HEARING AID SELECTION PROCEDURES - A REVIEW

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To,

my parents and 'G.V.'
for their everlasting love
and understanding.

CERTIFICATE

This is to certify that the Independent Project entitled "Hearing Aid Selection Procedures - A Review" is the bonafide work in part fulfilment for First Year M.Sc., (Speech and Hearing) of the student with Register No.M8702.

Dr.N.Rathna
Director
All India Institute of
Speech and Hearing
Mysore - 570006

CERTIFICATE

This is to certify that the Independent Project entitled:"Hearing Aid Selection Procedure - A Review" has been prepared under my supervision and guidance.

GUIDE

DECLARATION

This Independent Project entitled "Hearing Aid Selection Procedure - A Review" is the result of my own study undertaken under the guidance of Dr.M.N.Vyasamurthy, Department of Audiology, All India Institute of speech and Hearing, Mysore and has not been submitted earlier at any university for any other Diploma or Degree.

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INTRODUCTION

Our life time obligation to nature is to protect one of the valuable gifts which has been provided to us. And, that is hearing. The effects of hearing loss is profound both in adults and children. In adults it would interfere with the normal interpersonal communication thus leading to other social and psychological problems in the individual. Problems of isolation, guilt etc. are the commonly associated symptoms, whereas in children it has an effect on the development of speech and language, a basic mode of communication.

The rehabilitation of the hard of hearing includes early identification through measurement and good medical care.

One major step in the rehabilitation of the hard of hearing is the fitting of an appropriate amplification device. Hearing aid is such an amplification device which has a primary role in aural rehabilitation. Appropriate choice of a hearing aid is essential to give an optimum benefit to the client, which is a primary goal in hearing aid selection procedure. The hearing aid selection procedure should also enable one to predict the utility of the aid in real life conditions.

Various hearing aid selection procedures have been putforth since the advent of a wearable hearing aid. These procedures are applied to both children and adults. However, some modifications may be necessary when it comesto the selection procedures of children.

What follows here is a review of various selection procedures. An attempt at classifying these procedures has bean made. The various procedures for hearing aid selection shall be considered under the following titles:

(i) Comparative/selective procedures

(ii) Prescriptive procedures

(iii)Objective procedures.

A chapter on "pre selection considerations" has been elucidated before going into the details of the actual selection procedures. The review has been concluded by taking a brief look into the current trends in hearing aid selection procedures.

PRE SELECTION CONSIDERATIONS

Before prescribing an appropriate hearing aid to the client, some factors have to be considered. They are:

(A) Hearing Aid Candidacy: Non-audiological facts are to be considered to say whether or not an individual is a suitable candidate for a hearing aid.

Non-audioloaical facts: Hearing loss by itself cannot determine candidacy for amplification (schmits,1980). A hearing impaired individual becomes a prospective hearing aid candidate, if he himself evaluates objectively the benefits of amplification in communicative situations. so questions like the following which have to be asked to the candidate becomes quite important:

i) Is there a need for him in his social environment to hear and understand speech?

ii) Does he have serious communicative problems?

iii) Is he aware of the advantages and limitations of amplification?

iv) Is he financially in a position to procure an aid?

v) Does he have physical limitations that could make him difficult to operate the hearing aid?

vi) What is his attitude towards the hearing aid? etc.

Even if these are answered truthfully by the candidate who is willing to go in for amplification, it does not necessarily mean that he could be straight away selected as a prospective candidate.

Audiological facts: Audiological facts should also be considered which are indespensable. The two kinds of audiological facts which have to considered here are:

(i) Type of loss: According to Ross (1967) the hearing aid should approximately match the clients specific ear status, degree and configuration of the hearing loss However, there have been controversy over the type of hearing loss and candidacy.)

Until rather recently it was felt that only those patients with pure conductive hearing impairment could benefit from wearable amplification. Individuals with sensori-neural hearing losses were cautioned against wearing an aid and were told that amplification would not be helpful. Vyasamurthy (1983) also supports this view and states "Cases with mild hearing loss, unilateral senaori-neural loss (SN) (moderate, severe or profound) and unilateral or bilateral high frequency SN loss cases are not to be prescribed heating aids".)

According to Rosenberg (1967) the improvements in hearing aids, however, in conjunction with the achievement in testing techniques, has largely over come many of the previous problems that were encountered in using a hearing aid. Pascoe (1985) considers a SN hearing loss which cannot be aided as a 'false notion'. However, hearing aid candidacy is definitely contraindicated in individuals who have tolerance problem and with very poor discrimination.

(ii) Degree of loss: Apart from the type of hearing loss, even degree of hearing loss should be considered. The most frequently quoted audiometric criterion in the older literature was 30dB (ASA,1951) or more hearing threshold level (HTL) in the better ear. Berger and Millin (1971) consider severe and profound loss individuals as doubtful cases who would be benefitted from amplification. Profound losses, when acquired late in life, can be devastating to an individual's morale; hearing aids may easily be rejected because they are not able to restore tonal quality in those cases. Nevertheless, if an aid can facilitate audiovisual communication and can help an individual to monitor his own voice, it fulfills a useful purpose. However, according to schmitz (1980) candidacy is more properly determined by patient's communicative difficulty, not by an average hearing loss expressed in dB HL.

Strong criticism has bean seen for tables/charts which estimate usefulness of a hearing aid according to the degree of hearing loss. For example, the one given by Berger and Millin (1971). The following is the table for estimation of usefulness of a hearing aid according to the degree of hearing loss and motivation (Berger aad Millin, 1971).

TABLE-I

High frequency average in dB HL (1,2,4KHz)	Motivation	
	Positive	Negative
(1)	(2)	(3)
Mild loss		
25dB	Aid is seldom useful: can be used in special situations.	Aid is not needed and will not be accepted.
35 dB	Aid can be useful and may be accepted. Needs realistic expectations.	Aid could be useful but wil1 not be tolerated.
Moderate loss		
45dB	Aid ia accepted and will be helpful.	Should use aid, but may still refuse it.
55dB	Aid is indespensable and is used willingly and effectively.	Aid is clearly needed, but needs support to accept and try it.

(1)	(2)	(3)
Severe loss		
65dB	Uses aid sucesssfully, is aware of limits and adjusts accordingly.	Cannot function without it unleaa friends speak louder. If older, may still reject it.
75 dB	Cannot function without it and uses it conatantly.	Cannot function without it, but ia not aatlafied and uaea it aparingly.
Profound loss		
85dB	Is extremely akillful in use of auditory and viaual clues. Does wall except under adverae acouatical conditions.	Avoids liatening and reaorta to bluffing when meaaaage ia not clear. Attempts to control conversation by talking.
95dB	Primary source of information ia viaual, bat acouatic clues facilitate understanding. Speech rhythm and intonation are maintained through auditory feedback.	Not likely to uae aid. Depends entirely on viaual contact and is often unable to converae except through written or manual language.

Such a classification suffers from two weakness according to Paacoe (1985). First, the use of hearing loss categories such as mild or moderate does not always repreaent the status of boderline cases. This problem can be avoided if we assume that the center of a range ia the most representative of each category and that other levels fall on a continuum.

Second, the use of categories bated on speech recaption thresholds and the commonly used threshold averages for 500, 1000 and 2000Hz tend to underestimate the importance of high frequency hearing loss. A more useful average is based on the 1000, 2000 and 4000Hz thresholds since these frequencies contain the more important regions of the speech spectrum as described by Articulation Index (ANSI, 1969).

B. Otologic Examination:

Once it has been determined that a client is a prospective hearing aid candidate, then it is important to ensure that he has received an otologic examination no more than a few months prior to the hearing aid selection. This may be due to many reasons:

1. First of all, the client could have had a medical condition which requires treatment, either for health reasons or for the possible alleviation of the hearing loss. The recommendation of a hearing aid for such a client, without informing him of the possible alternatives, is neither ethically defensible nor in the client's best interest.
2. Secondly, sometimes a medically reversible condition can coexist with a medically irreversible condition; the amplification needs of a client may be different depend-

ing upon whether treatment is or is not instituted.

3. Last but not the least, an otologicn examination becomes important especially if wax is present in the ear. This could hinder the clinician's work while taking ear impression for the ear mold. The soft ear impression material will either flow around the cerumen or push it further back into the ear canal. In either case, the result is likely to be an ill fitting ear mold and acoustic feedback.

One could consider these factors as simple and mundane* but these often preclude the effective use of amplification.

C. Earmolds:

According to Lybarger (1978) the total performance of a hearing aid is determined by the interaction of the microphone* amplifier and the earphone-earmold characteristics modified by the acoustical properties of the body, head and ear canal.

It has been well documented that the acoustic response of hearing aid can be modified by altering the coupling system. Factors such as length, size and depth of earmold, tip, venting and acoustic leakage have been shown to influence the acoustic output of a hearing aid. when molds do not fit well, an acoustic squeal occurs at lower gain levels than would otherwise occur. This happens often in stock molds, Ross (1978) suggests fabrication of custom earmold for the client who undergoes hearing aid evaluation. This can be accomplished by scheduling hearing aid evaluations in two stages; one for the audiological evaluation and taking the ear impression and other, for the hearing aid evaluation itself, after a week or so. Konkle and Bess (1974) suggests that stock molds should be used whan no other alternative is possible. The greatest single advantage offered by the custom ear moid is the elimination of acoustic feedback when moderate or high gain level instruments are evaluated. Another clinical advantage of custom ear mold is that it can be easily modified through controlled venting for the purpose of low–frequency leakage or the release of excessive pressure. However, ia some cases, venting can also introduce unwanted resonances which may prove uncomfortable. Apart from these acoustical factors of the ear mold which could affect the hearing aid performance,physical factors could also contribute to the performance. Physical discomfort can be produced by pressure against either the canal or the pinna. Often such pressure is causal by improper tubing length. A short tube can cause pain either in the canal or in the top of the concha. Cutting the tubing too long tends to lift the

Behind-the-ear (B.T.E*) away from the ear and cause a sensation of loossness. Earmold edges and ridges can be a painful source of irritation and injection. (Pascoe 1985, page 945) suggests "The results of all modifications, either in the acoustical or the physical elements of the aid and earmold combination, should be investigated either with probe microphone or functional gain measurements. Ear mold design and its adjustments must be seen as inseparable elements in the total selection of hearing aids".

D. Binaural vs. Monoaural amplification:

Here the task of the clinician becomes to choose a mode of amplification. That is binaural amplification or a monoaural amplification. The use of a binaural hearing aid is strongly recommended whenever possible. Ross(1978). This is based on binaural assumption. The assumption is that hearing is at its best when it provides sufficient directional clues to allow the selection of one stimulus among others (Hirsh, 1950).

So it appears that the main function of binaural hearing is spatial separation of auditory images (Vyasamurthy, 1983). However a criticism may be encountered when binaural amplification la suggested. The view that binaural stimulation leads to binaural hearing ia held by many researchers* which often is quite time. It ia seen in many cases where people who have bilateral hearing loss do not have equivalent thresholds in the two ears, without knowing whet the thresholds for the two ears are, it would be very difficult to adjust the gain or make other electroacoustical adjustments in the two hearing aids. Especially in cases of children where accurate thresholds are difficult to establish, it could be quite detrimental to prescribe a binaural hearing aid if the child has asynmetrical thresholds. Ross (1967) prescribes a psuedo binaural aid for such children and says that this would be a leas detrimental approach. In these cases a hearing aid could use'Y' or 'V' cords.

If binaurility cannot be achieved due to the extreme deficiency of one ear, a single aid should be fitted. The question now would be regarding the ear to be aided - the better ear or the worse one? 'It is often stated that the ear with the better speech discrimination and wide dynamic range should be aided, unless it is good enough to function without an aid. But in some cases poor discrimination that we measure appears to be the result of an altered perception. This may be due to the dominance of the better ear over the poorer ear (Pascoe, 1985). When amplification is provided to the poorer ear, it can add significant information to the unaided reception of the better ear and the result can be surprisingly good (Pascoe, 1985). According to Ross (1967) if ear difference in acuity $\geq$ 20dB with loss in the better ear is equal to 60dB approximately, binaural amplification ia not useful. In these cases poorer ear is not suitable for ear level amplification while the better ear is. Ross (1973 P.525) reports that,when not contraindicated by a narrow dynamic range or poor speech discrimination, it is advisable to fit the poorer ear in instances when the HTL in the better ear is not greater than 30 or 40dB (ANSI, 1969)". When both ears are similar in terms of degree of loss, dynamic range and speech discrimination scores, than a comparison of the pure tone threshold configurations of the two ears can assist in determining which one ia the moat suitable for amplification. The ear with the flattest configuration is ordinarily selected (Miller, 1967).

There are a number of instances when it is not possible to Choose between the ears because cf similarities in all measured auditory dimenaions. In these eases, it is advisable to make an earmold for each ear and suggest that the client rotate use of the aid between the two ears. After such a trial, the client will frequently express a preference for one ear. The non—preferred ear should still be used on occasion in the event of temporary incapacity in the preferred ear, such as an ear infection or abrasions due to an ill fitting ear mold, and in preparation for possible binaural amplification in future.

E. Type of Hearing Aid:

There is a wide variety of choice of hearing aid type which is available to the client, and has to be described to the client before he makes a choice. The available types are body level hearing aids, eye glass aids, behind-the-ear (BTE) aids, all-in-the-ear aids (ITE), contralateral routing of signal (CROS)aids, bone conduction aids etc. A clear cut need for powerful pocket aids is with profound, mixed type losses. Individuals who have moderate sensory neural losses in addition to significant conductive impairments (eg. from mastoidectomy) often require amplified levels up to the 130 to 140dB sound pressure level (SPL) range.

Many small children are also better fitted with body aids (i) because the increased distance between microphone and earphone tends to reduce acoustic feedback problems and (ii) because of easier handling of the parent and teacher.

Eyeglass aids were quite popular during 1950's and 1960's but their sales have gradually dropped. According to Paacoe (1985) one reason given for this is that people prefer the versatility of separating their eye - glasses from the hearing aid so that one can be used without the other. However, some of them who use this aid do find it comfortable and efficient. Hence this should not be forgotten while discussing various alternatives. The varioua alternatives are:

a) Behind-the-ear (BTE)aids: BTE aids have became quite popular off late. This is because they are highly adjustable due to:

(i) their electronic controla, and circuits and

(ii) the acouatic veraatility offered by tubing ear mold modifications.

In addition, due to ita small size: it haa gained a great cosmetic value too.

b) All-in-the-ear (ITE) aids: ITE aids be they modular or custom made, are rapidly approaching "most used* status (Mahon, 1982). They are undoubtedly easier to insert in the ear, in comparison to either the BTE or the eye glass aids, but they are not necessarily easier to adjust to, particularly for the elderly. ITE are not less visible than the BTE units but they often appear ao to the prospective buyer. Their microphone and receiver positions are more efficient in the recaption and delivery of sound. However, they increase the probability of acoustic feed-back.

c) <u>Canal aids:</u> The new 'canal' aids are least visible type. It is well received by the public however more experience is needed to better evaluate their efficiency.

d) <u>Contralateral routing of signals (CROS) aids and its modifications:</u> CROS aids and its variations like BICROS, POWER CROS etc. should also be considered before selecting an aid. The advent of wireless CROS aids have made then even more attractive for those cases in which one ear is too poor to be aided. One of their greatest advantages is the possibility of keeping the ear canal open while avoiding acoustic feedback complications. Depending upon the degree of hearing in the better ear, a decision must be made between the CROS and the BICROS types. If the better ear can function reasonably well without amplification, the single CROS is indicated. If same gain is needed for the ear to be used, then the BICROS aid should be selected. The POWER CEOS is simply a pair of CROS units that can be used When extremely high outputs are needed without resorting to pocket aid. This combination avoids feedback and keeps the microphone on the head.

The various kinds of bone conduction aids like the pocket type, eye glass type, BEE type. are very limited in use. Unless the bone conduction thresholds are no worse than mildly depressed, it is unlikely that the power of a bone-conduction aid will be sufficient to provide satisfactory amplification of speech. Nevertheless these aids are used in cases in which the ear canal must be left open for medical reasons. Bone conduction aids may be indespensable for same individuals who have no piana or suffer from atresia of the ear canal as seen in Treacher Collin's syndrome.

F. Choice of circuit feature:

Here, before making a choice, the clinician should be thoroughly aware of the circuit features of the hearing aid.

First of all to look at the adjustable maximum power output (MPO) of the hearing aid. The aelection of MPO level is related to two objectives:

i) The need to limit the aids output to levels that do not cause discomfort or auditory damage to the user and

ii) The desire to avoid distortion caused by peak clipping at expected uae levels. If possible, aids should be chosen that include variable MPO adjustment posts; this would fulfill the above mentioned objective.

Secondly, the choice between linear amplification with peak clipping saturation and the use of compression circuits is dependent on the auditory dynamic range of the prospective user. In general, it would be better if all hearing aids included limiting compression. However, if the listener's discomfort threshold is atleast 25dB above his comfort range compression is not required. When the difference between comfort and discomfort levels is less than20dB, compression should be strongly considered, and when the difference is less than 15dB compression is mandatory.

Another aspect which we have to look for is input versus output compression. However,it has not been clearly resolved as far as choice of these are concerned. The choice is related to whether it is better (i) to let the listener Change the maximum output of his aid when he changes the gain setting using an input controlled circuit; or (ii) to pre-determine an unchanging maximum output level using the output controlled system. As Pascoe (l985,p.94O) puts it, " An input-controlled system added to a variable MPO is probably the better choice, but there is no research evidence to support this opinion".

Yet another issue which has been thoroughly investigated is regarding microphones. That is, which microphones are more preferable, directional or omnidirectional. Listener's tend to prefer aids with directional microphones probably because of improved listening in noise (Nielsen, 1973). This is a comparison that requires the use of competing signals from separate speakers Which must be confined in noisy environments.

G. Selective Amplification:

Another consideration for the clinician is the frequency response of the aids to be tested. If the audiologist selects a number of hearing aids with widely divergent responses, then the results of the evaluation may reflect either these divergent responses or other electroacoustic difference between the aids.

The concept of "selective amplification" that is, tailoring the frequency response curve of a hearing aid conformance with the client's audiogram has been with us since the early days of vaccum tube hearing aids. A lot of research has been done to prove the importance of this while others also contradict. Hence, it would be advisable for the clinician to be aware of the various views on this issue.

Although preselection considerations for adults and children are almost the same, some additional factors should be considered when it comes to children.

H. Preselection considerations in children:

In the case of children, three factors have to be considered before prescribing a hearing aid. They are:

a) Accrate diagnosis: The accurate diagnosis of a hearing impaired child is an obvious preliminary to recommending a hearing aid. The diagnosis should tell us regarding the type, severity and configuration of the hearing loss.

The advent of physiological measures like evoked potential audiometry, reflexometry etc., it has given a new trust towards accurate diagnosis. However we should not underestimate the value of information obtained through behavioural techniques. According to Ross and Tomassetti (1980) regardless of the evaluation technique employed, rarely is an accurate diagnostic picture complete before the ages of two or three or well into the maximum readiness period for speech and language development. Therefore, the audiologist is usually in a position in which he must either recommend a hearing aid on the basis of incomplete information or risk losing some very valuable time while he establishes precise diagnostics and threshold measurements. In the initial stages, a general approach is to assume the child's hearing acuity is approximately 10-15dB better than demonstrated by his minimal response levels in conditioned orienting or play response procedures. This approach which may occasionally underestimate the degree of hearing loss, will minimize the danger of over amplification and subsequent rejection on part of the child. It makes therapeutic sense to require bearing aide for all hearing impaired children at the earliest age possible. One important thing we should remember heze is not to fit the child with a hearing aid without otologic examination and clearance.

b) Physical characteristics: We should consider the physical aspect of the hearing aid when the child uses it. The physical dimensions of hearing aid should be appropriate to a child size user. External controls should be clearly labeled so that parents and other managing adults may have reference points when monitoring their child's amplification. However, too many controls and points may also confuse the case and parents.

The interval or circuit noise at "use" gain should permit at least a 30dB S/N ratio at normal input levels. If this is not achieved a hearing aid is to be rejected. A total distortion of 10% or more also excludes a hearing aid from further consideration. Some clinicians prefer post auricular hearing aids for Children because of various reasons. These include more flexebility and power, frequency response range etc. However, it is preferable to use body level aids initially for children under three or four years of age. This is due to easy manipulation and monitoring of controls of the hearing aid and also it requires less ear mold maintenance. As far as binaural to monoaural fittings are concerned in children, most often binaural hearing aids the preferred over monoaural aids. This is mainly due to two reasons:

i) Most of the children have eventually been found to have bilateral, fairly symmetrical losses with the ears rarely differing by more than 10 to 15dB at specific frequencies. Therefore, with a moderate degree of assurance, both aids can be equally adjusted, equally in terms of gain and output to the requirement of the better ear.

ii) Parents are much more receptive to the concept of binaural amplification when the child is first being fitted with hearing aids. However, this might not be true in all cases. Financial constraints have to be also looked upon before prescribing a binaural aid.

c) <u>Electroacouatic rationals</u>: The primary goal of amplification is to provide the child with the maximum auditory information consistent with his hearing loss. The interest thus becomes providing maximum acoustic energy in the speech range in as many situations as possible without approaching or exceeding the level at which the reception of speech is uncomfortable.

To make a hearing aid evaluation proceed successfully, one must recognise and incorporate the acoustics of speech as a basis for our selection considerations (Ling 1978; Boothroyd, 1978). An electroacouatic approach towards the selection of a hearing aid can be applied to hearing impaired individuals regardless of age, but it is particularly appropriate for young children with limited verbal skills.

A careful consideration of the factors discussed above would form a sound foundation for hearing aid selection and prescription.

The selective procedure which is also called as comparitive procedure by Carhart (1946) is baaed on speech audiometry for hearing aid selection. The word 'selective here means that, from the already preselected hearing aida (may be three to four hearing aids), we select the appropriate one using the following four criteria: The aid selected should provide -

1. The greatest improvement in speech reception threshold (SRT).
2. The beat discrimination score.
3. The widest dynamic,range, and
4. A satisfactory speech discrimination score even in the presence of noise.

In short, four dimensions of hearing aid performance are explored: Effective gains tolerance limit, efficiency in noise and word discrimination.

Following are the steps involved in the procedure. (Boss, 1978).

Step one: The subject's unaided sound field SRT, tolerance limit and discrimination score (PB-50 at 25dB SL) are measured. These score serve as the reference for comparison with aided score.

Step two: Gain control of the first instrument ia adjusted until the subject reports that a 40dB HTL speech signal is at his maximum comfortable level (MCL). An aided SRT and threshold of discomfort (TD) is measured then.

Step three: The hearing aid is then set on maximum gain and aided SRT and TD are again measured.

Step four: The gain control ia then adjusted to permit the subject to reach an MCL with a 5OdB HTL input speech signal. Two signal-to-noise (S/N) ratio are obtained, one with white noise and other with sawtooth noise. The intensity of the noise is alternately increased and decreased until a point where the subject can barely repeat several test words. The difference between the speech and the noise levels at this point defines the S/N ratio.

Step five: The hearing aid is again adjusted to permit the subject to reach an MCL this time with a 40dB HTL input speech signal. The aided SRT ia to be measured again for a reliability check against step two. A 50 word intelligibility test is administered at a 25dB SL.

Step two to five has to be repeated for each of the preselected aids. These tests permit the aids to be compared in terms of effective gain (which ia the difference in SRT aided and unaided), widest dynamic range (the difference between the aided SRTs and the aided TD's), signal to noise ratios (tolerance to higher levels of noiae before discrimination was disrupted) and relative discrimination scores., The selection of a specific aid is made on the basis of composite results. The performance on various dimensions are made and the best one selected. When several of the beat performing aid give similar results on these several dimensions, selection is then made on the basis of size, weight and asthetic preferences, in different settings, other factors like cost, warrnty, repair availability will have to be considered.

Modification of Carhart's Method -

Many modifications of the Cazhart's method have been putforth since he first described it. However, it is still one of the most widely weed clinical procedure for evaluation of hearing aids (Zelnick, 1982).

Ross (1978) gives the following modifications:

1. It is no longer common to measure SRT and TD with the aid set at maximum gain. First these measures provide little practical information regarding a client's use of the aid; second, if a client did have to utilise maximum gain setting of an aid fairly often, he undoubtedly

would require a more powerful aid; and third, except for some body aids, moat of which are probably placed on a baffle board some distance from the client, the occurrence of acoustic squeal at high gain levels will prevent thus setting with the average aid.

2. The most extensive modification relates to the measurement of discrimination under noise conditions, In the original method the noise level was varied until a point was reached where the constant speech signal was barely intelligible. Currently, this teat is accomplished by measuring discrimination against a competing signal, which may be either noise or speech. The signal-to-noise ratio is prederminad,usually at a level which depresses discrimination scores for normal listeners below their maximum performance. The competing signal and the speech emanate from two physically separated loud speakers. Open ended monosyllabic word lits still appear to be the most common stimuli for aided discrimination test.

3. The level at which intelligibility tests are administered has also undergone revision. In the original method, the teats, were administered at a 25dB SL. While some clinicians still administer discrimination lists at a fixed SL (eg. 25 to 40dB), other clinicians prefer to

to present the lists at a fixed HTL (approximately 40 to 50dB). The relative performance of hearing aids can be compared at any level. The rationale for a fixed HTL input is that the pertinent input to assess the relative performance of various aids is the level equivalent to average conversational speech.

4. Jerger and Hayes (1976) employed the recorded versions of the synthetic sentence identification (SSI) test. Objective scoring procedures on the closed response task (1 out of 10 possible sentences are identified), stimuli were presented from a frontally placed speaker at a 60dB SPL level, while another loudspeaker in the rear presents the competing stimuli at different intensity levels. A number of message competition ratios (MCR's) are generated, ranging from veryeasy (Plus 20dB3 to very difficult(minus 20dB), and the subject's score across all aids and/or combinations can be compared at the different MCRs. Thus differences in performances are teased out which may not be apparent at one MCR. The subjects scores can be viewed in terms of residual defecit, by comparing the scores to the function obtained by normal listeners.

Hodgson (1981) points out some advantages and disadvantages of the Carhart method.

Advantages:

1. Carhart's method is thorough and intensive.
2. It gets the patient involve in decision making regarding the selection procedure, fostering psychological commitment and responsibility.
3. It involved training as a part of selection procedure.

Disadvantage:

1. One of the obvious disadvantage is that it is very time consuming.

Over time, the classic procedure is shortened, probably due to time and cost considerations to consist of the follow-

a) Otologic and audiologic assessment.
b) Counselling the patient about the nature cf the hearing problem and of hearing aids, realistic expectations of help from amplification, and the nature and importance of other avenues of aural rehabilitation.
c) The measurement of speech gain, intelligibility through various hearing aids in quiet, and the subsequent recommendation of a specific aid,
d) Counselling the patient relative to the care and use of the aid recommended.

A more receat procedure for hearing aid selection using Carhart's technique is the "Texax tech" method of hearing aid selection. It is different from Carhart's method in that it uses prescriptive principles is addition to comparitive principles. The details of the prescriptive procedure will be elucidated in chapter 4.

<u>The Texex Tech method of hearing aid selection:</u>

The method is intended for the client, who ia old enough to follow instructions and with sufficient residual hearing to make the procedure practical. What the cut-off point is for residual hearing or age ia not yet known. This method has the advantage of being considerably less time consuming then the more traditional carhart method. Whether it is more scientific than the Carhart method possibly cannot be judged although it is difficult to see how it could be less scientific.

There are some basic considerations in this Method which Iekes (1993) sails it as 'unaided test battery'.

First, it should be determined if a medical examination and/or treatment is required before proceeding further.

Second basic preliminary information useful to the selection process should be taken, that is, which is the better ear for sensitivity, which ear has better discrimination or will a special fitting be required (CROS, AGC, binaural etc.).

The following ia the actual process for selecting the hearing aid assuming the above two information la present or determined.

1. Determining the LDL:

LDL used here is a practical limit which the client can tolerate. It is not the level of tickle or discomfort (120dB SPL) spoken of in text books concerned with psychophysics of audition. Because the instruction given to the subject will bias his response, the way the instructions are given is extremely important. Here Berger,s instruction is used which is as follows:

"Pulsing tones* (or words) will be given and they will become louder and louder. If they become so loud that they are uncomfortable to you, just say 'stop'.

If he cannot listen to the tones for 15 minutes or more, then consider the tone to be at an uncomfortable level.

An additional step follows for a step-up-step-down procedure to bracket in the LDL. After computing the ascending step, the procedure is started at maximum audiometric intensity and goes down. If the client reports pain or tickle, the tester goes down to a level Which can be tolerated, by the client. The instructions given for the descending procedure is,

"This time we will present the tone at a very loud level. we will then begin to make it softer and softer. When the tones reach a level where you could withstand and listen than for 15 minutes or more, than say 'stop'".

If the LDL for either pure tones or speech extends beyond the maximum output of the audiometer dial, it can be assumed that the LDL lies at an SPL of 115dB. After determining the LDL, required speech gain (RSG) of hearing aid is determined by the following formulae.

RSG - (LDL-10) - 60dBSPL

Here (LDL-10dB) is the LDL for speech measured in SPL-10dB (the SPL at Which maximum discrimination will occur) and where 60dB SPL is the normal conversational level.

The logic of this formulae is that the preponderance of information entering the mic of the hearing aid will be at a normal conversational level or 60dB SPL. Only enough gain is needed above the 60dB I/P to arrive at 10dB below LDL (point of maximum discrimination). More amplification than is needed will not improve discrimination further and may serve either to decrease discrimination or add to the discomfort of the client.

One SRT does not enter into the determination of gain requirements. Thus an individual with an SRT of 30dB HL (50dB SPL) with am LDL of 110dB SPL wiii require identically the same amount of gain as will an individual with an SRT of 50dB HL (70dB SPL) and LDL of llOdB SPL. For either individuals.

RSG = (llOdB - 10dB) - 60 dB

= 40 dB.

2. Determining speech gain:

Dirks (1978) described this procedure. The essence of what Dirks has found is that maximum speech discrimination score manifest approximately 10dB below the level at which speech becomes uncomfortable or in other words at LDL-10dB.

Increasing loudness for speech above the LDL does not result in further increase in the discrimination scores. On the other hand there may be a decrease in the discrimination score.

3. Determining maximum allowable hearing aid SSPL by frequency:

It would be possible to look at the ANSI specification sheets provided by the hearing aid manufacturer and match the high frequency average SSPL 90 O/P to the O/P requirements of the client. However, it is felt that additional information is needed regarding the maximum amplification which the client is able to tolerate for a broad range of frequencies, because Berger's (1956) system for determining the LDL for frequencies are used. The steps in completing this part of the procedure are as follows:

(A) Find the LDL for 500Hz, 1KHz, 2KHz, 3KHz and 4KHz. Use pulsed tone as stimuli. The initial findings are recorded on hearing level (HL).

(B) To find the maximum allowable SSPI., add the following values to HL. TABLE-2

a) 250HZ; 6dB or more below SSPL for 500Hz.

b) 500HZ: LDL + 8dB or lOdB whichever ia lower.

c) 1KHz: LDL + 4dB.

d) ZKHz; LDL + 6dB.

e) 3KHZ: LDL + 5dB.

f) 4KHz: LDL + 6dB.

(C) The above table represents the HL converted to SPL with a constant safegaurd of 3dB. Eg. OdBHL for 1KHz ia found at 7dB SPL (above .0002 dy/cm^2). subtracting 3dB (safegaurd) from 7dB yields 4dB.

(D) If LDL exceeds the maximum O/P of the audiometer, assume LDL lies at 115dB HL and than use the correction factors to convert to SPL.

Berger makes note that the emphasis on reducing SSPL for 250 and 500Hz beyond the requirements for other frequencies la an attempt to reduce ambient noise. This point is seen aa a major reason for including an examination of the LDL by frequency isno the hearing aid selection procedure.

4. <u>suggested testing sequence:</u>

a) Find the LDL for Speech.

b) Determine the amount of speech gain needed by the formula.

c) Find the LDL for puretones.

d) Convert LDL for puretones to maximum allowable aequency o/p levels by the formula.

e) Find out SDS at LBL for speech -10dB. This becomes a target score for comparison among various hearing aids.

f) Pre-select the hearing aids using the manufacturers specification sheets.

g) Check the gain and frequency response charactaristics of a heating aid by use of a hearing aid test box. Adjust the hearing aid until it meets the clients pre-determined needs. If no equipment ia available for the measurement of electroacoustic characteristics one only may have to rely entirely on the manufacturers specification(data).

h) Place the hearing aid on the client and adjust the volume to 40d3 HL (60dB SPL) which ia the normal conversational level.

i) Retest discrimination at normal conversational level, to make sure that discrimination reaches or comes close to, the unaided target level. The difference should not exceed 6%.

j) Try as many aids as needed until obtaining a satisfactory performance.

Since the procedure described here is concerned only with gain and o/p, we could try different hearing aids. In order to obtain satisfaction the dispenser may need to make other adjustments in frequency response, either through hearing aid adjustment or coupler adjustment.

PRESCRIPTIVE PROCEDURES

The earliest methods of selecting hearing aids were suggested by hearing aid manufacturers and dispensers of hearing aids. These methods are baaed on the principle of selective amplification. This refers to the tailoring of frequency response curve of a hearing aid in conformance with the client's audiogram (Ross, 1978). The audiometric information consists of the data determined by threshold tests of air conduction and bone conduction. Speech reception thresholds are also found in some cases. In addition, supra-threshold testa are often conducted consisting of teats of most comfortable loudness level, threshold of discomfort and speech discrimination scores. The hearing aid selected has specific performance in terms of gain, frequency response characteristics and maximum power output.

Proponents of selective amplification suggest that the gain of the hearing aid should increase in the frequency regions where the hearing loss increases so that the impaired listener could attain better audibility.

The various methods Which come under this procedure are:

l.Mirroring of the audiogram

2.Equal-loudness contour procedure

3. Bisection of the dynamic range.
4. Selection method for ski-slope loss cases.
5. Shapiro's method.
6. Zelnick formula.
7. Method proposed by Byrne and Tonnison.
8. Berger's formula.
9. Prescription of gain output (POGO) and its modification (POGO II)
10. The National acoustic laboratories (NAL) hearing aid selection procedure.
11. Lybargers formula.
12. State-of-the-art test procedure (SOTA).
13. Master hearing aid.
14. Hearing aid selection in children.

1. Mirroring of the audiogram:- This method is based on having the frequency gain characteristic of a hearing aid mirror the hearing loss as indicated on the pure tone audiogram was described by West in 1937. Mirroring the audiogram in terms of the required gain of a hearing aid can work well for persons with conductive loss. However, persons with a sensorineural loss due to cochlear dysfunction will have recruitment (abnormal growth of loudness) and will not require the overall gain indicated by the hearing loss. Pascoe (1975) has suggested a method of mirroring the audiogram less a constant amount for individuals with mild and moderate sensorineural impairments. Berger (1979, cited by

Zelnick, 1982) recommends determining gain by multiplying the HTL at a particular frequency by specific fraction auch as 0.5 at 500Hz and 6000Hz and by other fractions close to 0.5 at the critical frequencies of 1000Hz, 2000Hz, 3000Hz and 4000HB. In exercising the mirroring method, Pascoe suggests that care be exerted in evaluating 2cc coupler meaaurements of hearing aids, at the performance characte-riatics of the aid will differ significently from real ear measurements with a customised ear mold.

2. Equal-loudness contour procedure: - Watson and Knudsen (1940) were probably the firat supporters of the principle of determining moat comfortable loudness contour for the purpose of hearing aid selection. They proposed that optimum hearing aid performance could be obtained by amplifying the average level of speech to the most comfortable level for a 1000Hz tone be obtained for the hearing impaired subject. A loudness matching technique is then used for determining the most comfortable loudness at other specific significant frequenciea (250Hz, 500Hz, 2000Hz and 4000Hz), thus obtain-ing the most comfortable loudness contour with the lOOOHz tone as a reference. The gain of the hearing aid is then determined by finding the difference between the subjects equal-loudness contour and the normal auditory threshold.

3. Bisection of the dynamic range:- The dynamic range is equal to the threshold of discomfort minus the speech

reception threshold or the threshold of discomfort at a specific frequency minus the pure-tone air conduction threshold at such specific frequency. Proposed by Wallenfels in 1967, this method suggests that the optimal hearing level curve is equal to the line which bisects the region between the auditory threshold and the threshold of discomfort between 1000Hz and 4000Hz. Wallenfels recommends that below 1000Hz the hearing level curve depend on the slope of the bisection line between 1000Hz and 4000HZ. If that slope of the bisection line is steep, then the hearing level curve continues downward with the same slope; if the slope is less than 8dB per octave, then the downward slope below 1000Hz is fixed at 8dB to 10dB per octave. The limited gain suggested for frequencies below 1000Hz is recommended to prevent the upward spread of masking, in which the amplified low frequency components of speech or background noise could mask the high frequency components of speech (consonants) so important for speech intelligibility.

4. Selection method for ski-slope loss cases:- for severe high frequency (ski-slope) hearing losses, Skinner (1976) suggests a frequency response in which there is no gain below 500Hz. Between 500Hz and 1600Hz the average functional gain should mirror the aduiogram and an average of 23dB gain above 1600Hz. Skinner used 1/3 Octave bands of noise

for determining functional gain (the difference between the aided and unaided thresholds of audibility for narrow band noise).

5. Shapiro's method:- This method was given in 1976. In the procedure described by Shapiro, the MCL for narrow band noise (NBN) is determined by having the patient describe each presentation of the noise as being either "too loud" or "too soft" for just comfortable listening over an extended period of time. The pulsed signal is presented in an ascending manner in S dB steps.

MCL is defined as the level of 5dB below the lowest intensity level that is described being 'too loud' two out of three times.

Gain of the hearing aid is determined by subtracting 60dB which is the customary i/p SPL for measuring hearing aid gain, from MCL at 1, 2, 3 and 4KHz.

Cain at 500Hz is derived by subtracting 1OdB from the gain at 1KHz. This is done to counteract the masking effect of lower frequency vowels on the higher frequency consonants. Reserve gain is provided by adding 10dB to the resultant gain values.

Rationals for this procedure:

i) Hearing aid users are likely to adjust the gain of their aids so that speech is delivered to the car at their comfortable levels.

ii) Most hearing impaired listeners achieve their best speech discrimination scores at or near MCL.

According to Shapiro, gain at that particular frequency MCL - 60dB + 10dB.

For example, If MCL is 65dB,

Gain - 65 -60 +10

- 15dB.

6. Zelnick formula:- Zelnick (1982) has suggested formulae for gain for the following:

i) Average HAIC gain-MCL +20dB-65dB+10dB.

ii) average high frequency(HP) gain-MCL+20dB-55dB+10dB.

iii) Reference teat gain (RTG)-MCL+20dB-55dB.

The 20dB is a correction factor to convert the most comfortable loudness level (MCL) measured with the audiometer in dB HL to dB SPL. The average level of speech is 65dB SPL(however some researchers consider the average level of speech as 60dB SPL).

The average HAIC gain is based on measurements made at 500Hz, 1000Hz and 2000Hz. The 10dB is added in the formulae above so that the aid is not worn at full gain setting of the volume control; when the aid is adjusted to a preferred listening level by the user.

The average HF gain and RTG is based on measurements made at 1000Hz, 1600Hz, and 2500Hz. The 10dB is added in the average HP gain formula, so that the aid is not worn at maximum setting of the volume control as explained above.

One should be aware that in everyday use, the client will determine the gain setting of the aid in keeping with his/her needs and comfort.

Frequency response characteristic:- Zelnick et al (1985) recommend that the target in selecting appropriate amplification for a client should be amplification which mirrors the contour of the client's audiogram for the frequencies from 250Hz to 6000Hz. The recommended gain at which the aid is to be used should be at or hear the RTG level of the aid, when that level approximates the MCL of loudness for the client. The client will, eventually, fine tune the gain level to his particular needs.

The primary concern for selective amplification is to provide good audibility for speech sounds. The high-frequency unvoted consonants such as /p/, /t/, /f/, /th/, /h/, and /s/ are the moat important for speech. These phonemes are of weak intensity and cluster in the high frequency region of the speech spectrum, where most persons with a sensory hearing impairment have greatest loss. Amplification prescribed by the half-gain rule or the one-third gain rule falls abort of providing adequate high-frequency amplification for the high-frequency consonants necessary for speech intelligibility.

7. Method proposed by Byrne and Tonnison:- This procedure was suggested in 1976 which advise that the hearing aid gain should be selected so that the aid delivers speech to the ear at the clients MCL. This procedure is used in cases of children where in the preferred listening levels are derived from the threshold measurements. It has been determined that hearing aid users require 4.6dB of gain for every 10dB of hearing lose. On the basis of this, they derived a graph showing the association of required gain for each HTC.

The gains at the different frequencies are adjusted to compensate for the differences in loudness observed at the 60 phon equal loudness contour and for differences observed ia the levels of various frequency components of speech.

e. Berger's formula: The Berger method which was developed in 1972, comprises two major portions, each of which is further divided into two parts. The two parts are in turn subdivided.

The first step in the method is to obtain the operating gain (called 'preferred gain' or 'use gain' by others) varies from one prescriptive method to the next, in the Banger method the operating gain consists of an incomplete mirroring of the speech spectrum as overlaid on an individual's hearing threshold level..To this speech spectrum Berger et al. (1976) incorporated the so called half gain rule, which was developed by Lybarger in 1963. One purpose of operating gain is to predict the desired aided HTL. The resulting predicted HTL is assumed to closely relate to the ideal aided requirements in environments ranging from quiet to moderate noise.

The maximum gain is the result of the operating gain + reserve gain ± correction factors which depend upon Where the microphone is located on the body and how the gain-frequency response is measured. Maximum gain forms the first half of the prescription. Maximum gain a widely accepted term used within Audiology and appears in numerous standards on the subject of hearing aids.

Reserve gain can be whatever the clinician wants it to be. For convience Barger et al arbitrarily used 10dB. Although the 2cc coupler provides a far from perfect simulation of the ear, it is currently the most common measurement device used in determining the electroacoustic data on technical data sheets.

With minor changes by frequencies, the maximum gain portion of the prescription can be modified to applied to KEMAR with its zwislocki coupler or to any other similar measurement device.

The second portion of the prescription is the saturation sound pressure level (SSPL). The SSPL - formerly called 'output' - can be conviently divided into two parts: maximum permissible SSPL and minimum desirable SSPL. Maximum permissible SSPL is designed to ensure that loud sounds do not exceed the clients uncomfortable loudneaa level.' Therefore, uncomfortable loudness levels, asobtained with discrete frequency stimuli are converted to dB SPL and constitute the maximum permissible SSPL. That minimum desirable SSPL is determined by adding the clients operating gain requirement, at discrete frequencies, to the level of loud speech at the same frequencies.

Prescriptive gain formulas: The maximum gain formula for an in-the-ear hearing aid (that is an instrument with the microphone at or in the concha) is the operating gain formula pins reserve gain. The formula in dB is shown in the following table.

TABLE-3

$$\frac{\text{HTL at 500Hz+10}}{2}; \quad \frac{\text{HTL at 1000Hz+10}}{1.6}; \quad \frac{\text{HTL at 2000Hz+10}}{1.5}$$

$$\frac{\text{HTL at 3000HZ+10}}{1.7}; \quad \frac{\text{HTL at 4000Hz+10}}{1.9}; \quad \frac{\text{HTL at 6000Hz+10}}{2}$$

From this formula, it may be seen that the HTL is measured at six different frequencies. However, if the HTL at 6000HZ shows a Moderate or greater loss, then there is no value in prescribing gain at that frequency. This is so because about 500HZ the energy in speech decreases rapidly aad by 6000Hz the energy in speech is drastically reduced; at the same time hearing losses are typically greater at the higher frequencies. If all denominators were "2" this would be a straight forward half gain; since some denominators are smaller than two, the actual gain will be slightly above 50% of the HTL.

Some clinicians may prefer to add slightly more gain at 2000Hz and above because a closed ear mold will alter the resonant cavity of the ear canal at those frequencies. Also, lOdB of reserve gain is shown in the formula mentioned above the table, will be more than is necessary with canal aids, and often a little more than is necessary with conventional in-the-ear hearing aids.

For behind-the-ear hearing aids the formula for main gain is modified by adding 2dB at 2000Hz and 3dB at 3000Hz so as to partially offset the loss of pinna effect which occurs at those frequencies with in-the-ear hearing aids. Again however, the clinician may find it appropriate to add a few more decibels at 2000Hz and above when using technical data from Zee coupler measurement.

For body worn hearing aids* the gain is reduced at 500Hz and increased at 8000Hz in comparison with the in-the-ear formula. These changes are designed to atleast partially cancel the body baffle effect. The above maximum gain formulas apply to monoaural fittings and are for sensosi-neural hearing losses, using hearing aids with closed ear molds or ear molds with very small vents. For conductive losses, 25% of the air bone gap ia added to both the operating gain and the maximum gain, with no more than 9dB added regardless of conductive component. For binaural fittings, 3dB is subtracted from the maximum gain at each frequency from the prescription for a monoaural fitting;. In any case, the predicted aided response is the same for sensorineural hearing losses regardless of type of hearing aid (in-the-ear, canal, behind-the-ear, body worn), monoaural or binaural fitting, and age, of the client.

Saturation pound pressure level (SSPL): The second half of the prescription ia for SSPL. Maximum permissible SSPL is calculated as shown in the following table.

TABLE-4.

UCL at 500Hz in dB HL + lldB
UCL at 1000Hz in dB HL + 7dB
UCL at 2000HZ in dB HL + 9dB
UCL at 4000HZ in dB HL + 9dB

It may be seen that these calculations simply convert the UCL as obtained with discrete frequency stimuli, from dB HL to dB SPL.

minimum desirable SSPL is calculated as shown in the following table.

TABLE-5

Operating gain at 500HZ + 75dB

Operating gain at 1000Hz + 75 dB

Operating gain at 2000Hz + 72 dB

Operating gain at 4000Hz + 70 dB

The purpose of maximum permissible SSPL is to prevent loud sounds from exceeding the clients UCL. The purpose of minimum desirable SSPL is to ensure that loud speech sounds will be amplified without undue clipping and thereby minimizing amplifier distortion. Therefore, a hearing aid with output anywhere between the maximum permissible and minimum desirable SSPL's will satisfy both requirements. If the dynamic range of the client is small, the minimum desirable SSPL may be greater than the maximum permissible SSPL. This ofcourse means that the former cannot be used since by definition minimum cannot exceed maximum. It also indicates to the clinician that a hearing aid with compre-ssion circuitary may be more suitable for the client.

Using the prescription: The completed prescription may be used in several ways. First, the predicted aided response may be plotted on the client's audiogram so that after the hearing aid ia fitted the actual aided responses can be compared with the predicted aided response*. This comparison is particularly meaningful to the client because changes from unaided to aided threshold can easily be seen (Berger et al. 1988).

Second, the prescription data may be uaed to search through technical data sheets to find a healing aid model and setting that correspond to the prescription. Alternatively, the data may be sent to the manufacturer with a request for a hearing aid that needs the requirements as closely as possibly. In no case, however, will a hearing aid be found that exactly matches the prescribed factors.

Once a hearing aid approximating the prescribed factors has been fitted an aided threshold test will confirm if the hearing aid ia indeed providing the desired response. If the aided sound is uncomfortably loud the clinician can obtain aided UCL to determine whether the maximum permissible SSPL has been exceeded. If the unaided-to-aided comparison reveal a substantial mismatch between the desired and obtained hearing thresholds the clinician can improve the response by modifying the ear mold, using fitters, change in the tone control or by making other alterations.

Some clients adjust to a new hearing aid almost immediately. For others the adjustment period for both the feel of the aid and the new acoustic signal may be as long as a month. Thus, word discrimination scores obtained immediately after the fitting may be misleading, it is more meaningful to carry out aided speech audiometry only after the person has adjusted to the aid (Berger, et al. 1980).

(9). Prescription of gain output (P0GO) and its modification (POGO II).

This procedure was given by McCandless and Lyregard (1983). This is mainly based on the half gain rule of Lybarger and includes an additional reduction of the gain at low frequencies (at 200Hz, ½ HTL-lOdB, at 500Hz, ½ HTL-5dB).

The POGO fitting method, at present is restricted to the sensorineural hearing loss cases with recruitment. Gain and o/p for conductive loss however, can be calculated, but additional gain is required, which is not yet provided for, in the basic procedure. At present, this procedure is found useful only for hearing losses lees than 80dB HL,

Underlying principles:

a) To ensure that the sound levels which are most important in daily life be audible without being excessively loud (i.e. placed near MCL).
b) The POGO method includes an additional reduction at low frequencies, in order to reduce poor intelligibility of speech in noise. Whereas in the lateral application of

½ gain rules there might be poor intelligibility of speech in noise due to the upward spread of masking from lew frequency ambient noise.

c) MPO is selected ao that the sound level approaches the UCL without exceeding it.

Procedure:

Three basic steps involved are:

1. Calculation of characteristics based on audiometric information of:

a) Gain

b) MPO.

l.a) Gain: The gain can be calculated as given below, wherein, the values at each frequency are:

Frequency		Insertion gain (IG) in dB:
250HZ	½	HTL-10
500, 1000, 2000 3000, and 4000Hz	½	HTL-5.

l.b) MPO: The MPO la calculated using the given formula:

$$\frac{UCL_{500}+UCL_{1000}+UCL_{2000}}{3}$$

i.e. the MPO is given by the average of the UCL's at 500, 1000 and 2000Hz.

2. Implementation or required Gain and MPO:

First determine if the required MPO is within the adjustment range of the aid. Later, find out the maximum

IG in the region of 500-2000Hz. Check whether this maximum is within the adjustment range of the aid allowing for ±10dB reserve gain.

Compare the required insertion frequency response with the response available for each aid. In the present hearing aids, it is predominantly the frequency response in the region of 250-2000HZ which should fit. Minor ear mold modifications do not significantly affect the acoustical properties in the region of 250-3000Hz. The correction chart to be used when the earmold modifications are required to affect a specific response charge is given below:

TABLE-6

Type of earmold	Frequencies(Hz)					
	250	500	1000	2000	3000	4000
Vented	-13	2	0		0	0
IROS/CROS	-36	-24	-12	9	3	0
Mean	0		0	0	6	5

3. Verification:

Both IG and MPO should be checked in-situ, on the ear of the hearing impaired. This can be done using a probe tube microphone. The patient under test should be seated facing a loudspeaker which is at a distance of one meter, during the measurement. Using NBN, determine unaided threshold at audiometer frequencies of 250 to 4000HZ. Find the tided threshold with ear mold in place, including the volume control. Compere the difference (functional gain) with the required gain (unaided threshold). The difference should not exceed 5dB in the 500-2000Hz range.

4. Check of aided UCL:-

Turn the hearing aid volume control full on and gradually increase the level of NBN at 1000Hz. If this level can be turned up beyond 80dB HL, without reaching the patients UCL, then the MPO adjustment is considered satisfactory. Speech presented through a speaker or loud speech spoken directly to the patient can also be used for stimuli.

If the hearing aid does not match the requirements, readjustment of aid or mold or selection of a different aid may be necessary.

Modification of POGO (POGO II):

Most of the mathematical formulae, as given by Berger (1977)., Byrne and Tonnisson (1976) etc, try to place the long term aided speech spectrum between the listener*s most comfortable level (MCL) and his loudness discomfort level (LDL). The underlying rationale, for moat of these formulae, is supported only for patients with mild to moderate sensori-neural hearing loss. Hearing aid selection procedures designed for persons with only mild or moderate sansori-neural hearing loss might not be applicable for patients with severe-to-profound losses. Hence, to optimize speech reception at a comfort level gain setting for patients with severe-to-profound hearing loss, a modification of the POGO (Prescription of gain output) haa bean designed, called aa POGO II.

Daniel et al (1988), have found that the audiogram bisection method tends to over estimate, While the POGO which uses the one half gain rule underestimates gain values subjectively considered preferable by those with severe-to-profound sensitivity loss. They found that for hearing losses beyond 60dB, MCL grows at a higher rate than one half gain. On the basis of these data, therefore the original POGO formula, (which represents a 1:2 ratio of gain to hearing loss) is modified to a ratio of 1:1 for hearing losses above 65dB.

Formula for POGO II!

a) For hearing losses $\leq$ 65dB

Insertion gain = ½ HL-C,

Where, C=lOdB at 250Hz

and 5dB at 5OOHz.

b) For hearing losses > 65dB:

Insertion gain = ½HL - C+½ (HL-65)

Where, C = lOdB at 250Hz

and 5dB at 500Hz.

Thus, POGO was based on delivering all speech bands to MCL in order to compensate for the shift in MCL imposed by the hearing loss. But this will not meet the needs of the severe-to-profoundly impaired, became the preferred listening levels of such cases were seen to be only + +7dB SL on the average (Daniel, et al. 1988). Thus, POGO II represents the modified POGO equation, which provides amplification at a constant sensation level for hearing losses beyond 65dB.

POGO II represents a compromise between the one-half gain rule for normalizing MCL and the equal sensation level concept, Which will tend to deliver greater loudness in the frequency region, where hearing loss is largest, i.e. greater than 65dB.

Advantages of POGO-II:

1. Provides the hearing aid fitter with a simple and rapid estimate of the gain by frequency needed to make speech optimally audible, while maintaining within the comfort ranges for long-term listening.
2. MPO, which is the main hearing aid fitting factor of POGO, remains unchanged from POGO to POGO II.
3. POGO II is useful in attempting to fit patients whose hearing loss magnitude changes across frequency. In

such cases, ½ pain rule at frequencies with hearing loss less than 65dB and 1:1 gain (or approximately equal SL:± 7dB) at frequencies where hearing loss is greater, is applicable.

However, a caution on the POGO II procedure which might not be valid for patients with corner audiograms, must be taken. In such cases, a more appropriate estimate of required insertion gain can be derived from the more classical speech spectrum method.

10. The National acoustic laboratories (NAL) hearing aid selection procedure:

The first NAL procedure was described by Byrne et al. (1976). Its aim was to amplify all frequency bands of speech to make them equally loud when speech was at a comfortable listening level. It was thought that this would provide the maximum amount of audible signal when the hearing aid volume control was on the preferred setting and that this would therefore maximise understanding of speech under normal conditions. In common with earlier formulae, gain was increased by approximately half a decibel (actually 0.46dB) for every ldB increase in HTL. Gain at the midfrequencies (around lKHz) was about half of the HTL. When calculating gain at other frequencies, adjustments were made to compensate for the interfrequeacy differences in the long term average speech spectrum and in the 60 phon equal loudness contour. The overall effect was that for any given HTL, considerably less gain was provided at the low frequencies (250-500Hz) than at mid and high frequencies.

NAL research showed that the aim of the procedure was correct but that the formula did not consistently achieve this aim. The research data were used to calculate how the optimal frequency response could be predicted from an audiogrsm. On this basis a new formula was derived.

Hew NAL formola: The average gain of the new formula at 3 frequencies (0.5, 1 and 2KHz) is the same as that calculated for the old formula. That is, average gain increases by approximately 0.5dB for every ldB increase in HTL(the so called 'half-gain' rule). However, frequency response is varied by a 'third-slope' rule (i.e. 0.31 x audiogram slope). Thus, the new formula prescribes less variation in frequency response for variations in audiogram shape. It also prescribes more relative gain around 500Hz than did the old formula. The new formula, like the old one prescribes the required real ear (insertion or functional) gain from HTL at each frequency. As a hearing aid must be initially selected by using the gain measurement in a coupler, additional formulae are provided for calculating the 2cc coupler-measured gain that is most likely to provide the required real-ear gain.

The Table below shows the formulae for calculating the required real-ear gain and the required coupler gain for behind-the-ear (BTE), in-the-ear (ITS) and body-worn hearing aids.

TABLE-7

		2cc coupler at maximum volume setting		
	Real ear gain	BTE	ITS	Body-worn
G 250=X+0.31H250+	-17	1	-1	0
G 500=X+O.31H500+	-8	9	9	2
C 750=X+0.31H750+	-3	12	13	8
G 1K=X+0.31HlK+	1	16	16	13
G 1.5X=3*0.31H1.5K+	1	13	14	22
G 2K=X+O.31H2K+	-1	15	14	25
G 2K=X+0.31H3K+	-2	22	15	26
G 4K=X+0.3lH4K+	-2	18	13	17
G 6K-X+0.31H6K+	-2	12	4	-

Where G=Gain; H=HTL; X=0.05 (H500+H1K+H2K).

The coupler gain formulae include an adjustment for the average difference between coupler and real-ear gain. This adjustment varies for each type of hearing aid. There is also a constant 15dB adjustment because coupler measurements are made at the maximum volume setting whereas real ear gain refers to the average used setting which is expected to be 15dB lower.

The calculations are more complex than moat other formulae because of the combination of the half gain and third slope rules. They can, however, be made simple by using a set of slide charts or computers.

Fitting procedure:

1. Obtain an audiogram.
2. Calculate the required coupler gain at each frequency for the desired type of hearing aid.
3. Select and fit a hearing aid and combination of settings, that has the required coupler gain.
4. With the aid adjusted to the preferred volume, measure the real-ear gain at each frequency using an insertion gain analyser or by aided threshold testing.
5. Compare the measured real-ear frequency response with the required real-ear frequency response, as calculated from the zeal-ear gain formula.
6. If the measured and required real-ear frequency responses do not agree closely, then obtain a closer match, if possible, by changing the hearing aid, aid settings, acoustic dampers or ear molds type.

When applying the procedure, the required and measured realear gain values should be plotted on a graph so that the shape of the required and measured curves can be compared. It is important to match the shape rather than the levels of the curves as any difference in overall levels simply indicates that the individuals PLL is lower than or higher than average. The coupler gain values in the earlier table apply to a hearing aid with a fully occluding ear mold with 2mm tubing. If a different ear mold type is used, its effects should be taken into account when making initial selection. If the real-ear gain formula prescribes a negative value, this should be treated as OdB.

The NAL formula applies to SN losses. For conductive or mixed hearing losses, the gain at each frequency is increased by 25% of the difference between the air conduction and bone conduction thresholds. This rule has still to be verified or modified by future research. Special considerations also apply to very severely or profoundly hearing impaired. Some of these patients will require greater overall gain (i.e. at all frequencies) and some will require more relative low frequency gain than prescribed by the NAL formula.

11. <u>Lybargers formula:</u>

A one-half gain rule for hearing aid fitting based on the unaided average hearing threshold level was first proposed by Lybarger in 1953.. Although Lybarger's procedures were designed to assist dealers in the Radio ear organization, they received wider circulation and acceptance. In 1963, he simplified the gain formula.

Lybarger's 1953 gain formula was based on one-half of HTL in the speech frequencies plus the sum of a constant, a correction factor for AB gap and 5dB. This original formula was for maximum gain, which included 15dB of reserve gain.

Maximum gain = operating gain + Reserve gain. The 1963 version recognised that 15dB was too much reserve gain for ear-level hearing aids. Thus, the 1963 formula was for operating gain and it was simply the puretone average of 500Hz-1000Hz-2000Hz divided by 2, plus the sum of a correction factor for AB gap and 5dB.

$$OG = \frac{PTA(500, 1K, 2K)}{2} + \text{correction factor for AB gap} + 5dB$$

with the change from ASA to ISO or ANSI, audiometer calibration, the "plus 5dB" is omitted and there is an almost identical result.

However, the original Lybarger's formula which was given in 1944 is slightly different from that of 1953 and 1963. The formula for gain is simply one third of HTL at 500Hz and Half of HTL at 1KHz, 2KHz, 3KHz, and 4KHz.

The above mentioned Lybarger's formulae are also grouped under 'Threshold based formulae' which also includes the prescriptive procedures given by Byrne and Tonnisson, Berger et al.,McCandless and Lyregaard, and National Acoustic Laboratories.

12. State-of-the-art test procedure (SOTA):

The computerised probe microphone assembly allows for a SOTA test procedure based on calculating the predicted insertion gain and frequency response in the ear canal of the listener, implementation of this insertion gain with the appropriate heating aid and ear mold and verification by means of a computerised probe microphone assembly. The selection procedure is similar to POGO given by McCandless and Lyregaard.

Step-I: Is the calculation and prediction of required hearing aid and ear mold characteristics based on available audiometric information.

Gain formula: TABLE-8

frequency	IG.	
	POGO	Probe mic
250HZ	½HTL-lO	1/3 HTL-5
500HZ	½HTL-5	1/3HTL-3
1KHz	½gHTL	1/3HTL
2KHz	½gHTL	1/3HTL
3KHz	½sHTL	1/3HTL
4KHz	½HTL	1/3HTL
6KHz	0	1/3HTL-5

The POGO predictions, baaed on the half gain rule often are not realised clinically (Libby,1985). The preferred listening level (PLL) with the probe microphone were taken Ear hearing loss less than 70dB HTL based on a 70dB warble tone sweep of 125 - 8000Hz.

Findings based on the authors experience (Libby, 1985) with over 500 cases both adults and Children are as follows:

SN hearing loss subject PLL's is closer to 1/3 of HTL

Severe to profound subjects may need insertion gain closer to ¼ of HTL.

The preferred insertion gain with probe mic are closer to Fletcher's(1952) formula i.e.,

IG = 1/3 SL + ¼ CL (1-4KHz)

where SL = S.N.loss

CL = conductive loss.

In practice it is neither necessary nor possible to prescribe overall gain precisely. Except for a small minority of cases (infants) the hearing aid wearer will choose his own level of overall gain by adjusting the hearing aid volume control.

In general, the milder the hearing loss, the closer to one third insertion gain is recommended. Conversely, the greater the loss, the closer to half insertion gain is necessary.

Subjects with precipitously falling losses of 70-80dB in the high frequencies, however, prefer insertion gain closer to a third rather than half. Other subjects with severe hearing losses and flatter threshold configurations prefer insertion gain closer to a third rather than half (Libby, 1985).

Other factors like shape, smoothness and bandwidth of the frequency response can play critical roles in determining user satisfaction, at this time there is still no exact information as to the exact amount of insertion gain necessary to achieve optimal intelligibility and sound quality. Since it is often difficult to realise the desired coupler and insertion gain with the available hearing aids and ear mold modifications, compromises are often necessary.

Step-II: is the implementation. In general, goal should be to determine the minimum in use gain (IG) which help establish comfort, reasonable sound quality and good word recognition with ample reserve to prevent unnecessary distortion. The difficulty at this point is that hearing aid manufacturers do not utilise standard specifications in publishing hearing aid data. If insertion gain data is available then the objective is to determine which of the available hearing aids and ear mold coupling systems best fit the predicted frequency response plotted in Step-I with a reserve gain of approximately 15dB. If KEMAR insertion gain data is unavailable, it becomes necessary to calculate the appropriate correction figures.

Step-III: is the verification of selection procedure. It is to Check if the predicted hearing aid response characteristics are achieved. This verification is necessary because the same hearing aid characteristics may interact differently on each other individual ear. When a computerised probe mic is used, ear canal resonance and insertion gain with hearing aid and mold is masked (resonance of ear canal has been subtracted automatically).

Judgements of sound quality:

The computerised probe mic-assembly is ideally suited to test discomfort levels. In general the UCL should fall beneath the SSPL 90 at all frequencies. If occasional peaks occur which are annoying, appropriate acoustic damping and earmold modifications are performed. Patient's subjective response to a hearing aid system should also be considered.

Libby (1985) finds good repeatability from 125-4KHz in this procedure. At higher frequencies i.e. around 5 and 6KHz, it is less predictable.

i3. Master Hearing Aid:

Another approach that haw been recommended for hearing aid evaluation and selection is the use of master hearing aid. The purpose of the master heating aid is to try various performance characteristics such as changes in gain, frequency response, the maximum pressure output with the subject and to identify the characteristics that give optimum response. The dispenser then looks for those characteristics in a specific hearing aid or asks a manufacturer to modify an aid so that its electro-acoustic characteristics match those of the adjusted master hearing aid. A procedure that attempted to test the effects of master aid adjustments in a logical sequence was described by Lawrence and Black (1977, cited by Pascoe, 1985).

A similar procedure was later described by Levitt (1978 cited by Pascoe, 1985). In this adaptive procedure, called the "simplical method", two parameters of a wearable master aid are adjusted to create a set of frequency responses. A closed set of nonsense syllables are used to measure word discrimination, scores which are initially obtained using three responses combinations which are dependent on the previous scores. The best two scores are used as the base of a second triangle which is completed by a fourth response chosen in a direction diametrically opposed to the lowest score. This search continues until an area of optimal response is clearly defined.

According to Schimtz (1980, p.188) "In reality, the prescription of custom fitting of different hearing losses is probably one of the greatest misrepresentations perpetrated against the consuming public. Available filtering circuits in the master hearing aid are not individually reproducible. These are only a number of available circuit boards, amplifier and microphones that in combination will produce a limited number of frequency responses. These frequencies may or may not represent the patient's hearing loss and the necessary gain and o/p limitations of the aid as specified by the subjective evaluation. Manufacturers approximate the requirements of such descriptive information, and cannot exactly customize the response of the instruments in all cases. This is especially true for basin shaped, low frequency, and very steeply falling high frequency hearing losses".

Zelmick (1982) feels that the unpopularity of Master hearing aids could be because the manufacturers designed and produced these in line with their own hearing aids.

14. <u>Hearing aid selection in children:</u>

As far as hearing aid selection for children is concerned.Many of the procedures discussed in the previous chapters.may be applied in toto or in part while selecting them. For example, DDL method, use-gain method, objective procedures etc. However, some specific methods and procedures for obtaining the required gain, frequency response of hearing aids for children have also been suggested.

Colarado health Department recommends the following procedure to determine gain of hearing aids for children (cited by Northern and Downs (1978).

a) The acoustic reflex response method with conventional speech input is the method of choice in nonverbal children for determining hearing aid gain. The MCL method should be used whenever possible, or when acoustic reflex not present.

b) The following procedure is suggested for children who are in experienced hearing aid wearers and for whom no acoustic reflex are demonstrable.

i) Assumption will arbitrarily be made that the patients LDL will be l05dB SPL.

ii) Speech awareness level will be obtained and converted to SPL.

iii) Midpoint between 105dB SPL and speech awareness level should be calculated and increased by 5dB. A hearing aid should be selected which will provide this desired SPL with conventional speech input.

iv) The hearing aid should then be placed in a hearing aid test box. The hearing aid gain control is adjusted to achieve the desired SPL (as in III above), with a 70dB SPL speech spectrum noise i/p. The hearing aid gain control is marked at this setting to enable the gain level to be maintained when the aid is worn by the child.

v) The child should be entered in an auditory training program where therapists can help select the most comfortable level.

Besides the above, Northern and Downs (1978) recommend a hearing aid selection procedure for various age groups. They are as follows:-

1) <u>The preverbal child, birth to 2 to 3 years old</u>: The initial choice of those hearing aid brands from which to select an aid for the preverbal child should be made on the basis of principles that include dealer criteria:

a) <u>Dealers service</u>: This would include, questions regarding the hearing aid dispensed by the dealer. Factors like the availability of the hearing aid, sent on trial basis, guarantees repairs, performance information etc. have to be taken into consideration.

b) Appropriateness for children) Here one must ascertain whether the hearing aid prescribed is sturdy for the child's use, whether the hearing aid can withstand temperature changes and physical shocks etc.

c) Pretested approval: If a public or private agency is purchasing the aid for the child, is the aid on their approval list for pretested models. After a few general brands which furnish the approximate gain, power o/p and frequency response for a specific kind of loss can be chosen for further consideration. A further narrowing down of the list is made by specific application of the dynamic range principle described previously. To this, fait approximations of threshold levels and tolerance limits should be known.

When a tolerance limit is reached, the child may start crying. However, it should be noted that children with conductive loss have greater tolerance level than SN loss cases. The aid with the best dynamic range should be chosen.

2. The non-verbal child, 2 or 3 to 16 years old: The child two or three years and older who can be play conditioned or taught hand-rising responses to sounds can be given satisfactory hearing aid evaluation. Once a hearing aid is selected for trial, we should obtain these measures:

a) Using gross speech, obtain a speech awareness level through play conditioning techniques or hand rising. The simple word 'now' is as good a speech signal as any.

b) Using warbled tones, obtain an aided free field audiogram on each aid. Use intermediate frequencies in addition to the standard frequencies (750, 1500 and 3000Hz) if possible.

c) Test the tolerance limits of the aid on the child by raising the speech level gradually until the child evinces discomfort.

d) Evaluate the aids first on the basis of the best speech awareness in relation to tolerance levels. The measure of highest tolerance limits should be given precedence over the lowest speech awareness levels. An aid giving a 15 or 20dB HL speech awareness level but producing tolerance limit at 65dB should be eleminated in favour of one with a 25-to-30dB HL awareness level with a tolerance limit of 75 or 80dB HL.

e) The next evaluation of aids should be made on the basis of the aided pure tone thresholds. The threshold at 2000HZ is the most critical, and the aid showing best threshold should be given preferance.

This procedure should enable the tests to select two or more acceptable aids which can be recommended. In real life situation, the performance of the hearing aid can be oberserved by the parnets teachers etc

3. The verbal child 3 to 16 years: Depending upon the receptive and expressive language of the child, one of the various procedures described for use with adults can be used or modified to some extent. In addition, factors like degree of hearing loss, level of language skills, intellectual functioning of the child should be considered before any kind of modifications on the test procedure is made.

OBJECTIVE PROCEDURES

The basic problem in fitting infants with hearing aids is that the clinician is faced with making clinical determinations on difficult to obtain and often questionable non-verbal data (Mahoney, 1985).

Recommended at a National conference on heating did evaluation procedures (ASHA,1967), this effort involves "continuous monitoring" of the child while various hearing aids or hearing aid adjustments are made. Presumably, this monitoring focuses on observing the child's behavioral reactions under different listening conditions, in hope of making intelligent decisions concerning hearing aid types, electroacoustic settings, ear preference, and ear mold modifications.

Limitations in behavioural observations made researchers to seek a more objective approach in hearing assessment, hearing aid evaluation and selection.

Two hearing aid evaluation procedures that more closely fit a rigid definition of objective technique (i.e. those requiring no active participation).are those utilising the middleaar acoustic reflex and the auditory evoked potentials. These techniques seemingly offer a clinically valid approach to objective hearing aid evaluations and may, by virtue of their theoritieal potential, change the future direction of hearing aid evaluations for non-verbal and difficult to test patients.

i) Acoustic reflex method: The potential use of acoustic reflex measurement in the use of heating aid selection was also shown by McCandless and Miller in 1972. They also recommended the use of the "just uncomfortable" LDL to define maximum power output requirements for a hearing aid. They hypothesized that since the LDL occurs at the same level as the ART in persons with cochlear impairment, acoustic reflex thresholds can be used as an indicator of LDL. These results stimulated other clinicians to limit the power output of hearing aids fitted on patients with SN hearing loss.

McCandless (1973) re-examined the upper usable intensity level in cochlear hearing loss patients and noted that psychological tolerance measures were related to the threshold of the acoustic reflex and to the MPO of hearing aids. The LDL at the point where sound first becomes annoying is recommended as the tolerance measure of choice for fitting hearing aids. MPO requirements indicated by the LDL suggests a need for greater power limiting in hearing aids than that previously recognised, and in most cases should not exceed 100 to 105 dB SPL for mild losses, 115dB SPL for modrate heating losses and 120dB SPL for severe hearing losses. According to McCandless (1975) "The aided SPL delivered to the ear must not exceed the ART by more than 5-10dB or the aid will be judged uncomfortable, even in normal sound environments, and may thus be ultimately rejected by the patients".

Horning tl975) described improved hearing aid fitting inadults and children, previously not satisfied with amplification, or considered unaidable. She used ART level at 500, 1000 and 2000 to determine power output settings in recommending hearing aids. She fitted successfully an amplification device to a 4 year old retarded girl who had narrow dynamic range and reflexes at 90 to 95dB SPL with an approximate threshold of 65dB HL. She prescribed an aid which had MPO of 95d8 and 30dB acoustic gain. She concluded that it could be possible to aid a mild to moderate hearing impaired eag with an amplification device which previously would have been unaidable, with the help of acoustic reflex measurements.

Duckch, Keiser and Keith (1975) suggested an acoustic reflex method for setting volume control on hearing aids on young children or othersunable to give reliable reports of hearing aid loudness. The method, originally described by

Keith (1974), proposes to place the hearing aid in one ear and impedance meter probe in the opposite ear. When speech signals are presented at normal levels (70dB SPL), the hearing aid volume control is adjusted to a point where the acoustic reflex is visible on the compliance change meter of the impedance bridge. The volume is then turned down until the acoustic reflex activity is"just absent". That level, according to the authors, should provide relatively comfortable amplification for a patient with a cochlear lesion. The method may also be extended to include the use of frequency modulated tones in a sound field, to assess if the patient is receiving adequate amplification for the entire speech frequency range.

Toto and Ranivelle (1976) also report to use stapedial reflex measurement for hearing aid fittings. They use two methods (i) presentation of a 60dB sound field stimulus while increasing the hearing aid volume on the child to be fitted until the stapedial reflex is elicited. (ii) Adjusting the hearing aid on the patient at full-on-gain or just b low the UCL level, and gradually increasing the signal intensity in the sound field until the stapedial reflex is observed. Test signals can be warble tones in the speech frequency range, wide band or narrow band noise or speech. Infact, those r searchers believe that the test signal can be a sound field speech vowel of Low frequency content, which may elicit better auditory responses from infants than phonemes with high frequency content.

Rainvelle (1977) summarised the possible outcomes of sound field hearing aid acoustic reflex evaluations with threealternatives when bilateral normal tympanograms are present (i) if no acoustic reflex is present, aided or unaided, the patient may have unilateral or bilateral conductive hearing loss or bilaterally profound SN hearing loss (ii) if no reflex is present under unaided conditions, and the reflexes are noted under aided conditions, the patient must have bilateral SN hearing loss with hearing loss in excess of audiometer limits, or (iii) if acoustic reflexes are present under both aided and unaided conditions, the fitting of a hearing aid is appropriate and "real-ear" (functional) gain can be determined. The functional gain of a hearing aid is the decibel difference between the aided and unaided acoustic reflex thresholds.

Rapport and Tait (1976) examined the relationship between acoustic reflex and aided speech intelligibility in 18 patients with SN hearing loss. They were specifically interested in determining if the acoustic reflex could be used to identify the 'proper' hearing aid gain setting to to permit patients to obtain their maximum discrimination for phonetically balanced (PB maximum). The study was conducted by testing aided speech discrimination with monosyllabic words presented in a background connected discourse competing message at a message-to-competition ratio of +10d3 at four hearing aid gain settings for each subject. One of the gain settings was determining by measuring the acoustic reflex for filtered noise in the ear contralateral to the aided ear, while the other gain settings were +10dB and -lOdB relative to the acoustic reflex gain setting, respectively. The fourth gain setting was determined by having the patient adjust the gain to a comfortable level while listening to conversational speece. The acoustic reflex gain setting resulted in a mean word recognition score that was six to seven percent higher than the mean word recognition scores for other gain settings. Close analysis of the experimental results, however, revealed a large degree of variability between subjects and overlapping discrimination scores between different gain settings. More than 60% of the patients obtained their best discrimination score at the reflex threshold setting. While the other three setting produced the best score a relatively equal number of times.

They concluded that the measurements of an 'aided' acoustic reflex does have clinical utility. Although the reflex technique is probably not necessary for moat co-operative, able patients, they point out the important implications for determining gain settings for patients who are unable to select their own 'comfortable' listening level, particularly paadiatric and geriatric patients.

Kursane (1978) found out a linear relationship between vent size and ART (i.e. as ear mold vent size increased, the acoustic reflex was also increased indicating a decrease in hearing aid gain). However, she noticed significant individual variations.

McCandless and Keith (1980) discuss a number of techniques of determining sound saturation pressure level values, with help of acoustic reflexes. They suggest that the output of the aid should be at or slightly above the ART for pure tones 500,1000, 2000 and 4000Hz. Dudich et al (1975) and others suggest that the output of the aid ideally should be set 5 to 8dB higher than the ARTs, since they indicate that pure tones produce higher reflex thresholds than do verbal stimuli. To avoid overamplification and loudness discomfort, the out put of the hearing aid should be restricted to levels just below the point where speech and other stimuli elicit sustained! muscle contraction, but allow for periodic reflex activity caused by short bursts of energy.

The hearing aid gain setting is perhaps more important for children than it is for adults, because adults are able to manipulate the volume controls for the desired listening levels. Gain usually corresponds to the hearing aids users moat comfortable loudness (MCL) level setting. Although additional research is needed in the area of hearing aid fittings as it relates to the ART, there are practical and useful techniques for acoustic reflex measurements with some patients.

According to Northern (1978,p.20) "The role of the acoustic reflex with hearing aids must still be considered to be in its 'developmental' stages. It is not clear if the acoustic threshold represents a definable level of psychological loudness appreciation among hearing impaired persons. Although it is well established that the acoustic reflex is not necessarily related to loudness discomfort, many clinicians advocate its use as a guideline in hearing aid selection. Despite the objectivity of the acoustic reflex method when used to compare hearing aids in terms of 'real ear gain', earmold influence, MPO(ssPL 90), etc., there is need for additional verification through clinical experience and

and research prior to universal acceptance of its provocative procedure for selecting appropriate amplification. Acoustic impedance as an 'objective' hearing aid procedure needs additional refinement; however, acoustic impedance measurements can make important contributions to every hearing aid evaluation, selection and fitting".

AUDITORY BRAINSTEM RESPONSE HEARING AID SELECTION PROCEDURES

This is an objective approach and helps in evaluations as in nonverbal and difficult to test conditions. This was first demonstrated as a change in auditory evoked potential by Rapin and Graziani (1967).

Spreng (1971) used cortical evoked responses while Fristche, Flash and Knothe (1978) used vertex response for the selection of hearing aid.

Clinical applications of ABR are in:

a) Basic ear selection
b) Prescription of hearing aid gain
c) prescription of hearing aid frequency response
d) Output and compression characteristics.

The Parameters used for hearing aid selection are:

a. Wave threshold:

Threshold under aided and unaided conditions are obtained. If improvement is observed in the wave threshold then the hearing aid will be useful and thus helps in hearing aid prescription.

Limitation: It does not give information about supra-threshold auditory function and auditory dynamic range. So, it should be supplemented by information regarding comfort levels, discomfort levels test in quiet and incompetition, discrimination, recruitment estimates, frequency information, hearing aid trial in various listening conditions, etc.

2. Wave latency:

Two aspects of wave latency are considered. They are; (a) ABR absolute latency
(b) Latency intensity function (LIF).

Unaided and aided response should be compared in terms of improvement which is reflected in absolute latency and LI slope normalization.

The four assumptions baaed on Hecox study (1983) are:

i) The greater the displacement of the LIF from normal, the larger the gain requirements, when slope of the LIF is held constant. ABH should diminish the discrepancy between the normal and pathological absolute latencies or the slope of the LIF or both, for the frequency region assessed by the test.

ii) The steeper the LIF, the loss likely that linear amplification will prove superior to compression amplification. The absence of steep LIP does not ensure that compression will not be superior to linear amplification.

iii) There is no communication advantage to having an amplification system, whose operation introduces latencies of less than six m.secs for 60dB HL signals. This could set an objective standard for MPO by establishing that there is no advantage to amplifying speech to a level greater than conversational levels.

iv) Amplification is very unlikely to improve communication behaviour in patients with CAD.

Limitation here are:

a) It is difficult to perform many repeated latency intensity series in the time allowed by hypnotic sedation.
b) It is difficult to finding absolute wave-V latencies in the distorted wave form morphologies of some patients.

3. Amplitude:

Hearing aid settings can be adjusted in accordance with amplitude normalization (Kiessling, 1982).

Amplitude-intensity(AI) projection diagram determines gain, dynamic range, compression types,compression factors and compression onset level.

Combined approaches and considerations:

Stecker (1982) suggests use of combination of threshold, latency and amplitude in hearing aid selection.

The procedure suggested, after unaided measurements, is to carry out the following: aided measurements

a) Assess gain of hearing aid by rotating the hearing aid volume control to a point where the wave V latency stabilizes and its amplitude saturates.

b) At this level record L-I slope at various frequency and compression settings to determine most favourable amplified dynamic range.

c) Estimates of compression are to be made by unaided A-I function.

d) Choose the hearing aids whose compression variations demonstrate little or no effect on gain.

Disadvantages of ERA selection procedure are:

a) Hearing aids with compression circuits cannot be evaluated because, their circuits cannot follow the very fast stimulus rise time necessary to elicit ABR (Levillain et al. 1979; Keissling, 1982; and Stacker, 1982).

b) High frequency emphasis of ABR asuring aid evaluation procedure, i.e. reflects a frequency range of 1000-4000Hz. (Coates, and Martin, 1977; Moller and Blegeady (1976), by using clicks.

Tone pips can be used to assess low frequency amplification (Cox and Metz, 1980; stecker, 1982).

3. It has limited use in selecting amplification in severe and profound hearing losses cases.

FUTURE PERSPECTIVE IN HEARING AID SELECTION

The selection of hearing aids is presently hindered by four major problems (1) difficulties in making rapid adjustments to the test aid, (2) lengthy time requirements for the necessary measurements and comparisons (3) problems of reliability in these measurements and, most importantly (4) Unknown validity of the final selection.

According to Pascoe (1985) these problems can be avoided in the forseable future, when hearing aids and their selective procedures begin to make greater use of computer technology. The probable advent of digital hearing aids, aids that will be truly programmable, aids that can function as computer - controlled audiometers, master hearing aids and wearable aids all in one unit, will give us the tools to solve the major problem. The preselection of primary aid characteristics should be brief and based on either precriptive, comparitive or electrophysiological procedure. The selected characteristics can then be tested with other alternative responses, either in paired choice comparisons or with adaptive schemes that can be programmed. The comparison could either be interms of quality or speech discrimination efficiency.

Corell et al (1983) also suggests a fitting procedure using computers. They developed a computer program for hearing aid selection and used a small microcomputer (ABC 80, 16K Byte). With the programme, the computer recommends a number of hearing aids with adjustment specifications on the basis of audiological and non audiological data obtained from the patient.

Their programme consists of two parts. In the first part suitable hearing aids are selected from a selection of hearing aids on the basis of data store in the computer. A hearing aid is selected if it can be adjusted to give the calculated frequency and output response. In the second part the recommended control settings and type of ear mold are calculated.

However, Pascoe (1985) believes that computers and digital hearing aids will not solve all our problems of hearing aid selection. According to him, it should allow us to do more and to do it faster since better tools can help us to achieve the goals which Davis (1946 cited by Pascoe 1985, p.947) has described as: "to improve communication and maintain auditory comfort, thus increasing the enjoyment of life for those whose hearing has become a problem". Pascoe also suggests that the human touch and understanding in hearing aid selection becomes one of the primary needs.

In conclusion, it may be said that procedures are now available to the audiologist for the selection of hearing aids. These range from comparitive methods at one end to objective and computer aided fittings on the other. If one studies these carefully, it would be evident that some procedures consider only electroacoustic characteristics of hearing aids (Byrne, 1976 and others) for prescription purposes, while other consider real ear measurements (Libby, 1985 an* others) alone. There are yet other which go to the extent of what is known to be "throw-the-hearing-aid-on" procedures (cited by Schimtz, 1980) Where in, the customer himself chooses a hearing aid without any professional audio—logic advice.

with the growth in technology, equipment are now available with the help of which electroacoustic data of hearing aid could be measured precisely within a short time. While this information would largely improvise prescriptive procedures it must be remembered that such procedures do not consider the interaction between the electroacoustic parameters with the psychoacoustic processes involved. In other words, what may be predicted as an optimal requirement may not prove to be the ideal choice. This therefore calls for a middle-of-the-road approach. Such an approach would include the utilization of electroacoustic data and the prescriptive principles for selection of hearing aids followed by actual assessment or the client himself with a range of hearing aids that meet the predicted requirements. Such a combination may help reach the goal, that of selecting the optimal amplification device.

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