HEARING AID SELECTION PROCEDURE COMPARISON OF PRESCRIPTION OF GAIN AND OUTPUT (POGO) VERSUS FUNCTIONAL SPEECH MEASUREMENTS

Reg. No. M 9605

AN INDEPENDENT PROJECT SUBMITTED IN PART FULFILLMENT FOR THE FIRST YEAR MASTER'S DEGREE IN SPEECH AND HEARING TO THE UNIVERSITY OF MYSORE

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MYSORE - 570 006
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DECLARATION

This independent project entitled HEARING AID SELECTION PROCEDURE: COMPARISION OF PRESCRIPTION OF GAIN AND OUTPUT (POGO) VERSUS FUNCTIONAL SPEECH MEASUREMENTS, is the result of my own study, under the guidance of Dr. (Mrs) Asha Yathiraj Reader in Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other Diploma or Degree.

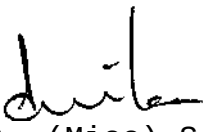
Mysore,

May 1997. Reg: No. M9605

CERTIFICATE

This is to certify that this Independent Project entitled HEARING AID SELECTION PROCEDURE: COMPARISON OF PRESCRIPTION OF GAIN AND OUTPUT (POGO) VERSUS FUNCTIONAL SPEECH MEASUREMENTS, is the bonafide work, done in part fulfillment for the first year of the Master's Degree in Speech and Hearing, of the student with Registration No. M-9605.

Mysore
May 97.



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CERTIFICATE

This is to certify that this Independent Project entitled HEARING AID SELECTION PROCEDURE: COMPARISON OF PRESCRIPTION OF GAIN AND OUTPUT (POGO) VERSUS FUNCTIONAL SPEECH MEASUREMENTS, has been prepared under my supervision and guidance.

Mysore
May 97.

Asha Yathiraj.

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INTRODUCTION

Man is highly dependent on his senses. It is through his senses that he is able to feel and experience the world around him. Of the five senses, hearing is one of the most important sense. It forms a vital link to the world of communication.

Hearing is essential for the acquisition of speech and language. It is through hearing of speech and other sounds in the environment that a child is able to acquire language. The hearing mechanism is also essential for monitoring one's own speech production. In addition, hearing also enables an individual to make judgements regarding the location of the different sound sources in the environment [Yost, 1994],

Impairment of hearing, therefore, not only renders a person unable to appreciate the different sounds present in his environment, but also reduces his capacity to understand and produce speech.

The communication difficulties experienced by the hearing impaired are proportionate to the severity of hearing impairment [Newby & Popelka, 1992]. The hearing impairment also produces some psychological maladjustment in the individuals. These psychological difficulties arising from the hearing loss, may sometimes become a greater problem for the hearing impaired person than the communicative difficulties [Newby and Popelka, 1992].

The problem can be mitigated by providing amplification. Amplification represents the single most important rehabilitative tool available to the hearing impaired population. [Ross, 1975; Ross & Giolas, 1978; Bess & McConnell, 1981]. Amplification devices provide a valuable communicative link between the hearing impaired listener and his acoustic environment.

Historically, there have been numerous divergent trends in the successful hearing aid fitting procedures. It is important to give a special consideration to the various procedures used for assessing the amplification devices, because, inappropriate or misused amplification can substantially degrade the communication ability and under certain conditions, can cause additional damage to the auditory system (Rintelmann & Bess, 1977; Humes and Bess, 1981).

Davis and Mueller (1987) have described the various hearing aid fitting procedures as either comparative or prescriptive methods.

The essence of the comparative hearing aid selection technique is to evaluate a number of hearing aids on the patient with hearing impairment, conduct some type of formal or informal speech based measurement with each hearing aid and then pick the best performing hearing aid for fitting. This technique is a direct descendant of the well known procedure described by Raymond Carhart (1946).

The comparative hearing aid evaluation was reported to be the most popular method (Smaldino & Hoene, 1981) compared to the other hearing aid selection procedures despite the fact that it has poor reliability and fitting validity.

The prescriptive hearing aid evaluation method, on the other hand, is based on the assumption that, given either a patient's puretone auditory thresholds. Most Comfortable Level (MCL), or Uncomfortable Levels (UCL), the appropriate amount of gain for each frequency can be calculated mathematically and optimum aided speech intelligibility can be obtained through a pre-determined formula. There are numerous prescriptive formula available. Some of the most popular ones are POGO (McCandless and Lyregaard, 1983), NAL (Byrne and Tonnison, 1976), Berger (1977).

To ensure that the fitting is appropriate and effective, every prescriptive selection procedure includes a technique to validate the final fitting. The various clinical validation techniques include the functional gain where the aided and unaided free field threshold are measured and compared using FM tone or narrow band stimuli; speech reception threshold; speech discrimination test and the subjective verification of comfort and clarity (Tate, 1994).

To date, no standardized technique for final validation are widely used (Walker et al. 1984).

More recently, the real ear insertion gain measurements have gained impetus and are increasingly used to validate the prescriptive gain target. The insertion gain measure provides an objective measure of the gain provided by the hearing aid.

It is, however, important to emphasize that real ear insertion gain measures are not a method of fitting hearing aids (Mueller, 1989). A real ear insertion gain matched to a prescriptive target gain, does not assure that the fitting will be successful and that the speech understanding ability has been maximized. In other words, there is no guarantee that the optimal fitting has been achieved (Mueller, 1992).

As outlined by Bratt and Sammeta (1991), the prescriptive targets should only be preliminary goals with the final real ear insertion gain response determined through the use of speech measures; assessment of individual needs and subjective reports of the hearing aid user.

NEED FOR THE STUDY:

Several studies have compared the prescribed gain with the use gain (Ryals and Auther, 1990; Byrne and Cotton, 1988; Davies and Muller, 1987) and the insertion gain with functional gain (Zemplenyi, Dirks & Gilman, 1985; Mason and Popelka, 1986; Tecca and Woodford, 1987). However, there are very few studies which have compared the effectiveness of a hearing aid fitting when the real ear insertion gain deviated

from the prescribed target gain and its effect on the speech understanding ability of the hearing aid uses. Therefore, there is a need to study the deviation of the gain of the hearing aid from the prescribed target and its effect on the speech understanding ability. There is, also, a need to investigate whether the deviation from the pescribed target can be considered acceptable or not. Hence, the present study was attempted.

AIM OF THE STUDY:

The aim of the study was to evaluate the relationship between the insertion gain using the POGO prescriptive formula (McCandless and Lyregaard, 1983) and the functional gain using the speech material under the following conditions:

a) When the gain was matched with the target gain in the speech frequencies,
b) When the gain of the hearing aid was overshooting the target gain in the speech frequencies,
c) When the gain of the hearing aid was under shooting the target gain in the speech frequencies.

REVIEW OF LITERATURE

The hearing aid evaluation procedure is a highly interactive process which involves adapting the hearing instrument to a particular individual (Mueller, Hawkins & Sedge, 1984). This challenges the expertise of every audiologist, who finds himself with a myriad of fitting methods that have been utilized with varying degrees of commitment.

Hearing aids vary in their electroacoustic output and the functions that they provide. Hence, a detailed hearing aid evaluation has to be performed for each individual to select the appropriate hearing aid that would best suit the individual's needs.

The search for an universally acceptable approach to hearing aid selection continues and the solution also continues to be elusive (Libby, 1985).

Although each dispenser develops his or her own specific selection procedures, some general principles and procedural categories exist that permit the description of various approaches.

COMPARATIVE PROCEDURES:

The comparative procedure was described by Carhart (1946).

The Carhart comparative procedure goal was to select the best hearing aid based on the percentage of correctly identified monosyllabic words. He recommended the ranking of hearing aids from a limited number of models by making comparisons of the aided thresholds and speech disrimination in quiet and noise. The hearing aid that produced the highest speech discrimination score was selected.

As Carhart was describing his recommended formal speech-based comparative evaluation, the Harvard report strategy was published (Davis, Hudgins, Marquis, Nichols, Peterson, Ross& Stevens, 1946). This report proposed that the utilization of hearing aids having either a flat frequency response or a rising 6 dB per octave frequency response was sufficient for all persons with impaired hearing requiring amplification.

There are a number of well recognized limitations to the comparative hearing aid selection procedure. The comparative procedures are time consuming. Also, as it is not possible to match every hearing aid against every other possible hearing aid, the audiologist selects only a few hearing aids for the listener to compare, thereby limiting the number of comparison.

Jerger (1987) pointed out that the monosyllable word scores do not rank order the different hearing aid systems in a sufficiently reliable fashion. Mueller and Grimes (1983) showed that the variability of speech materials used in the comparative procedures may actually be greater than

the differences among the hearing aids under evaluation. Shore, Bilger and Hirsh (1960) reported that speech discrimination testing using monosyllable words in quiet or background noise did not reveal the differences among the hearing aids. These findings were also confirmed by Jerger, Malmquist and Speaks (1966).

Nontheless, inspite of the limitations, the comparative hearing aid evaluation was reported to be the most popular method used by audiologists (Smaldino and Hoene, 1981).

PRESCRIPTIVE APPROACH:

The prescriptive approach refers to the tailoring of frequency response curve of a hearing aid in conformance with the client's audiogram (Rose, 1978).

Over the past few decades, there has been a dramatic shift in the way the hearing instruments were selected and fitted with many audiologists turning to the theoretically based prescriptive methods. Humes and Houghton (1992) attribute the following factors for such as trend. Firstly, to overcome the fundamental problems of the comparative approach. Secondly, evidences suggest that the gain characteristics of the hearing instrument should be individually tailored to the person's hearing loss. Finally, it is more feasible to use methods that require matching of observed gain to prescribed gain characteristics on an individual basis.

Proponents of prescriptive amplification suggest that the gain of the hearing aid should increase in the frequency-regions where the hearing loss increases so that the improved listener could attain better audibility. The hearing aid gain prescriptions often incorporate an adjustment to compensate for the fact that normal speech contains more low frequency-energy than high frequency energy. These prescriptions generally provide for less low frequency gain and greater high frequency gain.

There are numerous prescriptive formula available. Some of the prescriptive procedures utilize the thresholds while others utilize the Most comfortable loudness level.

The 'threshold based procedures' have the advantage that they are applicable to almost all the patients since they require only the ability to detect the presence of a sound.

The 'loundness based procedures' on the other hand, have the apparent advantage of providing more genuine information about a patient's auditory functioning. But the major disadvantage of this procedure is that not all patients can make loudness judgements. The test retest reliability is better with threshold procedures.

The various prescriptive methods based on the threshold are;

1) Mirroring of audiogram (West, 1937)

2) Byrne & Tonnison method (1976)

3) Bergers formula (Berger et al.19 77)
4) NAL (Byrne & Dillon,1986)
5) Lybargers formula (1944)
6) Libby's method (1985)

The prescriptive procedures based on the Loudness are;

1) Equal loudness contour procedure (Watson and Knudson, 1940).
2) Bissection of dynamic range (1967)
3) Shapiros method (1976)
4) Zelnick's formula (1982).

Martin and Morris (1989) reported that 71% of audiologists used a prescriptive fitting procedure and that 75% of them used either the Berger method, the POGO procedure or the NAL formula.

The following section gives a review of studies that have been conducted using the POGO formula.

POGO - PRESCRIPTION OF GAIN & OUTPUT:

The POGO was given by McCandless and Lyregaard in 1983. The POGO fitting method is used predominantly for individuals with sensoryneural hearing loss of less than 80 dB HL.

The underlying principle is that a sensory-neural hearing loss is accompanied by recruitment. Hence, sounds of low or moderate intensity are inordinately weak or inaudible, whereas intense sounds are as loud as they would

be for a normal hearing person and therefore would not require any amplification.

The application of half-gain principle results in the same amplification for both weak and intense sounds and leads to poor speech intelligibility in noise due to the upward spread of masking from low frequency ambient noise. Therefore, to ensure that the sound levels which are most important in daily life be audible without being excessively loud, the POGO method includes an additional reduction of gain at low frequencies. McCandless & Lyregaard (1983) pointed out that the speech intelligibility is not the only relevant property, but poor sound quality may also lead to rejection of hearing aid.

McCandless and Lyregaard (1983) have described three basic steps in using POGO.

Step One :- Calculation of the required characteristics. The required insertion gain in calculated by the formula.

Frequency (H2)	Insertion gain (dB)
250	1/2 HL -10
500	1/2 HL -5
1000	1/2 HL
2000	1/2 HL
3000	1/2 HL
4000	1/2 HL

The maximum power output (MPO) is equal to the average UCL in dB HL at 500, 1000, 2000Hz.

$$MPO = \frac{UCL500 + UCL1ooo + UCL2000}{3}$$

Step Two :- Implementation of required gain and MPO.

This step entails the selection and adjustment among the hearing aids.

It is determined if the required MPO is within the adjustment range of the aid. The maximum required insertion gain in the region of 500-2000 H2 is found and checked whether this maximum is within the adjustment range of the aid, allowing for $\pm$ 10 dB reserve gain.

Finally, the required insertion frequency response is compared with the responses available for each aid. McCandless and Lyregaard claim that with most hearing aids, the frequency response in the region of 250-2000 H2 should predominantly fit.

The step three: Involves the verification of the acoustic performance. Both the insertion gain and MPO should be checked in-situ on the ear.

MODIFICATION OF POGO:

Since the POGO procedure was designed for persons with only mild or moderate SN hearing loss, it is not applicable for patients with severe to profound losses. Hence to

optimize the speech reception at a comfort level gain setting for patients with severe hearing loss, a modification of the POGO had been designed by Schwartz, Lyregared, and Lundh (1988), called as the POGO II. Schwartz et al.(1988) found that for hearing losses beyond 60 dB, MCL grows at a higher rate than one-half gain. On the basis of these data, the original POGO formula (which represents a 1:2 ratio of gain to hearing loss) was modified to a ratio of 1:1 for hearing losses above 65 dB.

The formula for POGO II is given below;

a) For hearing losses < 65 dB

Insertion gain = 1/2 HL-C

where C = 10 dB at 250 Hz and

C = 5 dB at 500 Hz.

b) For hearing losses > 65 dB

Insertion gain = 1/2 HL - C + 1/2 (HL-65)

where C = 10 dB at 250 Hz & 5 dB at 500 Hz.

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

Advantages of POGO I & II:

1) The POGO procedure is simple (Mueller, 1992)
2) The POGO procedure is more practical (Mueller, 1992)

3) Both POGO I & POGO II, provide the hearing aid fitter with a simple and rapid estimate of the gain for frequencies needed to make speech optimally audible, while maintaining within the comfort ranges for long-term listening.

4) POGO II is useful in attempting to fit patients whose hearing loss magnitude changes across frequency.

However, no studies have been published on the accuracy or validity of the procedure.

Smriga (1984) evaluated 48 sensorineural hearing impaired adults for amplification using the POGO prescription and reported that POGO system appeared to improve the fitting accuracy. Also, there was a substantial user satisfaction in terms of sound quality.

In a survey conducted by Martin & Morris (1989) the POGO method was reported to be most frequently used fitting method. The survey also indicated that POGO method was an easy method to use in the clinical assessment process and was able to meet the acoustic needs of the patient. POGO method offered the best approximation of absolute electroacoustic characteristic responses required by the patient.

Lyregaar d (1986) studied the practical validity of POGO prescriptive formula using the BTE & ITE hearing aids. Twenty nine experienced hearing aid users were selected and the custom ITE hearing aids were manufactured in accordance with POGO and the tone balance was assessed using a questionaire.

Results indicated that 83% rated the tone balance "very good" or "good", 17% rated it 'average', whereas no one rated it "poor" or "very poor". This suggested that the insertion gain predicted by POGO was satifactory.

Snik and Hombergen (1993) compared the measured insertion gain to the desired gain resulting from prescriptive rules in the preschool children, primary school children, and adults and reported that POGO method was most appropriate for the children, while for adults the measured insertion gain was lying between the values prescribed by the half gain rule and one third gain rule. The results also indicated that the overall level of insertion gain was 7dB higher in the children group than in the adult group.

Snik, Vander Borne, Brokx and Hoekstra (1995) studied sixteen children with profound sensory neural hearing loss and compared the measured and calculated insertion gain using POGO II, Desired sensation level method & NAL-R. The results of this study , however, indicated that POGO II gave the most deviation in results. At 1 KHz and 2 KHz , a discrepancy of 12 dB or more was found between the calculated and measured insertion gain. Compared to the higher frequencies, POGO-II prescribed little gain at 250 Hz and 500Hz. Snik et al. (1995) reported that although such reductions are beneficial in patients with mild to moderate hearing loss, for patients with severe or profound hearing loss, amplification in the

low frequency region is of great importance for the speech recognition.

Byrne (19.7) compred the prescribed frequency responses from six theshold-based methods., Berger method, Byrne and Tonnison method (1976), Lybarger (1944) method, NAL-R (1986). POGO (1983) 4 Libby (1985) and found that the frequency responses were quite different across the six prescriptive methods. The high frequency slopes prescribed by the POGO method were significantly greater than those prescribed by Berger and Byrne and Tonnison methods. On performing the clusters analysis to assess the degree of similarity among these six prescriptive methods, the revised NAL, the POGO and Lybarger methods were grouped as members of one cluster while the Berger and Libby were members of one cluster.

Humes (1986) evaluated seven audiometric configuration using ten prescriptive methods which included POGO, NAL, Berger, Libby (1985), Cox (1983), Shapiro (1976) and found that different gain selection rationales resulted in the selection of different hearing aids for a given patient.

Punch and Patterson (1990) studied the extent of differences in both target gain and the target coupler gain values using the four prescriptive formulae, Berger (1977) POGO and NAL-R(1986). Three simulated audiometric configuration employed were a flat moderate hearing loss, a gradually sloping loss of mild degree in the speech frequency and a steeply sloping loss. The results indicated that of

the four prescriptive formulae, the Berger rule calls for the highest gain, NAL-Rrequires the least gain. The Lybarger and P060 methods required an intermediate and a very similar amount of gain. Punch and Patterson (1990), however, reported that these differences were substantial at 500, 1000 and 4000 Hz, with the degree of variation dependent on loss and slope.

Ryals and Auther (1990) compared the preferred insertion gain values of elderly (> 75 years) and younger (< 60years) subjects to the gain values predicted by the POGO (1983), NAL-R(1986), Berger (1977) and 1⁄3 gain formulae. They found that for both POGO and Berger methods, there was significantly more predicted gain than preferred gain. However, for the NAL'R and 1⁄3 gain methods, there was no significant differences between the average predicted and preferred gain. Further; no age effect was observed for average insertion gain. Ryals and Auther (1990) also reported that formulae that predict relatively low gain values provide appropriate target insertion gain values for older adults.

Berger (1989) plotted the predicted aided responses from three prescriptive hearing aid methods; Berger, NAL and POGO for seven hearing loss patterns, which included two flat losses, two moderately sloping down and two steeply high frequency loss and one low frequency loss. The aided responses were then compared to the range of soft speech and

loud speech- The soft speech was considered as averaging 55 dBSPL and loud speech as averaging 75 dB SPL. The results indicated that POGO method encompassed more of the loud speech energy while, Berger method encompasses slightly more of soft speech energy. Berger (1989) reported that the predicted aided thresholds differed less between the Berger and POGO methods than between Berger and NAL or POGO and NAL methods. Further, the three methods provided for adequate gain for soft speech at majority of the frequencies.

Humes and Hackett (1990) compared the measured insertion gain and that prescribed by the revised NAL, POGO-II and revised MSU method and found significant differences among the three methods in the prescribed frequency responses but not in the obtained frequency response. Humes .and Hackett (1990) also compared the speech recognition results and found no significant differences in the speech recognition performances in both noise and quiet among the instruments selected by each of the methods. Humes and Hackett (1990) reported that all the three prescriptive methods result in similar amount of benefit being derived from amplification with the largest improvements occurring in quiet.

Berger (1990) compared the three hearing aid prescriptive methods, that is, POGO, Berger method and NAL methods with the modified Articulation Index. He found that the articulation index ranged from 0.58 to 0.96 for the POGO method. The Berger method produced the highest articulation

index (0.56 to 0.98) while the NAL method produced the lowest articulation index (0.26-0.86). The differences in the articulation index between the three method was, however, small.

Rankovic (1991) also applied the articulation index to compare the amplification characteristics specified by NAL and POGO prescription. Results indicated that POGO prescription made the average speech spectrum more audible than the NAL prescription for all subjects. Also, the POGO and NAL prescriptions never prescribed gain that would amplify the speech peaks beyond the calculated UCLS.

Rankovic (1991) further reported that the frequency gain characteristic that maximized the audibility of the speech spectrum required more gain than either the NAL or POGO prescriptions. Also, for the AI max condition, the speech spectrum was selectively amplified so that the long term average one-third octave band level of speech in each band was 18 dB above the pure tone threshold when both speech and thresholds are expressed in spectrum level units.

Rankovic (1991) also reported that AI max condition did not always improve performance over that observed under amplification recommended by the prescriptive rules, but more importantly, did not degrade the performance for the majority of ears.

Humes (1986) has indicated that many of the contemporary prescriptive hearing aid selection methods do not differ in regard to the aided speech recognition performance.

From most of studies quoted, it is evident that most of the prescriptive techniques appear to provide an acceptable theoretical basis for the fitting of the amplification. And, although, there are significant differences in the amount of prescribed gain under various formulas, there have been, to date, few evaluative studies regarding the relative success of one formulae over the other (Humer 1986, Byrne 1987). It therefore, becomes the responsibility of the clinician in determining the specific prescriptive approach to be used.

Bratt and Sammeth (1991) have, recommended a four point rational:

1. Hearing aid fittings should be designed to achieve a goal that has a scientific basis and empirical validation, with measurable targets in terms of 2-cc coupler and real ear insertion gain.

2. Individual rather than the averaged data should be incorporated into the target calculation and fitting whenever possible.

3. The hearing aid performance should be verified in term of 2-cc coupler and REIG or functional gain.

4. The prescribed targets should be considered only as preliminary goals, with the final fitting characteristics dictated by measurement of aided responses to speech or speech like stimuli and by the individual needs and desires of the patient.

Kankle and Molloy (1995) also viewed that regardless of the prescriptive method used, it is very important to verify that an individual's hearing aid meets the specifications of the given prescription.

STUDIES COMPARING FUNCTIONAL GAIN AND INSERTION GAIN:

Research indicates that both functional gain and insertion gain measurements are essentially the equivalent methods for measuring the same aspect of the hearing aid performance. The insertion gain determines the difference in SPL developed at a given point in the auditory canal for unaided and aided conditions. The functional gain determines the difference in the sound-field thresholds for unaided and aided conditions. Both methods account for individual differences in ear geometry, acoustic characteristics of the individual ear and acoustic coupling factors. (Dillon and Murray, 1987., Mason and Popelka, 1986).

Zemplenyi, Dirks and Gilman (1985), Mason and Popelka (1986), Dillon and Murray (1987), Tecca and Woodford (1987), reported that insertion gain and functional gain were essentially equivalent measures.

Killion (1980) reported that it is possible to obtain good agreement between insertion gain and functional gain measurements.

Causey and Beck (1976) found less than a 2 dB difference at most frequencies between insertion gain of an over the ear hearing aid measured on KEMAR and the average functional gain measured on a group of subjects with sensory-neural hearing loss.

Popelka and Mason (1986) compared functional gain to insertion gain measured with a probe-tube microphone system and found that the average difference across the frequencies was less than 1 dB.

Tecca and Woodford (1987) also found that functional and insertion gain methods provided equivalent results on the average. However, they noted that very few cases agreed within $\pm$5 dB at all frequencies while most other cases agreed within +10 dB at all frequencies. Tecca and Woodford (1987) attributed these differences to the combined error associated with the measurement variables of both procedures.

Stelmachowicz and Lewis (1988) reported that the insertion and functional gain may not agree in the following three circumstances:

a) In high gain hearing aids with a relating low maximum output.
b) In cases of non linear hearing aids.
c) In cases of patients with profound SN loss.

They reported that in such conditions, the insertion gain provided a valid estimate of the real-ear gain because these measures are obtained at supra threshold levels.

Many of the audiologists prefer to use the insertion gain measurements because of the limitations of the functional gain. Since functional gain is based on behavioral measurements, all the well-known factors leading to the variability noted in the behavioural auditory tests will influence the functional gain results as well. Functional gain measurements are often time consuming. Considerable attention must be given to the careful callibration of the test stimuli and masking of the non-test ear. The internal hearing instrument noise and the amplified ambient noise may both lead to invalid functional gain measurements.

The insertion gain measurements, on the other hand, provide an objective measure of the gain provided by a hearing aid. The verification of a prescription in difficult-to-test patients, like children is also best accomplished by using the insertion gain methods.

Hawkins and Mueller (1986) reported that though the insertion gain measurements are a reliable and more rapid substitute for functional gain measurements, they are not, however, a substitute for speech testing.

Humes (1991) reported that aided speech audiometry is essential, even if there is a perfect match between the insertion gain and the prescribed target. Since patients seek amplification because they are unable to understand speech, it seems reasonable to determine if speech understanding has been maximized, or at least improved, before the fitting is considered appropriate.

Pascoe (1980) commented that both real ear insertion gain and speech audiometry play an important role in the validation of the hearing aid fitting and it would be best to incorporate both measurements into the hearing aid evaluation.

Further, Mueller, Byrant, Brown & Budinger (1991) reported that it is also important to consider the patients subjective judgements. Sometimes patient's subjective judgement may not indicate an optimum fitting even when the REIR is a perfect match to the prescriptive gain targets. The solution in such cases involve making certain deviations from the prescriptive gain target.

Audiologists are not in agreement concerning what Real Ear Insertion Gain (REIG) - prescriptive target gain match constitutes an acceptable fitting.

In a survey conducted by Mueller et al.(1991), even the Real Ear Insertion Gain with greatest deviations from the prescriptive target was judged as acceptable by nearly one-

half of the audiologists, yet a number of audiologists did not consider even the 'best' REIR as acceptable.

Mueller et al.(1991) discussed two different approaches to establishing a cut off for Real Ear Insertion Gain-target gain differences.

The ideal approach was to fail the hearing aid if the deviation from the target gain was great enough to cause a significant decrease in the patient's speech understanding ability.

The second approach for establishing an insertion gain pass or fail protocol is to compare the REIG-target gain differences for a given patient to similar measures obtain from a large pool of hearing aid fittings. The hearing aid would be judged as good on bad, based on deviations from the target.

To assist in determining what deviation from the target can be considered clinically acceptable or least tolerable, Bratt and Sammeth (1991) compared the percentage of hearing aids that would be considered acceptable as a function of the REIG deviation from NAL prescriptive formula and the POGO method.

They reported that the fitting error is similar for the two methods in the low and mid frequencies. However, at 3000 and 4000 Hz the fitting error for the POGO method is about 5

dB larger than that obtained using NAL. This finding is a reflection of the fact that POGO gain targets are higher than NAL targets at 3000 & 4000Hz, when a downward-sloping hearing loss is present.

Bratt and Sammeth (1991) emphasized that the target values are only a starting point and may need to be altered based on speech testing and subjective responses from the hearing aid user. The real ear insertion gain measurements provide a useful method to validate the prescriptive gain targets. But, these measures are not sufficient for fitting the hearing aids. Even when the REIR measurements are in good agreement with the prescribed gain target, there is no guarantee that the optimal fitting has been obtained. The prescribed targets should be only preliminary goals, with the final REIR determined though the use of speech measures.

Further, research studies are required in this regard to provide answers to questions like how much of deviation from the target gain could be acceptable and what are the effects on the speech performance.

A preliminary attempt has been made in this study to study the effect of the deviation from the target gain prescribed by POGO formula on the speech understanding ability.

METHODOLOGY

a) SUBJECTS :

Eleven subjects including ten males and one female were selected for the study. The subjects fulfilled the following criteria.

i) The subjects had sensory-neural hearing loss with the degree varying from moderate to moderately severe.

ii) All the subjects had the speech identification scores of above sixty five persent.

iii) The immittance audiometry revealed no middle ear pathology

iv) All the subjects underwent an ENT checkup to rule out the presence of any external or middle ear problem.

v) All the subjects were Kannada speakers.

b) INSTRUMENTATION:

The following instruments were used for the study.

i) The FONIX 6500-C, hearing aid test system was used to perform the real ear measurements. The instrument was calibrated as per the instructions given in the operations manual (appendix-I)•

ii) The clinical audiometer Madsen OB822 with matching loudspeakers was used for performing speech audiometry. The instrument was calibrated as per ANSI S3-26 (1989) standards (Appendix-III).

iii) A moderate gain hearing aid was used for the study. The electro-acoustic properties of the hearing aid were in accordance with the IS (1984) standards.

c) TEST ENVIRONMENT:

Both the probe-tube measurements and the speech audiometry were carried out in sound treated rooms where the ambient noise levels were within the permissible limits (IS [1991] Standard).

d) TEST SIGNAL:

For the probe measurements, a composite tone signal wa3 presented through the loudspeakers at an intensity of 70 dBSPL.

e) TEST MATERIAL FOR SPEECH:

Paired words and everyday sentences (appendix IV) in Kannada which were developed in the department of Audiology, All India Institute of speech and Hearing, were used for the speech audiometric test.

f) TEST PROCEDURE:

a) For **real ear Measurements:**

Pre-measurement Procedure: The leveling of the instrument FONIX 6500C was carried out prior to the measurements (appendix II).

The audiometric data was fed and the target gain curve was obtained using the POGO formula given by Mc Candless& Lyregaard, 1983, (appendix V).

The subjects were seated 12 inches from the loudspeaker. The loudspeakers were placed at a 45° azimuth relative to the patient's seating. The head band was secured above the ears and the ear hanger was placed around the ear to be tested. The reference microphone was placed firmly over the head band. The probe tube was placed in the ear of the subject such that it extended 5mm beyond the canal portion of the ear mold. The probe tube was then marked with a marker pen. The patient was instructed to look straight and not to move or talk until the test was complete.

Probe measurements: The following steps were carried out to obtain the real ear probe measurements.

* Initially, the Real Ear Unaided Response (REUR) was measured. This response gave the information regarding the ear-canal resonance.

* The ear mold was then placed along with the probe tube and the hearing aid was switched on, and the Real Ear Aided Response (REAR) was obtained.

* The Real Ear Insertion Gain (REIG) was determined automatically by the instrument.

* The tone and the volume controls of the hearing aid were adjusted such that:

    a) The insertion gain curve matched the target gain curve in the speech frequencies,

    b) The insertion gain curve was undershooting the target gain curve by about 5-10 dB in the speech frequencies,

    c) The insertion gain curve was overshooting the target gain curve by about 5-10 dB in the speech frequencies.

The settings of the tone and volume controls in the above three conditions were noted.

PRECAUTIONS TAKEN WHILE CARRYING OUT THE PROBE TUBE MEASUREMENTS:

i) Care was taken to exclude the reflecting surfaces in the testing conditions.

ii) Head movements on the part of the patient were avoided as these might affect the measurement.

iii) A constant insertion depth of the probe-tube was maintained throughout the measurement.

iv) Care was taken to ensure that the loudspeaker azimuth was always maintained at 45^0.

v) During the Real Ear Unaided Response (REUR) measurements, negative values were obtained whenever the probe tube was crimped or the tip was directly against the wall of the canal. Reinsertion or removal of the crimp was done to solve the problem.

vi) During the Real Ear Unaided Response, it was ensured that the ear mold fitted 3nugly in the concha so that low frequency leakage was minimized.

b) PROCEDURE FOR SPEECH AUDIOMETRY :

The subject was seated one meter away from the loudspeaker, which was placed at a 45° azimuth.

The speech material consisting of paired words and everyday sentences in Kannada were presented through the loudspeakers in the free-field condition using the clinical audiometer Madsen OB822. The intensity level was kept at 40-45 dBHL. The subject was instructed to answer the questions and to repeat the paired words. The item was repeated a second time when the subjects did not answer. The aided performance was assessed at the different volume and tone settings obtained through the probe measurements. And the

scores were noted. A score of two was assigned for each correct response and a score of one was assigned when the correct response was obtained after the item was repeated.

RESULTS AND DISCUSSION

The main purpose of the study was to find out whether there was any significant difference in the speech understanding ability of the hearing aid user when the insertion gain matched the prescribed target gainusing POGO formula developed by Mc Candless and Lyregaard (1983) and when the insertion gain deviated from the target gain by overshooting and undershooting the target gain curve.

The data was collected based on the methodology given in the previous chapter. The mean and standard deviation values for sentences & paired words were tabulated (table A & B respectively).

TABLE A: MEAN AND S.D VALUES FOR SENTENCES AT DIFFERENT HEARING AID VOLUME SETTINGS

	UNDERSHOOTING	MATCHING	OVERSHOOTING
Mean (maximum score = 10)	4.818	8.454	9.909
S.D	2.367	2.871	0.286

TABLE B: MEAN AND S.D VALUES FOR PAIRED WORDS AT DIFFERENT HEARING AID VOLUME SETTINGS

	UNDERSHOOTING	MATCHING	OVERSHOOTING
Mean (maximum score = 10)	4.363	7.454	8.909
S.D	2.185	2.965	1.708

The non-parametric statistical analysis was carried out * using the t-Test (Garrett, 1966). The t-scores for both sentences and paired words were calculated.

TABLE C SHOWING SIGNIFICANCE OF **DIFFERENCE BETWEEN** MEANS FOR DIFFERENT VOLUME CONTROL SETTINGS.

	SENTENCES	PAIRED WORDS
Between Undershooting and Matching	*3.06	*2.657
Between Overshooting and Matching	1.597	1.345

* Statistically significant at 0.01 levels.

The analysis of t-scores indicated that:

a) There was a significant difference in the speech performance of the subjects for both sentences and paired words between the undershooting and the matched conditions. The t-scores were found to be significant at the 0.01 levels of significance.

b) There was, however, no significant difference in the performance of the subjects for both sentences and paired words between the matched and the overshooting of the prescribed target gain curve condition. The t-scores were found to be not significant even at 0.05 levels.

Thus, from the above study, the following conclusions were drawn.

a) The deviation from the prescribed target gain tends to significantly affect the speech understanding ability of the

subject only when the measured insertion gain was much below than that prescribed by the POGO formula.

In the undershooting condition, the word and sentence identification scores were found to be very poor, as per the classification for word identification ability given by Goetzinger (1978).

b) The subjects performance was better not only when the measured insection gain was matched to the prescribed gain, but also when the measured insertion gain was overshooting the target gain. Both the conditions resulted only in a slight difficulty in the word and sentence identification as per the Goetzinger's classification (1978). The subjects also did not complain of any discomfort or tolerance problem for conversational speech, when the volume setting was overshooting the target gain.

The results obtained in the study are in agreement with the results of Rankovic (1991). He reported that the POGO prescriptions made the average speech spectrum more audible than the NAL prescription. However, the frequency gain characteristics that maximized the audibility of the speech spectra required more gain than that prescribed by the POGO prescription. Rankovic (1991), further reported that the gain prescribed by the POGO target curve never amplified the speech peaks beyond the calculated UCLS. Hence, a deviation of the gain above that prescribed by the POGO can still be considered acceptable.

However, it is recommended that the clinician should be cautious to check for a tolerance problem when the output of the hearing aid overshoots the prescribed target curve (POGO).

SUMMARY AND CONCLUSIONS

Amplification represents the single most important rehabilitative tool available to the hearing impaired. The various hearing aid fitting procedures have been described as either comparative or prescripture methods. Though several studies have compared the prescribed gain with the use gain (Ryals and Auther, 1990., Byrne and Cotton, 1986), and the insertion gain with the functional gain (Zemplenyi, Dirks &, Gilman, 1985., Mason and Popelka, 1986), very few studies have compared the effectiveness of a hearing aid fitting when the insertion gain deviated from the prescribed target gain (Bratt and Sameth, 1991., Mueller, 1991).

Therefore, the present study aimed at studying the effect of deviation of the insertion gain from the target using the POGO formula (Mc candless and Lyregaard, 1983) and its effects on the speech understanding ability of the hearing aid user.

Eleven subjects (including 10 males and 1 female) with bilateral moderate to moderately severe sensory-neural hearing loss were included in the study.

The study was conducted in two steps.Initially,the probe tube measurements were performed using a moderate gain hearing aid and the tone and volume controls were adjusted such that :

a) the insertion gain matched the target gain curve (POGO) in the speech frequencies.

b) the insertion gain was undershooting the target gain curve by about 5-10 dB in the speech frequencies,

c) the insertion gain was overshooting the target gain curve by about 5-10 dB in the speech frequencies.

Secondly, the speech audiometry was carried out in the above three settings of the hearing aid and the aided scores were noted down.

Statistical analysis revealed that there was no significant difference in the performance of the subject when the insertion gain of the hearing aid was overshooting the target compared to, when it matched the target. However, there was a statistically significant difference in the performance when the insertion gain was below the target gain by about 5-10 dB, compared to the matched condition.

Therefore, it can be concluded from the study that a good performance could be achieved not only when the insertion gain matched the target gain, but also when the insertion gain was 5-10 dB above the target gain curve, using the POGO formula. On the contrary, a poor performance was noted when the insertion gain was below the target gain by about 5-10 dB.

SUGGESTIONS FOR FURTHER STUDY

1) Different prescriptive formula could be used to study the effect from their deviation.

2) A similar study could be replicated using hearing impaired individuals with different degrees and types of hearing loss.

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APPENDIX - I

CALIBRATION OF THE QUICK PROBE II OF THE FONIX 6500-C HEARING AID TEST SYSTEM.

The calibration was carried out as per the procedure described below.

Instruments required : Sound level calibrator (Quest CA-12), 14mm to 1 inch adaptor, probe microphone calibrator adaptor and the calibration clip.

Procedure:

The sound level calibrator's battery was initially checked. Following this, a 14mm - to 1 inch adaptor was put into the calibrator and the reference microphone was inserted into it. To calibrate the reference microphone, the measured microphone amplitude **was** compared to the intensity of signal picked up by the reference microphone. If the intensity of the reference microphone was not within ldB of the calibration value, (110 for quest CA-12) the gain of the reference microphone was adjusted with a small screwdriver using the control marked 'REFERENCE' on the bottom of the quick-probe module.

To calibrate the probe microphone, the reference microphone was removed from the calibrator and the probe microphone adaptor was inserted. The probe tube **was** fully inserted into the calibrator adaptor. It was checked to make

certain that nothing was clogging the probe tube, and that it was properly connected to the body of the probe microphone The measured microphone amplitude was compared with the intensity of the calibrator level. If the value of the probe amplitude was significantly below the calibration level (110 for quest CA-12), it was checked to see that the probe tube has gone all the way into the adaptor. This was done by taking the probe calibrator adaptor out to check. If necessary, the gain of the probe microphone was adjusted with a small screw driver using the control marked "PROBE" on the bottom of the remote module. Using the above procedure, calibration was done for the reference and probe microphones of the Fonix 6500C.

Calibrating the sound field loudspeaker of FONIX-6500C:

The subject wearing the headband was seated in the proper position near the loud speaker.

The reference microphone and the probe microphone were combined with the calibration clip. The tip of the probe was kept at the centre of the grid of the reference microphone. Both microphones were positioned on the headband just above the ear nearest to the loudspeaker. The test signal was turned on. The RMS source SPL was compared to the RMS OUTSPL. If the level were with in 3dB of each other, the calibration was correct. When the difference was greater than 3dB, the adjustment for the loudspeaker on the back panel of the main module was adjusted, until the RMS source and RMS OUT level were within 3dB of each other.

Appendix-II

Leveling (Automatic Adjustment of the loudspeaker Response) was done as per the instructions given below.

With the speaker, the reference microphone & probe tube in position, the 'level' button on the remote control was operated.

A composite tone at 69 dBSPL was presented from the speaker. Depending on the instrument location and the ambient noise, one of following three different leveling conditions resulted.

a) If leveling was achieved within 2dB in the frequencies between 600 & 5000 Hz, the word 'leveled' appeared on the screen. The measured response curve appeared in the lower graph. Probe testing was continued if the displayed curve was within the acceptable limits.

b) If the RMS amplitude of the reference microphone was not within 6 dB of the target, the screen showed the word unleveled.

Following this, it was checked to see if

i) The speaker was too close or too far away from the reference microphone
ii) The microphones were unplugged and
iii) The calibration of the sound field speaker and the microphones were checked.

If still unsuccessful, the sound field environment was changed before trying the level again.

c) If leveling was attempted and neither 'leveled' nor 'unleveled' appeared in the message area, it meant that the present leveling compensation was some where between the conditions described in (a) and (b) above. The sound field conditions and the position of the reference microphone, were checked once again before leveling.

Appendix III

SPEECH AUDIOMETRY CALIBRATION

Loudspeaker output level calibration procedure:

The controls on the audiometer were set to the free field testing operation. The SPL meter (B&K 2209) was placed one meter away from the loudspeaker at a position where the subject's head is likely to be during the test situation. The speech noise was presented through the loudspeaker at 80 dBHL (ANSI-S3-26, 1989). The output from the audiometer to loudspeaker was monitored to zero on the VU meter. The SL meter was set to 'Linear scale' and the readings were taken. The internal calibration was carried out if the output of the loudspeaker did not match the recommended value as per ANSI-S3-26 (1989) standards.

Speech Output Level Calibration:

The controls on the audiometer were set for speech audiometry and intensity dial to 80dBHL. A lOOOHz tone (calibrating tone) was introduced through the microphone continuously. The input intensity level was adjusted until the VU meter was monitored to 'zero'. The output level from the SL meter with 'Linear setting' were noted and compared with the standards. If the discrepancy was more than + 2.5 dB between the observed values and recommended values, the internal calibration was done.

Linearity Check:

The intensity dial of the audiometer was set at the maximum level and the attenuator on the SLM was set at a level corresponding to the maximum level on the audiometer. The attenuator setting on the audiometer was decreased in 5 dB steps and the corresponding reading on the SLM was noted. For every decrease in the attenuator setting, the SLM indicated a corresponding reduction.

VU Meter Calibration Procedure:

A puretone was fed from the oscillator through the electronic switch to the input of the audiometer. The VU meter was monitored. A rapidly interrupted signal was produced by activating the electronic switch. The VU meter was again monitored to confirm whether there is any overshoot or undershoot with reference to the steady state signal.

Appendix IV

Teat Items Used For Hearing Aid Selection

SET A

Every day questions

1. nimma ṭandeja hesaru e:nu?
2. ni:vu illige basalli bandra:?
3. ni:vu ra:ṭri eʃṭu gaṇṭege malugutira:?
4. nimma u:ru ja:vaḍu?
5. ni:vu beḷage e:nuṭindi ṭindri?

Paired words

1. be:le-ka:lu
2. gaṇṭu-mu:ṭe
3. aṭṭa:-iṭṭa:
4. suṭṭa:-muṭṭa:
5. hola:-gaḍe

SET B

Every day questions

1. nimage eʃṭu varʃa?
2. nimma hesaru e:nu?
3. nimage ja:va kivijalli tʃanna:gi ke:ḷusuṭe?
4. ni:vu e:nu kelsa ma:ḍuṭira?
5. nimage ja:va ja:va ba:ʃe baruṭe:?

Paired words

1. kaʃṭa-sukha
2. ṭa:ji-ṭaṇḍe
3. aṇḍa-tʃaṇḍa
4. hoṭṭe-baṭṭe
5. naḍe-nuḍi

SET C

Every day questions

1. nimage eʃṭu dzana akka ṭaṇgijaru iḍa:re?
2. i:ga gaṇṭe eʃṭu?
3. manejalli ja:va bha:ʃe ma:ṭaṇaduṭi:ra?
4. ni:vu e:nu o:ḍiḍi:ra?
5. nimma manejalli eʃṭu jana iḍa:re?

Paired words

1. aṭi-a:se
2. kappe-tʃippu
3. mane-maṭa
4. namma-nimma
5. guru-ʃiʃya

SET D

Every day questions

1. ni:vu beḷage eʃṭu gaṇṭege eḷuṭi:ra?
2. nimage eʃṭu dzana aṇṇa ṭammaṇḍiru iḍa:re?
3. ni:vu manege basalli ho:guṭi:ra, oṭo:ḍalli ho:guṭi:ra?
4. nimma mane ellide?
5. nimma dzoṭe ja:ru baṇḍiḍare:?

Paired words

1. tindi-ti:rta
2. alli-illi
3. sanna-putta
4. kanasu-nanasu
5. kallu-mannu

SET E

Every day questions

1. nimma ta:jina hesaru e:nu?
2. ivatu ja:vu va:ra?
3. ni:vu kofi atava ti: kuditi:ra?
4. ni:vu illige eʃtu gantege bandri?
5. nimage ja:va:galinda kivi ke:lusuta:illa:?

Paired words

1. mi:na-me:ʃa
2. betta-gudda
3. atta-itta
4. hetʃu-kammi
5. tʃinna-belli

Appendix V

The formula used to calcualte the Prescription of Gain and Output (POGO) target curve from the audiogram is as follows:

	Frequency (Hz)	Insertion gain (dB)
	250	1/2 HTL - 10 dB
	500	1/2 HTL - 5 dB
*	750	1/2 HTL - 2.5 dB
	1000	1/2 HTL
*	1500	1/2 HTL
	2000	1/2 HTL
	3000	1/2 HTL
	4000	1/2 HTL
*	6000	1/2 HTL
*	8000	1/2 HTL

Note :- Frequencies preceded by an asterisk (*) are interpolated.