various sets of measurements which could be expected to be related. The conclusion was that the speech-in-noise tests used in this study, which were similar to those used by other investigators were suitable for demonstrating group trends but were not very satisfactory for determining particular binaural advantages in individual cases.

Next, Byrne and Dermody (1975) investigated binaural advantages with respect to localization presenting bursts of noise at ear level, using a semi-circular array of loudspeakers. In one experiment they compared localization ability under impaired adults who were ia-the-ear aids aided binaural and aided momaural conditions for 16 hearing aids, using a white noise stimulus presented at sensation levels of 10, 20, 30 and 40 dB. At higher sensation levels monaural localisation improved but was still less accurate than binaural localisation which did not change with sensation level. Using the same procedure, they also tested 4 subjects who wore binaural body - worn hearing aids.

Table 20 shows the correlations between stimulus position, and subjects reports under various conditions. Table 21 gives the localisation (correlation between actual and reported stimulus position) for four hearing - Impaired subjects wearing body hearing aids.

Table:21 - shoes correlations between stimulus position and subjects reports under various conditions:

SL	Binaural	Left	Right
l0dB	.86	.28	.25
20dB	.85	.40	.57
30dB	.85	.74	.75
40dB	.88	.66	.73

Table:21 - Localization for 4 hearing - impaired subjects wearing body hearing aids.

SL	Binaural	Left	Right
20dB	.78	.27	-35 .
40dB	.89	.11	.45

Comparison under aided binaural and monaural conditions for white noise at 20dBSL for 4 normal hearing subjects were performed. This is only one of the many sets of measurements which all show a clear cut binaural advantage which diminishes to some extent at higher sensation levels but is still appreciable. From a series of measurements performed with binuaral hearing aids worn at various distance apart, results revealed that localisation was best when the hearing aid microphones were separated by a distance of 7 to 10 inches. Localisation of sounds presented from behind the subject was of the same order of accuracy as for sounds from the front and the optimum aid separation was the same. They also found that the optimum distance was independent of stimulus frequency and that the same effects occurred irrespective of whether the aids had forward-facing or upward-facing microphones.

To provide comparative data, localisation tests were carried out using the same 4 subjects wearing binaural post-auricular aids and under unaided binaural and nomaural conditions (one ear was covered with an ear muff for the unaided monaural condition). It was found that, for the test situation they used, localization with binaural body worn aids (worn 7-10" apart), was far superior to localization with two post-ausicular aids. However, in all aided conditions localisation was less accurate then unaided binaural localization.

The answers they arrived at from the study are: It seemed evident that all the recognized advantages of binaural hearing aids can be obtained by the hearing-impaired through the use of binaural hearing aids. This was so for all their tests with atleast some of theirhearing impaired subjects. Further more, these advantages were obtained with both ear-level and body-worn aid fittings, infact for the tests they have used body-worn aids were not demonstrably inferior to ear-level aids.

They point out that in view of certain limitations of most available tests, it is impossible to say precisely how many or what types of cases can benefit from binaural fitting.

They also indicate that their attempts to develop clinical techniques for binaural fitting, have, at this stage, been partially successful. The technique used in their loudness summation, studies is not feasible for general clinical use, and, as discussed earlier, their speech-in-noise tests are not satisfactory for demonstrating binaural advantages in the individual case. They add that localisation testing seems much more promising although it requires equipment not currently available in most clinics. Apart from testing localisation, it seems a reasonable, although unproven,presumption that if binaural aids are fitted to otpimize localisation, the other binaural advantages are also most likely to occur. However, at this stage, they are not convinced that there is any completely satisfactory way of ensuring that binaural aids are fitted optimally. They, therefore, suggest that other types of test needs to be developed and, in particular, the inter-relationships between binaural phenomenon need to be defined.

The two studies mentioned above (Kuyper and deBoer (1969); Byrne and Deemody, (1975) indicate that localization can be used as a procedure to determine binaural superiority. But Harris (1975) points out that one incorrect assumption, for example, is that localization of is exclusively a binaural function. Very good monaural localization of sound is possible (Angell and Fite, 1901) (quoted by Harries (1975)), with timbre cues as a function of azimuth (pierce, 1901; (referred by Harries (1975)), with head movement (wallach, (1940); referred by Harries (1975)) with cues from sound shadow and from pinna diffiaction (Fisher and Freeman (1968); referred by Harries (1975)), interposition, and perhaps of other cues. Evidently a careful test of binaural superiority in localisation could not consist simply of a couple of loudspeakers at $\pm 45^0$, since the monaural mode might well be as efficient, but the test situation would have to be constructed powerful enough to exhaust the capabilities of the monaural case and to top the possible extra resources of the binaural - Harris (1975)).

Harris (1975) also indicates that for studies of the binaural advantage for speech reception, it is not a simple thing to arrange acoustic conditions in the lab so that the binaural advantage, if present (and it is certainly not present in some acoustic situations) could be expected to appear. The placement of loudspeakers with respect to the ears in the monaural/binaural comparisons has often been sorestled with by carhart (1965) (referred by Harris (1975) himself, as well as by others.

Quoting studies of Kodman (1961) and Decroix and DeHaussey (1962a,b), mentioned earlier in this section, Harries (1975) contemplates that it is admittedly difficult then, but not impossible for the experimented to create acoustic conditions in which the effect of various fittings of localization, speech reception, or both, can correctly be assessed. To do less is to prejudice the case against the potentially more powerful prosthesis.

Ma%kides (1977), with the purpose to explore the possibility of restoring binaural hearing advantages to hearing - impaired people through the use of hearing aids, has used both free - field speech discrimination test and directional hearing test. His investigation included 96 subjects, 30 with normal hearing, 22 with symmetrical hearing impairment, 20 with asymmetrical hearing impairment and 24 with Unilateral hearing impairment (16 aidable and 8 unaidable). The free-field speech discrimination test employed Fry's 10 PB word tests (35 monosyllables or 100 phonemes in each work list) as the speech material presented through a loudspeaker which was placed 45^0 to one side of the subjects median plane and at 6 feet distance from the centre of the subject's head in the horizontal plane. The fire-field speech discrimination test was presented to each subject at four signal-to-noise ratios. The competing noise used was continuous wideband noise shaped to correspond roughly to the speech frequency spectrum. The four signal-to-noise ratios employed were OdB, +5dB, +10dB and + 20dB. Each subject with either normal hearing or with a bilateral hearing impairment was tested under three modes of listening. Monaural near-ear listening, monaural far-ear listening and binaural listening. Subjects with unilateral aidable hearing impairment were tested with and without an ear-level hearing aid while speech was presented from the side of the good ear (direct listening) and while speech was coming from the side of the affected ear (indirect listening). Subjects with unilateral unaidable hearing impairment were tested in the same method but using the CROS hearing aid system. The experiments in this investigation were carried out in a highly sound-treated room with a very low ambient noise level. To study effects of reverberation on binaural hearing aids, several experiments were also carried out in a more reverberent room with similar shape and size. The hearing aids kg used in this study are:

a) Two matched ear- level with external receivers

b) TWo matched ear- level with conchal pick-up tubes

c) Two matched Medesco 0L56 with 0L575 receivers (Effective frequency amplification 200 - 4000 Hz).

d) Two matched commercial bodyworn hearing aids with extended low frequency amplification (Effective frequency amplification 50 - 4000 Hz).

e) Two matched commercial body worn hearing aids with extended high frequency amplification (Effective frequncy amplification 300 - 6000 Hz).

f) One of the Medrescos with "Y-lead" (pscudo-binaural).

g) High-fidelity amplification using two amplifiers with one feeding the speech loudspeaker and the other one the noise loudspeaker (Effective frequency amplification 100-20 Hz).

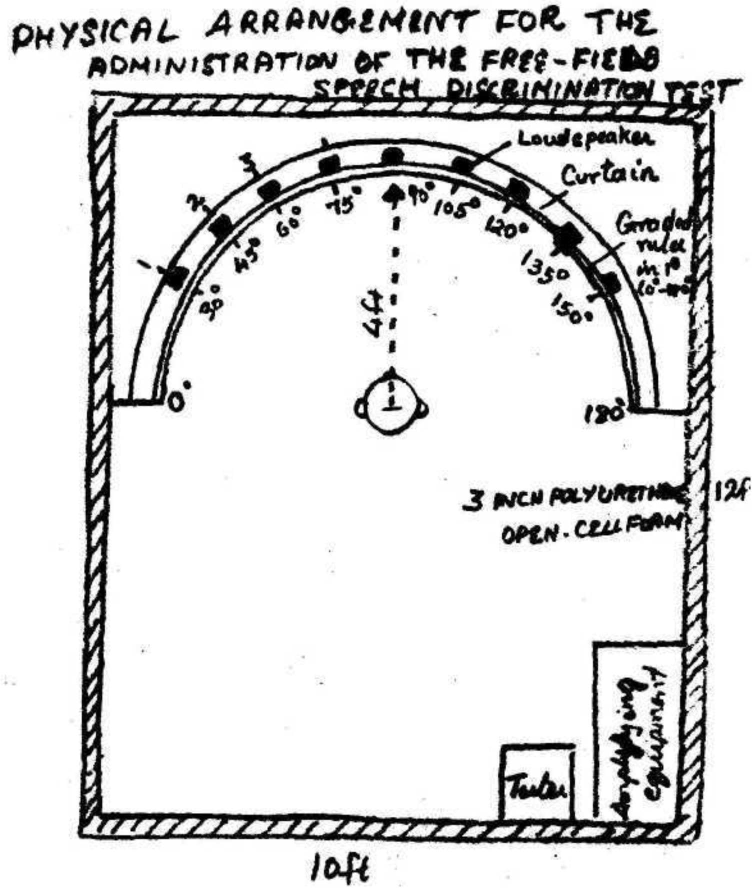
h) One of the ear-level hearing aids with external receiver used with subjects with unilateral aidable hearing impairment.

i) One CROS hearing aid used with subjects with unilateral unaidable hearing impairment.

The hearing aids in each pair were matched with regard to frequency response characteristics and harmonic distortion. Such measurements were periodically performed during the course of the investigation in order to ensure uniformity of testing. Slight deviations from the original measurements were observed but none were substantial enough to influence the matching of the hearing aids in each pair.

The physical arrangement for the administration of the free-field speech discrimination is shown in the figure10

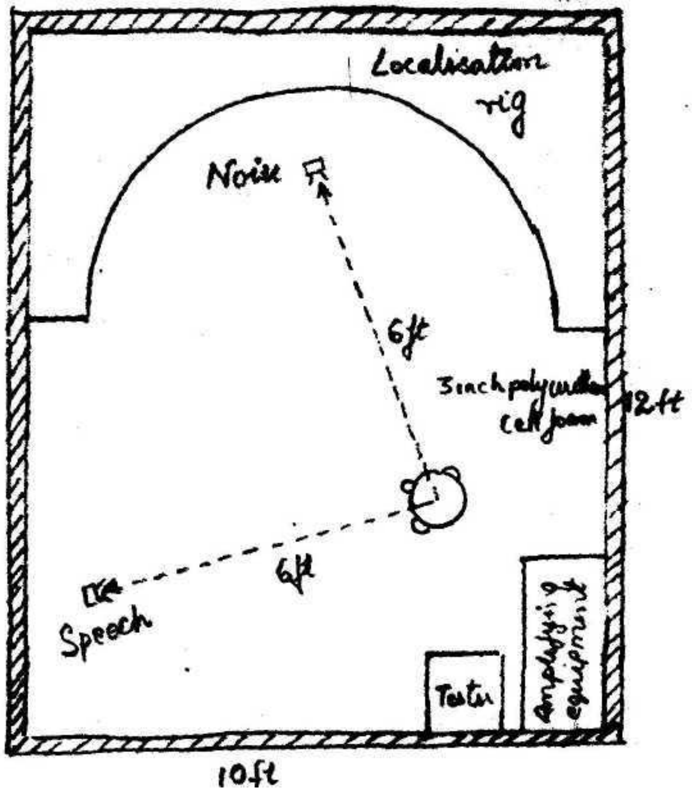
Figure: 10



The purpose of the directional hearing test was to ascertain the advantages in localising in the horizontal plane, if any, of binaural as opppsed to monaural listening as made available by hearing aid use. A semicircular localisation rig having a radius of 4 feet and a height of five feet was constructed. The flgure 11 shows the localisation rig and the placement of the subject in the rig. The stimulus material used for this test was recorded speech.

PHYSICAL ARRANGEMENT FOR LOCALISATION TEST

Figure:11



Results for binaural advantages in hearing of speech revealed that for normally - hearing people and for both the conductive and the sensorineural group hearing aids, whether of the ear-level or bodywom types, were significantly superior to monaural hearing aids in terms of speech discrimination at all S/N ratios employed.

Results for binauaal advantages in localisation of speech showed that binaural hearing aids, whether of the ear-level or body worn type, were far superior to monaural hearing aids. This was true with both normally hearing subjects and with subjects with symmetrical or asymmetrical bilaterial hearing impairment.

Thus, the clinical technique developed by Markides (1977) determines who can experience binaural advantages and hence who can benefit from binaural amplification.

Sterns (1982) indicates that there are many alter native methods existing for fitting hearing aids, some having more value than the others. He believes that both qualitative and quantitave results are important and over the years has found the testing of word discrimination in noise to be among the most effective.The procedure, according to him, consists of placing the subject in a sound field with both noise (cocktail party, speech habble or other simulated "real world" noise conditions) with PB words emanating from the same speaker. (Typically +5dB S/N or + lOdB S/N if severe understanding problems are encountered). An individual first should be checked unaided at 65dB SPL 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 such as the addition of more high frequencies or movement of a break frequencies, with the goal in mind of achieving a 75% or 100% or more improvement in speech understanding (example Speech) Discrimination score increases from 30% to 70% or 45% to 85%).

He adds that before any sound field testing begins, determine if the user is comfortable, with the aids, does not feel stuffy, has a fairly 'natural' voice and if the gain power levels in the aids are adequate for good balance.

If only one aid is being fit, the question of hearing balance should be posed to determine if the individual can tell in which ear sounds are being heard. Finally, a check of binaural performance will determine overall speech understanding.

He also points out that, however, 'real world' conditions can alter aid response settings determined as optimum for speech understanding during testing. Therefore when the patient is rechecked in one or two weeks, questions should be posed carefully to elicit information regarding stereo balance, loudness of wound, men's versus women's voices, music appreciation, directionability of the sounds and overall comfort and naturalness of the individual's voice. He recommends checking the individual once or twice after the initial fitting followed by a 3 - month check and aid readjustment.

Giving reports of seven casehistories representative of both monaural and binaural hearing aid fittings, he points out that attention has been given to achieving best speech understanding and also directionability, comfort and music appreciation*

Briskey and Core (1983) used a questionnaire survey to determine the consumer evaluation of Binaural hearing aids. Information elicited included prior awareness of of binaural hearing aids, wearers initial reaction, adjustment period, hours of use and client rating of binaural performance in various listening situations. The survey reflects the practical application of amplification in real - life situations through a direct application by the person using the aids.

Thus in the above study, a subjective method has been used to determine as to who can benefit from amplification. Here each individual fitted with a binaural hearing aids has been given the opportunity to decide whether he is a candidate for binaural amplification or not.

One of criteria, pointed out earlier, for determination of 'candidate' for binaural amplification is that binaural scores should be superior to monaural scores. This implies that individual must have binaural advantages.

Valente (1983) reports of binaural advantages revealed by 'objective' research. One of them is binaural summation at threshold. In this, he points out that one of the criticism of research on binaural amplification (for that matter all research rising speech as stimulus) has been that magnitude of improvement revealed binaurally is small relative to the test retest variability of the test measurement. There is much truth to this criticism. Test - retest variability of pure tones, however, is typically much smaller than that of speech. Therefore, an improvement revealed actilizing puretones instead of speech may be viewed as a 'real' improvement and not subjected to the criticism stated above. In short, he opines that pure tones are a more valid stimuli than speech in assessing this binaural advantage (binaural summation at threshold). Considering the 'improved localization in the horizontal plane', he points out that several investigation have suggested that the thurst of clinical evaluation of binaural amplification be toward illustrating binaural advantages of understanding speech in noise or quiet.

Valente (1983) gives a number of ways for the cliniciane tr investigate the binaural advantage of'binaural squelch and head shadow/intelligibility in noise' (1) Compare binaural aided listening to the optimal monaural aided listening situation. This would occur when the primary signal (usually speech) arrives to the aided ear from a loudspeaker situated on the side of the listener's head where the aid is placed. For example, if the aid were placed on the listener's right ear during the monaural evaluation, then the optimal monaural situation wouldoccur when the loudspeaker was somewhere (30^0 - to 90^0 azimuth) on the right-side of the head. Thus, the difference between the bi naural

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score and the optimal monaural score would be the binaural squelch effect. Also the monaural score has sometimes been referred to as the 'near ear' (NE) score.

(2) The second procedure is an indirect one. Indirectly, the binaural advantage can be determind by finding the optimal monaural aided score (NE) and then determining the least favourable monaural aided score. The latter will occur when the hearing aid is placed on the ear that is in the 'shadow of the head' and furthest away from the wanted signal. For example, if the aid were placed on the left ear and the signal arrived from a loudspeaker adjacent to the right side of the head, this would result in the least favourable monaural listening situation. This least favora-ble monaural score also has been referred to as the 'far ear' (FE) score. The difference between the optimal monaural score (NE) and far ear (FE) score has been labelled as the Head shadow effect (HSE) for obvious reasons.

(3) A third manner would be to look at the binaural score and compare it to the manaural near ear and monaural far ear scores that is, evaluate the binaural advantages in comparison to the least monaural listening, situations (binaural squelch), as well as the least favourable monaural listening situation (HSE). He feels that, it is first as valid to evaluate the situation that will create the smallest binaural advantage that is, to look at the range of binaural advantage and not

simply the least or more favourable binaural advantage.

The magnitude of squelch and head shadow effect has been investigated by many researchers in the past (Belzile and Markle, 1959; Carhart, 1965; Causey and Bender, 1980; Coxet al 1981; Dirks and Wilson 1969; Hedgecock and Sheets, 1959; Jerger et al 1961; Lewis and Green, 1962, Luterman, 1969; Mackeith and Coles, 1971; Mackides, 1980; Markle and Aber, 1958; Moncur and Dirks, 1967; Nabelick and Pickett, 1974; Nordlund and Fritzell, 1963; Olsen and Carhart, 1967; Ross 1980; Wright and Carhart, 1970; Yonovltz et al; 1979; Zelnick,1970), (referred by valente,(1983)). The table 22 summarise selected studies investigating binaural gain (in dB) in comparison to near and far ear listening.

Table 22: Summary of selected studies investigating Binaural Gain (in dB) in comparison to Near and Far ear listening (given by Valente, 1983).

Authors	Near Ear	Far Ear	Signal/Competition
Dirks and Wilson (1969)	2.7-4.2	7.7-11.2	SRT;SSI/Speech noise, connected Discourse.
Cox Di, Chicchis and Mark (1981)	1.9-5.3	-	NU-6/SixTalku Babble
Maskides (1980)	2.0-3.0	6.0-7.0	PB/Speech Noise
Mackeith and Coles (1971)	1.1-4.0	1.0-8.7	PB/Speech Noise

Laterman (1969)	3.5-4.1	-	connected disc and 1000 Hz.
Wright and Carhart (1960)	2.0	6.0	Spondee/Saw Today Noise.
Nabelek and Pickett (1974)	3.0-5.0	—	MRT/Babble; Cl

A cursory examination of the data in table 22, reported in decibels of improvement, reveals a range of 1.1 to 5.3 dB for the squelch effect (NE) and a range of 1.0 to 11.2 dB for the binaural advantage nor monaural far ear (FE) listening (Valente, 1983).

A cursory examination at the signal/competition column reveals a variety of stimuli used by the investigators as signal and competition material.

Valente (1984) also outlines the several loudspeaker arrangements used by the investigators to illustrate the superiority of binaural amplification. Table 23 gives a summary of loudspeaker arrangements used by several investigators to determine the possible binaural advantage.

Table 23: Summary of Loudspeaker Arrangements used by several Investigators to Determine possible Binaural Advantage (Valente, 1984).

Arrangement	Author(s)
S = 0^0, N = 90^0 R+L	Ross (1980); Zelnick (1970)
S = 45^0; N = 45^0	Olsen and carhart (1967); Markides (1980); Carhart (1965); Markle and Aber (1958); Belzile and Markle (1950).
S . $0^{0;}$ N- 75^0 + 105^0	Cox et al (1981)
S = 0^0, N-45^0 R + L	Causey and Bender (1980); Zelnick (1970)
S = $0^{0;}$ N=60^0 R+L	Yonovitz et al (1979); Mueller et a (1981)
S + N = 45^0	Jerger, Carhart and Dirks (1961)
S = 0^0	Hedgecock and Sheets (1958)
S = 45^0	Luterman (1969)
S = 45^0 R + L; N=0^0	Moncur and Dirks (1967)
S + N = 0^0	Dirks and Wilson (1969)
S = 90^0; N = 0^0	Dirks and Wilson (1969); cox et al (1981)
S = 0^0; N = 90^0	Carhart (1965)
S = 0^0, 30^0, 60^0, 90^0, 135^0 or 180^0	Nordlund and Fritzell (1963)
8 loudspeakers in 45^0 increments.	Mackeith and Coles (1971)
S = 0^0, or 45^0 R or L; 90^0 R or L	Causey and Bender (1980)

S + N = 52^0	Core et al (1981)
S + N - 41^0	Core et al (1981)
S = 0^0, N=180^0	Core et al (1981)

A scan at the loudspeaker arrangements reveals that there has certainly not been lack of creativity in determining how to arrange loudspeakers in a small sound suite and from which loudspeaker (s) the signal and competition should be emitted.

Valante (1984) gives that reveal authors have used reports of questionnaires and surveys. thus from the sumary given by Valente,(1983) and Valente, (1984), a picture of the research available on procedures for determining binaural advantages can be obtained.

Valente (1983) considers that it should be the informed patient, selected by the clinician as a candidate for binaural amplification, who makes the final descion as to whether binaural amplification is to be worn for a trial period. But Schreurs and Olsen (1985) seem to have a different view point. They consider that, sincethere is no fool proof clinical method for assessing satisfaction from binaural versus monaural hearing aid use, a practical method could seem to be to advise the patient about the possibilities of a trial period comparison of monaural and binaural hearing aids. This will allow each person to arrive at his or her own decision based on everyday experiences with amplification, and to evaluate the advantages and disadvantages, of both monaural and binaural hearing aid use. The patient can then decide which arrangement is 'worth while' in terms of his or her experiences, needs and circumstances. In their study, thirty hearing imparied patients compared monaural and binaural hearing aid use for a period of 40 weeks. Results showed that more subjects thought binaural aid use was better than monaural hearing aid use was better than monaural hearing aid use in quiet listening, while a noisy environments they perferred monaural hearing aids.

Mercola and Mercola (1985) points out that in treating bilateral hearing losses with amplification, binaural candidacy, traditionally has been determined by an evaluation of monaural test data. TO a large extent this has been possible because binaural test procedures have not been advanced. He describes a simple test procedure from which one can determine the suitability of a binaural fitting regardless of the symmetry of hearing losses. The procedure is called 'The MeVcon method for Binaural MCL'. "The Mercon Method for Binaural MCL".

The procedure produces a balanced, binaurally fused signal that is perceived in the center of the head on the median plane. If the signals to each ear are perceived to have the same loudness, the fused signal will be located in the "Centre of the head.

The equipment required: It can be performed with any two - channel speech audiometer with independently adjustable attenuators.

The signal recommended for use with this procedure is speech, so that the binaural balance between the ears is obtained over the frequency range of speech. Any speech signal of sufficient duration, such as cold running speech will suffice.

Monawal MCLs lead to Binaural Balance: The first step in this procedure is to obtain monaural MCLs for each ear. Any MCL procedure can be used - that is, whatever is effective in arriving at the most comfortable listening level for speech. The next step, the binaural balance, is begun by applying the speech signal to the ear having the lower MCL at 3dB below the MCL for that ear and keeping it at that same level throughout the balancing process; The identical speech signal is then simulataneously applied to the opposite ear beginning at a level well below its MCL and increased gradually until the perceived speech signal is moved to the median plane. When the fused signal is heard in the median plane, a binaural balance is achieved. The relative intensity to each ear is thep maintained, and a binaural MCL is obtained by either raising or lowering both intensities slightly if necessary. The binaural MCL, therefore, is the individual intensities applied to each ear at the most conformable listening level. Because of the binaural summation effect, the binaural MCL is usually about 5 dB lower for each ear than the individual monaural MCLs. However, the true binaural MCL cannot be extrapolated from monaural MCL data.

The instructions to the patient for the balancing procedure are that he indicate clearly with his hand at which location he is perceiving the sound. If the sound is perceived at his left ear, for exapple, his hand would be at his left eye, and so forth. For simplicity, the diagram in figure 12 indicates five equally spaced positions. However, in actual practice,the perceived sound may be heard at any location between the two ears, depending on the relatives intensities of the two signals. Furthermore, the perceived sound will move in a continuous fashion if the signals presented are changed continuously.

The balanced condition is achieved when the sound is perceived at the median plane. They recommend that the opposite - ear signal be increased above or decreased below the level required for balance. This is to verify that the patient has understood all instructions for this procedure and that the true binaural balance is achieved, a producere much the same as verifying a threshold. This is illustrated

Figure : 12 Simplified Positions For Indicating Location Of Speech Signal

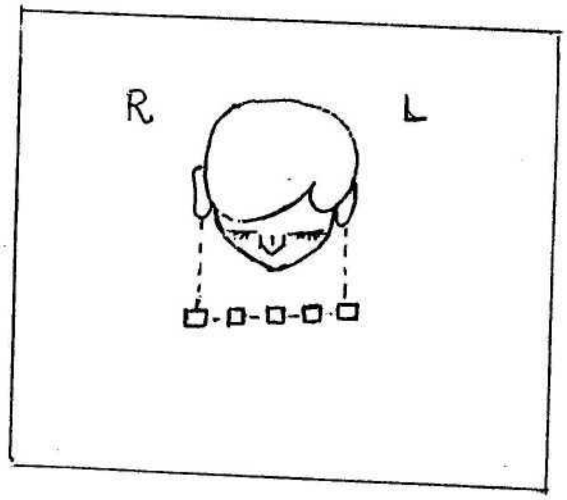
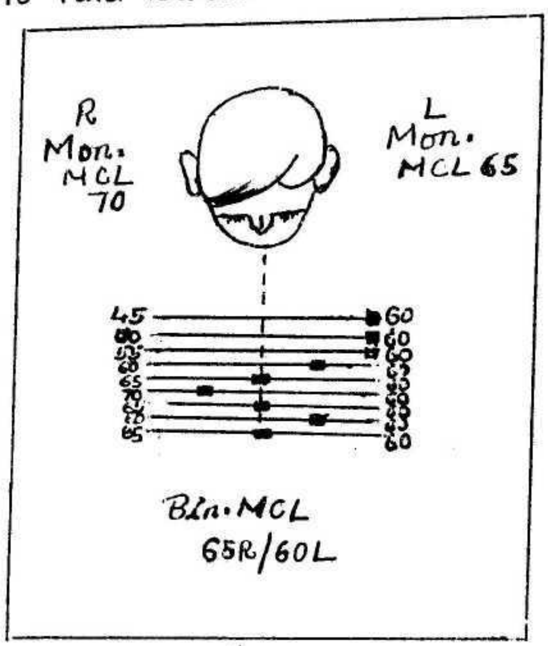


Figure : 13 The Indication Of The Location Of Speech Signal As Level In Right Ear is Changed To Find Binaural MCL.



in figure 13. It can be noted that the median plane is corssed from both directions and that the levels for balance are thus verified several times.

Determining Amplification Needs;- The binaural MCL consists of two levels, one for each ear, which when applied to the two ears create a balanced, binaurally fused signal in the center of the head and at the most comfortable listening level. Examination of each of these two component levels of this binaural MCL provides considerable Insight into the patient's amplification needs : (l) if the components of the binaural MCL both are substantially above normal, then binaural amplification is suggested and should be further evaluated. (2) If neither binaural MCL component is substantially above normal, then no amplification is required, (3) If only one binaural MCL component is above normal, then only one monaural amplification to that side is suggested (4) If binaural fusion cannot be obtained, then binaural amplification must be ruled out.

They say that the discussion regarding the use of binaural MCL to determine amplification needs is qualitative and requires further comments. Although no one disagrees with the notion that the patient must exhibit the need for amplification before it is provided to him the question arises as to what level of hearing loss constitutes sufficient need. They say that the question - "when is a loss a loss?" - Which has been asked over and over gain has not been debated by them. But, in their experience, MCL is a much more accurate predictor of hearing aid need than the traditionally used threshold measurements; far too often threshold measurements have been missleading.

They also state that though, binaural MCL components are both substantially above normal and hence binaural amplification is suggested, before recommending a binaural hearing aid system, however, it should be determined that the patient will infact hear best with such a system. In other words the patient should be further evaluated. To know which system is best requires comparative testing, both monaurally and binaurally.

TO demonstrate improvement, the most generally accepted measure of performance has been speech discrimination testing. Within the limitations of speech discrimination testing, the system providing the bestscore is considered the best system. They state that though small differences in discrimination scores are not statistically significant, but this should not discridit speech discrimination as a measure of performance improvement.

In using speech discrimination testing, it is recommended that the levels of speech to each ear be presented in accordance with the binaural MCL. This will result in a balanced signal and will allow both ears to participate in the discriminative process, which generally yields the best binaural discrimination score. For the monaural discriminated testing, the level of speech will simply be in accordancewith the monaural MCL for that ear, end this will generally produce the best monaural discrimination score. Comparisons can then be made easily. They also give a reminder that the benefits of binaural hearing are many and neither can be, nor should have to be, demonstrated in their test room for each patient. For example, if binaural fusion exists, then can assume that the patient can localize. The point is that if binaural discrimination scores are comparable to or better than monaural scores, within the accuracy of discrimination testing, then can say that because of all the added advantages of binaural hearing, maximum improvement will be achieved binaurally.

Lundeen (1988) talks of "moderate approach" to select binaural hearing aid candidates. He has used the audiogram to give a criteria for a binaural hearing aid candidate, but concludes that communication needs from case history and other sources must be primary considerations in evaluating candidates for binaural hearing aids.

Mueller (1988) comments on the approach used by Lundeen (1988). He states that user - acceptance data cited and the information about average speech spectrum make it difficult to view Lundeen's minimum hearing loss criterion as a moderate one .Similar concerns could be raised relative to Lundeen's recommendations for symmetry (speech - recognition scores within 20%) and maximum hearing loss (1000 to 2000 Hz average not exceeding 90 dB). He comments further saying that it seems obvious that establishing arbitrary numerical cut-off points for determining who can benefit from binaural hearing aids only hinders the effectiveness of the professional tasked with determining the optimum hearing aid fitting.

Finally Mueller (1988) says : "What would I consider moderate approach? I have yet to formulate one, perhaps because I do not see an immediate need to slow down the binaural pendulum, which is barely moving as it is. And there are other reasons. First, most persons with two hearing - imparied ears will benefit from two hearing aids. Therefore, the likelihood of making a mistake when fitting someone binaurally is not great. Second, many individualswho are intent on a monaural fitting will accept only one hearing aid (even when no cost is involved), and thus they will helpers us reduce our mistakes. Finally, some of those who are _not_ candidates for binaural hearing aids can be identified through careful assessment prior to the hearing aid fitting. Will unnecessary binaural fittings still occur? Certainly. But the consequences of this approach seem less severe that what coulc result from the decision made by a health insurance fund averaging two numbers."

In the evaluation of binaural amplification in pediatric and the geriatric population and consequently determining Who can benefit from binaural amplification, care has to be exercised.

It has been stated that children are unable to make judgements regarding monaural versus binaural hearing aid use, and the decision falls to someone else. The clinical evaluation prodedure is typically hardpressed to show superior performance with binaural hearing aid over a monaural hearing aid and this single fact has stoked the monaural - binaural contraversy for years.

Ross et al (1974) indicate that the development of maximum auditory skills is a primary goal for the education of young hearing impaired. A critical factor in achieving this goal is the selection of appropriate amplification. This requires that there is an urgent need to devise or improve criteria for comparing binaural and monaural amplification. They say that one commonly used criterion for comparison is the speech intelligibility score, but this can only be obtained when the subjects possess sufficient linguistic ability Nonlinguistic criteria, such as the ability of hearing impaired children to localise a sourceof sound, must therefore be used to compare the effectiveness of monaural and binaural hearing aids with prelingually deaferred young children (Ross et al, 1974).

Pollack (1975) states that although standardized tests in a sound proof suite are not representative of real life situations in which hearing aids are worn, they are the only measurements which can be reported at this time. In an Acoupedic Program, they measure speech reception threshold and discrimination monaurally and binaurally without lip reading cues. In cases of very young children, use pictures or toys to represent spondees, such as airplane, arm chair and so on. Many children can be tested for discrimination with the WIPI test or the PBK-50 list.

But it is not enough if the age of the child and type of test correlate, but the degree of impairment and the type of test should also correlate.

Madell (1978) points out that to have the child tested on a standard speech discrimination test such as CID W-22 should be the goal in speech audiometry. This is obviously not possible at the initial hearing aid evaluation procedures with very young, severally hearing impaired children. So he suggests that first, a speech awareness threshold should be obtained for every child with hearing aid being evaluated. He points that for many children, SRTs are possible even at the initial hearing evaluation. If a standard speeeh reception task is not possible, it may be possible to test using spondee pictures or objects. If not possible with standard procedures.

then discussion with parent or clinician, what words the child understands when using auditory stimuli without the use of visual clues, is required. It may be possible to obtain a speech threshold using other words the child knows, such as body parts, numbers or colours. If SRT is obtained, a speech discrimination test should be obtained. While the W-22 is a preferred test, it may be a long time before the child can use it. There are also other valuable techniques that can be used: The CID tests and WIPI Test by Ross and Lehrman (1971).

Grimer, Mueller, Sweeton (1979) - point out that WIPI is one of the most widely used speech discrimination tests for children, it is clear that this test is too difficult for many severally hearing impaired subjects. They point out that rather than abandoning the concept of speech discrimination testing for these patients, must continue to formulate yet easier speech discrimination tests. Possibilities would include a standardized spondee - discrimination test, a same-different test, and perhaps a speech discrimination test that has inter list equivalency for both auditory and visual (that is speech - reading) components. Given the major discrimination advantage of binaural amplification such as localization, elimination of the headshadow effect, and binaural squelch and the finding in their investigation that binaural speech discrimination scores are not poorer than monaural they conclude that binaural amplification is justified in majority of the cases. They also add that one must approach'every hearing impaired child as an individial with unique hearing status. Therefore, appropriate evaluation procedures including monaural versus binaural testing must be carried out prior to any hearing aid recommendation.

Just as the children are given special considerations while evaluating binaural amplficiation, in them and hence determining who can benefit from amplification, the elderly hearing impaired individuals at the otherextreme in the age scale too have to be given special considerations.

Aging produces deficits in pure-tone thresholds, the speech reception threshold and speech discrimination but not all losses can be corrected with a hearing aid. Binaural (stereophonic) devices are psychoacoustically superior to monaural devices; however behavioural and personality changes in the older patients create problems of adaptation to the binaural aid. These changes may also affect the fitting of an aid and the patients ability to learn to use it.

Frederikeen et al (1974) attempted binaural treatment of ear-level hearing aids in 172 patients with prubyacusis in the age range 70 to 80 years, selection being based on the patients motivation to carry through the binaural treatment, their hearing requirements, mental and physical state. They did a follow-up of 100 patients after a period of 1/2 - 2 years which revealed that only one-quarter used both hearing aids from morning till evening. Half of the patients used two hearing aids part of the day, while the remaining quarter-had stopped using binaural amplification, 2% gave up using binaural amplification, 2% gave up using hearing aids. They also obtained the reasons from the patients for their respective preferences.

Thus in the study by Frederiksen et al (1974), audiometric data and follow-up examination was used to determine who were the candidates using binaural amplification.

Overall, both subjective reports and experimental studies have been used as approaches in evaluating candidacy for binaural amplification.

* * * * * * * * * * * . 4

BINAURAL HEARING AID FITTINGS AND ITS EVEHTUAL

Binaural hearing aid Fittings. The bilaterally hearing impaired individual, having obtained a medical clearance turns towards the nomedical line of treatment to crectify his loss. In the rehabilitation process, with amplification, if he is a candidate for binaural amplification then precise binaural hearing aid fittings should be carried out.

This calls for a number of decisions. They include :

1. Determining whether one ear should be fitted first and then the other or simultaneous fitting of hearing aids to both ears. If one ear should be fitted first, a decision should be made as to which of the ears should be fitted first.
2. Ear mold type
3. Gain setting
4. Selection of SSPL - 90
5. Non-acceptance of the binaural hearing aids by binaural candidates.
6. Adjustment period and counselling.

1. Decision to fit one ear and then the other or both iimultaneously -

Stephens (1984) lists the factors which influence this decision. The following table (stores E) delineates the factors.

Factos in immediate/delayed binaural fitting decision	
Stores 6	Binaural immediately?
1 A 5.1	Previous wearable instrument
1 B .1	Psychological - borderline attitude
1 B .2	Socialogical - distance
1 C .2	Upperlimit function
1 C .3	Related aural pathology - temporary disorder.

He points that the first factor of relevance depends on whether the individual is an experienced hearing - aid user in which case once the decision to go to binaural fitting has been made, this should be done immediately. If the patient is a time user, however, particularly if some handling problems are anticipated, he suggests that a monaural fitting be made. A patient who has an uncertain attitude towards binaural fitting may be initially fitted with a single aid. Subsequently, when he realises the acoustic problems associ-ated with a monaural fitting, he may have a more positive attitude to a binaural approach. He adds that the same is true of those individuals who have some handling problems initially, and who might be deterred by having to cope with two aids at the outset. Further, patients with a temporary unilateral disorder, (such as otitis extrema) do come in this category. On the, other hand, he points out that whose who have to travel a long distance to seek help and who are unlikely to return for many subsequent visits should be fitted binaurally at the outset unless there is a strong reason not to do so.

In the decision as to which ear to fit, Stephens (1984) indicates a number of factors. He points out thatthe first factor to be considered is the patients auditory sensitivity. In bilateral losses, patients and audiologists usually favour the ear with the worse threshold unless factors such as a severely impaired discrimination ability or a markedly reduced DR in the impaired ear mitigate against it. The patient may prefer a particular ear and by accepting this preference his motivation can be maintained. In work or educational environments the individual may be placed in a particular position in a group so that one ear should be aided, or he might have the habit of using a telephone on one ear. This latter, in cases with mild to moderate hearing losses would lead to a fitting of the opposite ear, but in more severe losses to an aiding of to telephone-preferred ear together with the use of electro-magnetic coupler on the telephone. The next factor is upper limit deformities. In those patients with upper limit deformities following accidents cardio-vascular disease or Dupuytren's contractive may find it easier to handle an aid fitted to one ear rather than the other. Similarly unilateral otownoea or Tuliiophenomen will indicate that the opposite ear should be fitted. He points out that tinnitus may be a positive or a negative indicator to the ear to be fitted. Generally in cases with unilateral tinnitus and otherwise equal hearing loes, the ear with tinnitus should be fitted. The reason is that the amplification leads to suppression of the symptsom and he adds a word of caution saying that the hearing aid may sometimes accentuate the symptom.

2. Ear mould decision.

W.P. Steams (1982) states that the earmould, accdtical item in proper fittings, provides physical comfort and "naturalness" in the individuals voice. He recommends a positive venting PW - type canal and in many instances, such such as Ski - slopes losses, an " all- vent" with PW because the user's voice effects need to be minimized in the hearing process. Furthermore, this assists in optimum understanding in a noisy environment and hence increases user comfort.

3. Gain - setting

Domoracki, Berger and Millin (1982) in a comparison of monaural versus binaural gain settings made by the clients reveal that the differences in monaural - binaural gain settings made by clients appear to involve an interaction between degree of hearing loss, type of aid, procedural strategy and electroacoustic, characteristics parameters of the hearing aids. They conclude that although hearing aid users listen to speech will above theresholds, if a correction factor is to be used in presciptive hearing aid procedures, a subtraction of 2 or 3 dB of gain from the monaural prescription for binaural fittingsseem to be appropriate than alarger correction. They also add that Nonetheless, considerable individual variation in monaural binaural gain setting differences may be expected.

Berger (1988) uses similarity of audiometric data between ears as a criteria recommending binaural hearing aids. So his prescriptive procedure has certain rules, for determining binaural candidacy or for prescribing hearing aids. A gain-frequency response is prescribed on the basis of the HTL-in the better ear if there is a difference between ears. At this point, 3dB is substracted from the monaural maximum gain prescription, to account for the binaural effect. He also found that subtracting 3 dB from the monaural-gain presciption will approximate the functional gain with binaural users.

4. SSPL-90 selection

Briskey ()983) indicates that for a binaural fitting, the SSPL-90 of the two aids should be properly selected to prevent the sum of the outputs from being too loud for the client.

He points out that adjustment to amplification depends upon utilization of the difference information provided by the right ear advantage and appropriate selection of the output level for the two ears based on a binaural LDL (loudness discomfort level).

Considering binaural hearing, two signals are louder
a
than one. At threshold this summery effect may provide approximately 3dB, however, at suprathreshold levels the increase can be greater. Fitting binaurally, it takes less gain and less output to achieve asatisfactory listening level. "The SSPL 90 of the two aids should be properly selected to preventthe sum of the outputs from being too lound for the client." (Briskey 1983 Obtaining a binaural LDL will account for this summation effect as well as prevention improper balance in case one of the stapedies muscles is not functioning.

Briskey (1983) describes a procedure for obtaining binaural LDL. Then the binaural LDL should be retested, and the selection of aids should be according to the levels obtained. As a general rule, if reliable LDL cannot be obtained, the specialist should select two aids that give an HFAVG SSPL 90 3dB below the lower monaural LDL obtained.

The test procedures will provde the specialist with a single dedbel number level for ear which is used in selecting an appropriate hearing aid.

The final combination of any hearing aid selection and fitting is in the aided measurement. Thus, to vrify and validate a fitting of the hearing aid in cinjunction with the correct earmold, the hearing aid specialist should conduct unaided and aided measurements in the sound field as described by Briskey (1983).

Hawkins (1986) reports of two different views in selection of an approproate SSPL 90, available in literature. The first is that by Briskey alone, who recomm-ends binaural LDSs be obtained prior to the hearing aid fitting in order to select an appropriate SSPL 90. The other view is that two monaurally obtained LDLs are suffi-cient and that if the SSPL 90 is set separately to the LDLs for the indivudual ears, loudness discomfort will not result under binaural aided conditions.

He concludes that it is unclear examining literature whether the measurment of binaural LDLs for the purpose of SSPL 90 is necessary. So in his study he determined if whether there was sufficient binaural loudness summation in the LDL task to aquire the measurement of binaural LDLs in order to assure the avoidance of loudness discomfact for the binaural hearing aid user.

The results suggested that for the hearing imparired as a group, it not ncessary to measure binaural LDLs when selecting SSPL 90. The average amount of binaural summation is negligible. The results he says, do not justify a recommendation to make such measurements on all cases in the clinical practice. "However, if the option is to measure either two monaural LDLs or one binaural LDL for the selection of SSPL 90 for the binaural hearing aid user, the binaural LDL would appear to be the logical and preferable measurement."

Berger (1988) - "The SSPL - prescription portion of our method is the same for binaural and monaural fittings, because we have observed no differences with the output problems between binaural and monaural fittings. Recently, e perimental results have shown no need for the SSPL in binaural fittings to bedifferent from that of monaural fittings."

5 Non- acceptance of the binaural hearing aids by binaural candidates.

Mueller (1986) points out that there should be a fitting approach for the large percentage of binaural candidates who prefer to use one aid only:-

The simplest approach is to fit monaurally, so that he or she will be usually pleased with the decision. The second approach involves explaining the potential benefits of monaural - binaural amplification and to arrange for a binaural/monaural comparision during a 30 - day trial period. This trial is based on the assumption thatthe patient is more knowledge able than the professional about what is best for him. It is pointed out that this might be true, but that assumption appears inconsistent with treatment strategies for other health disorders.

The third approach is to inform the patient that his impariment dictates the use of two hearing aids and to proceed with a binaural fitting unless the patient objects strongly. He indicates that this approach is as 'The herd sell' but there is evidence to suggest that the strategy has merit.

6. Adjustment to amplification and counselling.

Briskey and 6ore (1983) indicate that a rapid adjustment, less than one month, can be considered an important criterion of a successful binaural fitting. In their report on the U.S. survey, they point out that 66% of their respondnets fall into this category, the persons who requiredmore than two months to adjust to the binaural fitting were experiencing various difficulties with such problems as balance, localisation, manipulation difficulty in in acrowd, and an uncomfortable feeling when wearing the aid.

Zelnick (1985) indicates that when an individual with a hearing impariment is fitted with a hearing aid, there is a period of adjustment in the recognition of the auditory stimuli presented to the ear. Further, it appears that thelonger an individual has suffered from a hearing problem without the benefit of amplification; the more difficult the adaptation to the hearing aid.

When a hearing aid is first fitted to a client, there will most likely exist a mismatch between the code of the 1/p to the recognition device andthe performance of this device. This mismatch will gradually decrease as a result of adaptation on the part of the hearing imparied individual (Barford, 1979; referred to by Zelnick, 1985). Zelnick (1985) also points out that since learned patterns of decoding the acoustic stimuli into speech perception has been through the use of two ears, the use of binaural hearing aids should make the adaption process much easier and shorter for the average presbyasis sclient. '

Briskey and Core (1983) observed that; a client who has been fitted binaurally should be monitored very carefully upto 30 days. If after that difficulty in adjusting continues, a careful refitting should be done to try to resolve the situation. They add that further counselling and direction; during the first month may resolve some of these problems before the adjustment period becomes excessive.

Counselling is an important aspect in the hearing aid fitting. Forquer (1987) points out that in counselling patients on whether they should use one or two hearing instruments they should be encouraged to do what is best for themselves.

The clients should be explained about the functioning of the ear and thatthe objective of the hearing aid fitting is to obtain not only significantly improved speech understanding under most environmental condition, but also better music appreciation, directionality of sounds (that is, stero effects) and comfort through reduced background noise and naturalness of the individuals voice.

Valente (1984) points out that he suspects that the key to any successful fitting, whether monaural or binaural, is to counsel the patientextensively concerning the realistic expectations of what one may experience with amplification.

The Final Hearing Recommendation

Finally, the amplification recommendation always must be made contingent upon clinical needs. The audiologist must ascertain how critical the demands are which are placed upon this person's hearing, what the acoustic environment is in which this person must listen, and the motivation of the client (Ross and Giolas, 1978; referred to by Chermak 1981).

Eventual use of a Binaural Fitting

Apart from the contraindications to the binaural amplification, a number of other audiological, psychological and social factors influents the eventual use of a binaural fitting Chung and Stephens (1986) delineate these different factors -

1. Seventy of hearing loss - The general conclusion is that the more severe the hearing loss for speech the more the patient will use the hearing aid (Stephens, 1977; Brooks, 1981) (referred to by Chung and Stephens, 1986). However, some studies showed no clear relationship (Jerger and Hayer, 1976; Kapteyn, 1977) (referred to by Chung and Stephens, 1986).

2. Type of hearing loss - patients with conductive disorders tended to showgreater hearing aid use, than those with sensoifineural type of loss (Haskins and Hardy, 1960; Stephens, 1977) (referred to by Chung and Stephens, 1986). Certain studies (Jordan et al, 1967; Bentzen et al, 1969 - referred to by Chung and Stephens, 1986) found that the nature of hearing loss did significantly affect binaural hearing aid use.

3. Age of patient - In nine published studies into hearing aid use, no relationship was found between amount of use and age of the users. In 5 studies a decline in hearing aid use was found with increasing age (Stephens 1977; Brooks, 1981) (referredto by Chung and Stephens, 1986).

4. Sex of patient - Kapteyn (1977) (referred to by Chung and Stephens, 1986) showed that the satisfaction with a hearing aid was a little higher in men than women for matched mean hearing loss and discrimination, but the mean age of his female sub-population was about 5 years higher than the man. Ewertson (1974) (referred to by Chung and Stephens, 1986) indicated that women tended to use their hearing aids more than men. Brooks (1981) (referred to by chung and Stephens, 1986) found no significant differences between the sexes and hearing aid use.

5. Provision of counselling (after-care) - They report that in 5 published studies into hearing aid use, a significantly greater use was observed in subjects receiving counselling than those who did not, especially in elderly subjects (Kopra, 1976y Surr, et al, 1978, Brooks, 1981; Brooks and Bulmer, 1981) (referred to by Chung and Stephens, 1986).

6. Psychosocial problems - They feel that there is little point in proceeding with the hearing aid selection process until the hearing imparied individual and family are positively motivated towards their use (Goffman, 1963; Freedman and Doob, 1968) (referred to by Chung and Stephens, 1986), especially when according to Bentzen (1980) (referred to by

Chung and Stephens, 1986) wearing two hearing aids implies 'double deafness'.

In short, in fitting binaural hearing aids and in the eventual use of the prescribed binaural hearing aid, a number of factors have to be considered.

SUMMARY AND CONCLUSION

A normally hearing individual, hearing with two ears (binaural hearing) experiences balanced hearing. The advantages of binaural hearing,due to the differences in the intensity, time and spectrum,include summration of accoustic energy enhanced speech inteligibility and improved localisation.

A hearing impaired individual cannot use the cues (differences in intensity, time and spectrum) and hence requires an aid external to his system. The hearing impaired individual seeks medical line of management initially to rectify his hearing loss. If permanent hearting impairment continues to exist following medical care, the first and most logical step in the aural rehabilitation process is a hearing aid evaluation (Tannahill, Walter and Smoski, 1985). For some individuals successful use of amplification resolves the communication handicap, however, for many others the acquisition of a hearing aid is the first step in along line of aural rehabilitation procedures (Tannahill, Walter and Smoski,1985).

The hearing impaired individual based on the number of ears involved can be classified as unilaterally hearing impaired or a bilaterally hearing impaired..

The aid, if presceibed, to a unilateral hearing impaired individuals is a monaural fitting. The amplification system or the hearing aid that can be provided to a bilaterally hearing impaired individual include one hearing aid delivering sound to one ear (monaural) one hearing aid delevering sound to both ears (pseudo binaural or Y-cold), or two hearing aids (binaural).

As mentioned earlier, binaural hearing has advantages. Wernick (1985) points out - "Thus the evidence is in. Poeple can hear better with two ears rather than one". This occurs in a normally hearing individual, who has a noramal auditory lay out.

With binaural amplification, a trial is made to restore balanced hearing for the bilateral hearing impaired individual.

Historically, manufacturers and dispensers of hearing aids have strongly advocated binaural fittings, while audio-logists are more reluctant to do so. (Pollack, 1975).

Ginaural amplification has been defined by Konkle and Schwartz,(1981)

True dichotic or stereophonic stimulation of each ear independently is binaural amplification".

The purpose of binaural amplification is to create a sound environment for the listener that is a faithful reproduction of the original acoustic event so that one can take advantage of the intensity, time and spectrum differences of the auditory signal at each ear. (Wright, 1959? referred to by Pollack 1975).

In binaural amplification, the system has two separate microphones, two amplifiers and two receivers; each set (microphone - amplifier - receiver) stimulating each ear independently. The type of hearing aids which can give binaural mode of stimulation are 2 body - level aids, 2 ear-level aids, 2 IROS aids and BiFROS aids.

A great deal of formal and informal research has been performed in an attempt to demonstrate the advantage of binaural amplification (Pollack, 1975), Investigations with babtfs and children done by investigators example - Watson and Tolan, 1949, referred to by Harris, 1975); Bender 1960) referred to byHarris, 1975; Bender and Wug (1960); Leuurfa and Green (1962); Ross (1969); Kuyper and deBoer (1969); Luterman (1970); Pollack (1975), Zelnick (1985) reveal that the paediatric population benefits from binaural amplification. But study by Rice (1963) does not indicate superiority of binaural amplification system over the other systems of amplification. Experimental studies and subjective reports have been obtained with adult hearing impaired individuals. The advantages reported include improved speech discrimination ability, easy of listening, better quality and enhanced localisation. Investigators, Dirks and Carhart (1962), Schraurs and Olsen (1985) indicate that binaural amplification is of limited benefit when speech occurs in the presence of background noise. Binaural amplification benefits have been demonstrated even in the geriatric population (Bentzen, 1968; Frederiksen et al (1974) But not all the elderly individuals cap take up binaural amplification. This may be because of the degeneration of the central acoustic tracts in presbycusis rather than the changes in the peripheral sense organs (example Hensen, 1973 and Jerger 1973; referred to by Frederiksen et al, 1974).

Though the advantages of binaural amplification has been demonstrated in the literature, it is essential to determine whether all candidates with bilateral hearing impairment can benefit from binaural amplification. This has led to the controversy of whether to fit or not to fit binauraly, individuals with asymmetrical hearing losses.

Pollack (1975) and Berger (1984) do not recommend fitting binaural aids for asymmetrical losses. But Byrne and Dermody (1974), Pollack (1975), Ross and Stephens (1986), Erdman and Sedge (1986) recommend binaural aid fittings for asymmetrical losses.

Valente (1984) giving a summary of suggestions appearing in the literature concerning who is a candidate for a binaural amplification points out that the determination of candidacy typically goes beyond looking at the audiogram and speech audiometric results. For example, It is better if a patient who has prior experience with amplification (monaural and especially binaural) is a better if a patient who has 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 in-experienced user of amplification' from a summary given by valente (1984) as to who is a candidate and who is not and from the factors given by chung and Stephens (1986) which contia indicate binaural amplification, it is possible to conclude that criteria for binaural candidature is highly idiosyncretic.

A glance at the criteria for binaural candidacy reveals that audiogram configuration speech audiometric tests, subjective reports including past experience with hearing aids, present experience with binaural hearing aids, adjustment ability, financial status; and objective clinical techniques showing the binaural advantages were the procedures used to delineate the binaural candidacy criteria.

A variety of procedures have been used by different investigators. Some have used audiogram configuration reports and clinical techniques demonstrating the binaural advantages to determine as to who can benefit from binaural amplification while some have used objective clinical techniques and subjective reports.

Heffler and Shultz (1964) list the several parameteys,that the clinical aperiemental literature reveal, which contribute to the design of an appropriate test. The include;

1) the presence of a competing noise
2) S/N which permits improvement due to the second ear to be measured.
3) elimination of alization and sidedness factor-
4) long-duration speech sinals with partial credit possible.

Kuyper and de Boer (1969) indicate that of the two tests; 1) cocktail party effect and 2) directional hearing can be used to demonstrate the superiorty of sterophonlc fitting of the hearing aids,but of the two directional hearing is a better tool.

Markides (1977) has used both free-field speech discrimination tests and directional hearing to demonstrate the binaural advantages in the hearing impaired individuals.

Valente (1983) and Valente (1984) list the different clinical techniques used by the different investlgatiors to demonstrate the superiority of binaural amplification and hence determine who is a candidate is for binaural amplification.

Mercola and Mercola (1985) have putforth a new procedure for determining binaural candidacy. It is called the 'Mercon method of Binaural MCL'.

But Schruers and Olsen (1985) have a different view point. They say that since there is no foolproof clinical method for assessing satisfaction from binaural versus monaural hearing aid use, a practical method could seem to be is to advise the patient about the possibilities of a trial period comparison of monaural and binaural hearing aids.

Hearing determined who is the candidate for binaural amplification, precise binaural hearing aid fittings have to be carried out.
This calls for deciding the following:-

1) To fit both ears simultaneously or to fit one initially and she other later and if one ear is to be fitted, which ear to fit.

2) Earmould
3) Gain setting
4) SSPL - 90
5) Considering binaural hearing aid candidates who do not want to use binaural hearing aids.

6) Adjustment period and counselling.

Finally, the amplification recommendation should always be made contingent upon the clinical needs. The audiologist must ascertain how critical the demands are which are placed upon this person's hearing, what the acoustic environment is in which the person must listen, and the motivation of the client (Ross and Giolas, 1978, referred to by Charmak, 1981).

Lastly, the eventual use of a binaural hearing fitting, depends upon contraindications of binaural amplification and a number of other audiological psychological and social factors (6hung and stephons, (1986)).

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