The Efficacy of the Prescription of Gain/Output (POGO) in Fitting Hearing Aids to Mild and Moderate Sensorineural Hearing Losses

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ABSTRACT

This study investigated the effectiveness of the application of the Prescription of Gain / Output (POGO) in hearing aid fittings. Six subjects were tested. Each presented with binaural mild to moderate sensorineural hearing losses and were previously fitted monaurally with behind-the-ear aids using modifications of the traditional Carhart (1946) approach. Functional gain requirements stipulated by POGO were calculated from unaided thresholds and compared to actual functional gain measurements. Five subjects, whose functional gain measures were not within prescribed limits, were referred for modification of the gain and frequency responses of their hearing aids and earmoulds. Post-modified functional gain measurements were analysed. The extent to which the required functional gain measurements were met, was investigated statistically in relation to word recognition scores and subjective ratings of perceived benefit. The conclusion reached was that the application of POGO results in improved word recognition scores and self-reported user satisfaction.

OPSOMMING

Hierdie studie het die doeltreffendheid van die aanwending van Voorskrif van Vordering / Uitset (VVU) in gehoorapparaatpassing ondersoek. Ses proefpersone is gebruik. Elk het met 'n geringe tot matige binaurale sensories-neurale gehoorverlies gepresenteer en was voorheen met monaurale, agter-die-oor tipe gehoorapparate gepas deur modifikasies van die tradisionele Carhart-benadering (1946) te gebruik. Funksionele wins vereistes wat deur VVU gestipuleer is, is bereken vanaf nie-versterkte drempels en is vergelyk met werklike funksionele vordering. Vyf proefpersone, wie se winsmetings nie binne die voorgeskrewe perke was nie, is verwys vir modifikasie van die wins en frekwensie responskurwes van hulle gehoorapparate en oorstukke. Post-modifiseerde funksionele winsmetings is geanaliseer. Die mate waarin die vereiste funksionele wins-metings nagekom is, is statisties bereken in verhouding tot woordherkenningstellings en subjektiewe beoordeling van waargenome voordeel. Die gevolgtrekking is gemaak dat die aanwending van VVU gelei het tot verbeterde woordherkenningstellings en verbruikerstevredenheid tot gevolg gehad het.

INTRODUCTION

"Although electronic hearing aids have existed for over forty years, there still is no consensus of opinion today regarding the most appropriate method for hearing aid selection and adjustment to an individual" (McCandless & Lyregaard, 1983, p.16). Unfortunately, this comment has held its validity even though it was made more than a decade ago.

While the principles of selective amplification (the supply of gain according to different frequency requirements based on pure-tone audiogram results) are now generally accepted, the most prevalent technique of hearing aid fitting in South Africa is still based on Carhart's (1946) Comparative Procedure and its modifications. This approach attends to the relationship between hearing aid frequency response and the unaided audiogram in a general way and relies on aided speech thresholds and word recognition scores to differentiate hearing aid performance when selecting the best hearing aid for the individual patient (Hodgson, 1986). Limitations of this procedure and its modifications are highlighted as the following :

1. Due to the large statistical spread in speech intelligibility scores, only large differences between hearing aids can be reliably interpreted due to the poor test-retest reliability of these procedures (Northern, 1993).
2. Speech tests are time consuming and therefore expensive. Moreover, Northern (1993) comments that the reliability of speech scores is not good enough to warrant the investment of extensive clinical time.
3. Speech-based tests have a severely limited application in a multilingual country such as South Africa.
4. Speech intelligibility is not the only relevant property to be considered in hearing aid selection as poor sound quality can result in the rejection of the hear-

ing aid (McCandless & Lyregaard, 1983). In 1946, Davis et al., (cited in Rose, 1977) maintained that the hearing impaired patient is usually primarily interested in obtaining a hearing aid with a pleasing or natural quality, however, the quality preferred by the patient is not always compatible with the greatest intelligibility.

5. Although speech tests may demonstrate that a particular hearing aid is not adequate, they fail to identify which electroacoustic characteristics may contribute to better word recognition (Angelo & Miller, 1988). Speech tests in isolation are unable to prescribe modifications required to improve performance. Indeed Berger (1991, p.40) comments that these methods "often consisted of no more than a guess at the gain-frequency response needed for a given hearing loss".

Contemporary alternatives of hearing aid selection based on a variety of mathematical formulae were thus devised. These utilise audiogram-based prescriptions of appropriate amplification and the measurement of unaided and aided sound field thresholds (Hawkins, Montgomery, Prosek & Walden, 1987). "The basis of a prescriptive method is to select the hearing aid's characteristics of frequency and gain, by relating the aid's electroacoustic characteristics to relevant characteristics of the individual's hearing loss, based on a theory about this relationship" (Angelo & Miller, 1988, p.184).

Although prescriptive methods differ somewhat in their underlying principles they are all based on the belief that different electroacoustic features are needed for different individuals and that a rationale exists, linking audiological and electroacoustic characteristics (Buerkli-Halevy, 1988). They tend to share the following basic tenents :

1. The amount of hearing aid gain is determined as a function of frequency and is related to the degree of hearing loss (Buerkli-Halevy, 1988).
2. The frequency response is related to the audiometric configuration and the input signal. The goal of any method is to provide the hearing aid user with an aid that reproduces speech that is highly intelligible while also being comfortable to listen to (Angelo & Miller, 1988).
3. Reduced gain at the lower frequencies to avoid the upward spread of masking and thus improve speech intelligibility in noise (Berger, 1991).
4. The selection of maximum output such that it exceeds the threshold of hearing without exceeding the uncomfortable loudness level (Buerkli-Halevy, 1988).

Berger (1991) highlights the advantages of using prescriptive methods of hearing aid selection. He comments that since its use is based on hearing threshold levels its test-retest reliability is considerably better than word recognition testing. They are also applicable to a larger sector of the population since they do not require any particular linguistic competence or intellectual abilities. By providing a method of evaluating the hearing aid's performance, it is also more objective than traditionally used methods based on speech audiometry.

One such method, **Prescription of Gain/Output (POGO)** proposed by McCandless & Lyregaard in 1983, attempts to combine simplicity and practicality in hearing aid fitting procedures. The authors of POGO conclude that this prescription method represents a consensus amongst existing proposed prescriptive methods following comparative research in the area. They claim that their procedure is a close approximation of the required characteristics which constitute the best fitting procedure and thus it essentially provides a starting point for any subsequent fine adjustment (Angelo & Miller, 1988). POGO is based on the premise that the hearing aid should ensure that sound levels which are important in daily life, are audible without being excessively loud.

POGO is based on the half gain principle proposed by Lybarger in 1963 (McCandless & Lyregaard, 1983; Berger, 1991) where the optimum functional gain is equal to one half of the magnitude of the hearing loss. However, this half gain rule has been modified in POGO in order to reduce the effects of the upward spread of masking by reducing the gain in the low frequencies. To ensure hearing aid acceptability, the method includes the selection of maximum output such that intense sound levels will approach the uncomfortable loudness level without exceeding it.

The use of the POGO has been advocated by various researchers (Angelo & Miller, 1988; Chasin, 1988). Smirga (1984) cited in Hodgson (1986), reported an improvement in the sound quality and user satisfaction when aids were adjusted according to the POGO criteria. McCandless & Lyregaard(1983) report that a study of several existing selection methods such as those suggested by Berger and National Acoustics Laboratory, revealed results closely approximating those predicted by POGO and therefore argue that POGO represents a consensus of expert opinion but that this method is exceptional in that it is a simple procedure capable of administration within a short time.

A high level of hearing aid acceptance and benefit for the user involves a compromise between good speech intelligibility and comfortable sound according to McCandless & Lyregaard (1983). In this study, we have attempted to answer questions regarding whether the application of the POGO method results in good speech intelligibility and sound quality, and thus subject satisfaction, as a high level of hearing aid acceptance and benefit for the user involves a compromise between good speech intelligibility and comfortable sound (McCandless & Lyregaard, 1983).

The term "functional gain" has been used in this text to refer to the effective gain of the aid i.e., the difference in Sound Pressure Level with and without the hearing aid, measured behaviourally on a sound-field audiogram. Although the use of real-ear insertion gain measurements have also been advocated, the expense of such equipment places it beyond the reach of most practising audiologists and its cheaper alternative using sound-field measurements was therefore chosen. Furthermore, the term "required gain" refers to the gain specified by the prescription formula as calculated in Table 1.

METHODOLOGY

AIMS

The main aim of the study was to investigate the efficacy of POGO in hearing aid fittings of mild and moderate sensorineural hearing losses. This involved :

1. determining the extent to which the required gain according to POGO and the functional gain differ;
2. (a) determining the correlation between the difference between functional and required gains, and word recognition scores;
   (b) determining changes in word recognition when the aid was modified to meet the prescription more closely;
   (a) determining the correlation between the difference between functional and required gains, and subject satisfaction.
   (b) determining changes in subject satisfaction when the aid was modified to meet the prescription more closely.

'BJECTS

Six subjects with bilaterally symmetrical ısorineural hearing losses ranging from mild to modıtely severe levels (pure tone averages (PTA) better ın 65dBHL) were tested. Subjects with severe and ›found hearing losses have different amplification ıuirements, requiring hearing aids to assist in speechıding and to increase awareness of environmental ınds. All subjects were experienced hearing aid us-ı. The audiometric configuration was not considered be an important selection criteria for this study, alıugh all subjects had either a rising or flat audiomet- slope. Details regarding the method of initial hear-ı aid fitting were unavailable although all hearing ls were fitted using general principles from the tra-...ional Carhart approach. These subjects were fitted monaurally with behind-the-ear aids and although it is well established that a binaural fitting would have been more beneficial, many could only afford a single hearing aid due to financial constraints. The ages of the subjects ranged from 52 to 83 years with a mean of 72,3 years. None of the subjects showed evidence of central auditory processing deficits as suggested by a poor correlation between pure-tone findings and word recognition tasks, not by a significant deterioration in word recognition abilities in the presence of noise.

Pure tone and word recognition testing were conducted in an Inter-Acoustics Company (IAC) two-roomed sound-proof booth, using a Grason Stadler GSI-10 audiometer. Sound-field frequency-modulated pure tones at 250 - 4000Hz were generated and routed through the audiometer and amplified to a loudspeaker located in the sound booth. This speaker was also used for the word recognition testing. The audiometer, earphones, speakers and sound field had been calibrated to ISO (1964) specifications four months previously.

Word recognition testing was conducted using the CID W22 phonetically balanced word lists developed by Hirsch (1952). Due to the unresolved controversy re-

Table 1. Calculation of gain and maximum power output according to POGO (McCandless and Lyregaard, 1983)

The required insertion gain is calculated as follows:

FREQUENCY (Hz)	INSERTION GAIN (dB)
250	0,5 HTL - 10
500	0,5 HTL - 5
1000	0,5 HTL
2000	0,5 HTL
3000	0,5 HTL
4000	0,5 HTL

(where HTL refers to Hearing Threshold Level)

The maximum power output (MPO) is calculated as follows :

$$MPO = (UCL_{500} + UCL_{1000} + UCL_{2000})/3$$

(where UCL refers to the Uncomfortable Loudness Level)

1 Obtain frequency-modulated pure-tone thresholds for aided ear.

2 Calculate the required gain and output characteristics based on POGO.

3 Administer hearing aid questionnaire.

4 Determine aided sound-field thresholds.

4.1 Calculate functional insertion gain.

5 Compare functional gain with required insertion gain.

5.1 **Functional gain within specified limits**

6 Check aided UCL

7 Speech discrimination in quiet and noise.

5.2 **Functional gain not within specified limits**

6 Check aided UCL

7 Speech discrimination testing in quiet and noise.

8 Refer subject to hearing aid acoustician for modification if necessary.

8.1 Subject returns to clinic after two weeks adjustment period.

8.2 Return to Step 3 above and proceed.

Figure 1. Flow diagram of the administrated test procedure

garding 25 or 50 word testing, the entire list of 50 words was administered (Schmitz, 1980).

A hearing aid questionnaire developed by Maclean (1988) was administered to assess the effectiveness of hearing aid performance in the reduction of the hearing handicap (refer Appendix A). The subjects were not permitted to peruse the questions before answering, in order to avoid premeditated responses.

TEST PROCEDURES

Figure 1 provides a diagrammatic representation of the procedure followed.

1. **Pure tone audiometry**
A pure tone audiogram was established for each subject's aided ear at 250, 500, 1000, 2000, 3000 and 4000Hz.

2. **Calculate gain and maximum power output requirements**
The required gain and maximum power output (MPO) according to POGO was determined as indicated in the table below (McCandless & Lyregaard, 1983).

3. **Hearing aid questionnaire**
Subjects evaluated their aids subjectively by means of a hearing aid assessment questionnaire (Maclean, 1988) (Appendix 1). Due to statistical reasons related to the small population size it was not feasible to devise a rating scale.

4. **Aided sound-field audiogram**
An aided sound-field audiogram was obtained using frequency-modulated pure tones as recommended by McCandless & Lyregaard (1983). The subject was seated at 0 degrees azimuth at a distance of one metre from the speaker. The non test ear was muffed with an earphone to prevent its influence on test results.

   4.1 Calculate required functional gain
   Functional gain was determined by calculating the difference between unaided and aided thresholds at each frequency.

5. **Comparison of actual functional gain with required gain**
The criteria for acceptance of the hearing aid fittings were adapted from McCandless & Lyregaard (1983). Deviations between the measurements in the region 500 - 2000Hz should not exceed 5dBs to constitute an acceptable hearing aid fitting. Occasionally a 10dB deviation is felt to be unavoidable and larger deviations are acceptable if they occur at all frequencies and in the same direction as this may be adjusted by the volume control.

   5.1 Functional gain within specified limits
   If the subject's functional gain met those specified by POGO, the hearing aid fitting was considered appropriate.

   5.2 Functional gain not within specified limits
   If functional gain was not within specified limits, the fitting was not considered appropriate and the subject was referred for further modification and testing.

6. **Checking uncomfortable loudness levels (UCL)**
To determine whether the maximum power output (MPO) of the hearing aid is appropriately set, McCandless & Lyregaard (1983) recommend that the procedure incorporate testing to ensure that the UCL is not exceeded. This involved turning the hearing aid control full on and gradually increasing the level of narrow band noise at 1000Hz. The MPO adjustment is considered satisfactory if the level of narrow band noise can be turned up beyond 80dBHL without reaching the subject's UCL.

7. **Word recognition testing**
"The purpose of a hearing aid is to enable hard of hearing subject to hear sounds that he cannot otherwise hear but desires to hear - particularly the human voice ... (It) must make speech intelligible ..." (Davis et al., 1946 as cited in Pascoe, 1985).

As difficulty in understanding speech is often the primary complaint in hearing impaired persons (Martin, 1975 as cited in Downs, 1982), a comparison of unaided and aided performance is an integral part of the Hearing Aid Evaluation procedure. Although not included in the prescriptive approach, the importance of word recognition testing cannot be easily dismissed because of its intuitively high face validity.

Unaided and aided word recognition testing was administered in a sound field situation. The subject was seated at 0 degrees azimuth at a distance of one metre from the speaker . Both the primary message (speech) and the competing message (speech-weighted noise) were routed through the same speaker. Monitored live voice was selected as the presentation mode to allow for the variations in response time required by the individual subject and to facilitate reinstruction or reinforcement where necessary (Hodgson, 1987).

Word recognition testing was administered in both quiet and noisy situations. The use of background noise represents an approach that allows some realistic prediction about a person's functioning in real life noisy communicative settings (Schmitz, 1980). A signal-to-noise ratio of 0dBHL, utilising speech-weighted noise was selected as representative of the most difficult listening condition encountered (Lawrence et.al., 1976 cited in Bress and Bratt, 1977).

A level of 65dBHL was selected to conduct word recognition testing. Whilst this level overcame the stressful effects of having speech presented at a level too soft for the subject to respond to, as reported by most of the subjects, it nevertheless served as an appropriate level at which the subjects experienced substantial difficulty unaided (Hodgson, 1986).

8. **Referral to the hearing aid acoustician**
The stipulated conditions for modification were that only earmould, tone control, gain settings and MPO changes be implemented to adjust the response of the aid and that a new hearing aid would not be recommended.

Subjects were required to wear their hearing aids for at least two weeks following modifications. This time period allowed the subjects the opportunity to use the modified aid extensively within their everyday routine, thereby enabling them to comment on the new set of electroacoustic characteristics. Subjects were then required to re-evaluate their aids subjectively using the hearing aid questionnaire. Finally, a new sound field audiogram was obtained to determine whether gain requirements had been met. Word recognition testing was then readministered.

RESULTS AND DISCUSSION

All results should be considered in the light of the small sample size which had a direct bearing on the statistical procedures which could be applied. Although trends have been established, all results should be seen as largely qualitative and not quantitative. In those circumstances where statistics cannot be applied at all, a descriptive analysis will be provided.

1. *COMPARISON BETWEEN ACTUAL AND REQUIRED FUNCTIONAL GAIN*

As shown in Table 2, the extent to which the ideal and actual functional gain differ ranges from 0,4dBs at 500Hz to 17,1dBs at 4000Hz. According to McCandless & Lyregaard's (1983) criteria for acceptance, only the gain at 250 and 1000Hz represents acceptable fittings i.e., deviations between the actual and ideal do not exceed 5dBs at these frequencies. All these patients were originally fitted for amplification using the general principles of the modified Comparative approach suggested by Carhart (1946), although exact details were unavailable.

There is much controversy about the importance of the high frequencies in speech intelligibility abilities. McCandless & Lyregaard (1983) state that the hearing aids' frequency response should predominantly fit the region of 250 to 2000Hz. For frequencies above 2000Hz, the requirements should be met as far as possible but are not as important as the lower and middle frequencies. A large discrepancy between ideal and actual gain means at 3000 and 4000Hz is evident. However, Pascoe (1985) comments that the critical range of frequencies which have a significant effect on word recognition scores, particulary those in noise, are those between 2500 and 6300Hz. The relevance of this statement will be discussed later, however, it is important to note that this region is critical for speech intelligibility.

As the difference between the ideal and actual functional gain is the basis for which an aid is accepted as a good or poor fitting, none of these aids would be accepted as appropriate and thus modifications were recommended for all subjects.

Subject dissatisfaction is often related to unsatisfactory MPO settings, therefore these were evaluated. According to McCandless & Lyregaard's (1983) MPO specifications, all subjects' MPO levels were appropriate and thus did not require any adjustments.

Only five of the six subjects were prepared to have their hearing aid response altered by means of modifications to their earmoulds and/or tone control/gain settings. The results following modification of the hearing aids of these five subjects are presented in Table 3 below.

All subjects were using standard earmoulds and bores. Although minor variations in earmoulds will not significantly alter the acoustical properties in the region 250 to 3000Hz (McCandless & Lyregaard, 1983), improvement of high frequency amplification from an increase in the inner diameter of the sound canal from the hook of the hearing aid to the tip of the earmould has been reported in the literature (Ringdahl, Leijon, Liden & Backelin, 1984). The use of a horn also provides an increase in functional gain at 3000 and 4000Hz (Hodgson, 1986). As these are the frequencies where the most modification was necessary, their implementation was discussed with the hearing aid acoustician.

Table 2. The aided mean of ideal and actual functional gain at each frequency, and differences between them before modifications.

Hz	250	500	1000	2000	3000	4000
Required gain (dB)	5,4	13,3	21,7	25,4	27,1	25,4
Actual gain (dB)	5,0	6,7	17,5	14,2	15,0	8,3
Delta FG (dB)	0,4	6,6	14,2	11,2	12,1	17,1

Table 3. The aided mean of ideal and actual functional gain at each frequency, and the difference between them after modification.

Hz	250	500	1000	2000	3000	4000
Required gain (dB)	4,5	13,0	21	26	27	25
Actual gain (dB)	9,0	14,0	22	21	22	17
Delta FG (dB)	4,5	-1	-1	5	5	8

Table 4. Unaided word recognition scores in quiet and noise conditions

Subjects	A	B	C	D	E	F
Quiet	20%	6%	16%	26%	32%	30%
Noise	24%	6%	10%	24%	10%	24%

Table 5. Aided speech discrimination scores in quiet and noise before and after modification to the hearing aid.

	Subject	A	B	C	D	E	F
BEFORE	Quiet	56%	46%	54%	54%	46%	36%
	Noise	36%	18%	34%	42%	34%	24%
AFTER	Quiet	68%	64%	-	66%	80%	48%
	Noise	42%	30%	-	52%	40%	34%

However, strategies to improve the hearing aid response were left to the acoustician's discretion. As it was stipulated that a new hearing aid could not be recommended, it is important to bear in mind the limitations on the extent to which the hearing aid's response can be modified.

Table 3 indicates that a great improvement in functional gain was obtained across all frequencies. Accordingly, all fittings except at 4000Hz would be considered acceptable by McCandless & Lyregaards' (1983) standards. Shapiro (1976) stated that the predicted gain at 4000Hz is the most difficult to attain. The significance of the negative numbers in the table is that too much gain was provided at those frequencies, i.e., over-amplification occurred, but these values are still within the acceptable range.

2. ***WORD RECOGNITION TESTING***

Results of the word recognition testing are presented below (Table 4) :

The relevance of unaided word recognition scores and the benefits from aiding are particularly significant. Hodgson (1986) states that poor discrimination ability is indicative of poor hearing aid candidacy and substantiates this statement by adding that individuals with unaided discrimination scores below 50% cannot expect to follow conversation even with amplification (Williamson & Webber, 1985). Hence, none of these subjects are candidates for successful amplification.

A comparison of word recognition scores in quiet and noise, before and after modifications is illustrated in Table 5.

The criteria for a good hearing aid fitting in terms of word recognition scores is 80% or above according to Ewerston (1966) and Niemeyer (1969), thus only subject E's response in quiet conditions can be considered a good fitting.

A scatterplot of word recognition scores in both quiet and noisy situations versus delta functional gain (delta FG), where delta FG refers to the modulus of the difference between actual and ideal FG generated and a definite trend noted. Linear regression lines are as indicated in Figure 2 below.

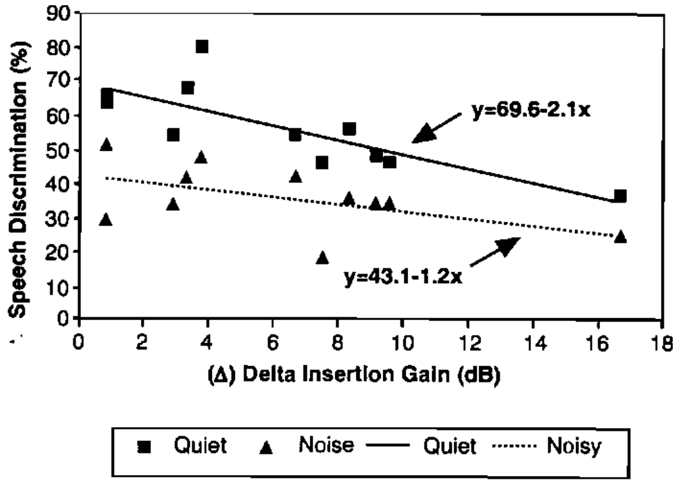

Figure 2. Linear regression of word recognition scores versus Delta functional gain.

(a) **Quiet Conditions**

There appears to be a general trend towards improved word recognition scores as delta FG decreases. This suggests that POGO could provide some acceptable criteria for hearing aid use in quiet situations. A correlation coefficient of 0,79 confirms an acceptable correlation between word recognition scores and delta FG and is statistically significant. The regression line for the quiet condition is more reliable than that generated in noise. An R-square value of 63,39 implies that the regression curves account for 63% of the variation in the data. The correlation coefficient of 0,79 confirms an acceptable correlation between word recognition scores and delta FG. The f-ratio of 15,6 also describes the significance of the curve as a whole.

(b) **Noisy Conditions**

There is a far weaker trend towards improvement of word recognition in noise, and decreases in delta FG. Indeed with regard to the regression line obtained for noisy conditions, only 29% of the variation is explained by the regression line i.e., R-square value of 29,49. This slope cannot be regarded as statistically significant. The curve could, however, still intuitively be considered significant and shows the kind of trend expected. However, these results are not convincing and may be due to the fact that required gain was not always successfully met at 4000Hz as illustrated in Table 3. Alternatively, POGO may not be providing sufficient high frequency amplification as considered essential by Pascoe (1985), or does not limit low frequency amplification to prevent the upward spread of low frequency masking in the presence of background noise.

In summary, the regression line for quiet conditions supports the argument that as the delta FG decreases so word recognition scores improve. In addition, it acknowledges that a relationship does exist. On the other hand, the regression line for noisy conditions does not support this argument convincingly although a slight trend can be seen. Intuitively some relationship does seem to exist since statistically the slope of this line cannot be construed as being zero. The correlation coefficient and R-square values support the latter statement.

It is evident from the above analysis that a closer approximation to ideal functional gain measurements as prescribed by POGO results in an improvement in word recognition scores, especially in quiet conditions. A disappointing correlation was found in noisy situations but it is anticipated that a closer approximation of ideal gain at 4000Hz could improve results.

Welzl-Muller & Sattler (1984) note that patients whose hearing defects already cause a marked deterioration of word recognition in noise without a hearing aid, are considerably impaired even with a hearing aid. This may account for the poor relationship between word recognition scores in noise and delta FG. Moreover, the central processing deficits in the geriatric population have been well documented and the difficulties encountered in noise is particularly noteworthy (Staab, 1993).

The results should, however, be viewed critically because of the poor test-retest reliability of word recognition testing and the high probability that differences in performance could be due to chance and not changes in electroacoustic characteristics of the hearing aid

(Schwartz & Walden, 1983). Hence, it is difficult to distinguish whether changes in word recognition scores are due to a closer approximation of functional gain values with POGO or the unreliablity of word recognition measures.

3. *SUBJECT SATISFACTION*

Subject satisfaction was determined from responses to question 1 of the Hearing Aid Questionnaire (refer Appendix 1), taking into account questions 7 to 10. The former gave an indication of the subject's fundamental feeling about the hearing aid, whilst the latter determined specific circumstances of communication difficulty, benefits derived from the hearing aid and the necessity for further changes to the aid. Satisfaction was ranked as 0 for happy and 1 for unhappy. In order to determine the relationship between satisfaction and delta FG, the following procedure was administered. Delta FG was ranked as 0 for small differences and 1 for large differences. A grand mean of means of the differences in FG and satisfaction was taken for 11 data sets i.e., six subjects before and five subjects after modification. Delta FG was compared to this grand mean. Two of these differences were excluded from the analysis as their closeness to the grand mean implies that they were indeterminate differences i.e., neither small nor large.

With the remaining nine data sets, a correlation matrix was drawn up showing an apparent correlation between satisfaction and delta FG. A ranking of 0 represents small Delta FGs or good satisfaction with the hearing aid whilst a ranking of 1 shows that large differences exist between required and functional gain or that the patient was dissatisfied with the hearing aids. Table 6 reflects that in 4 cases where the difference between actual and required gain is small, the subject is happy with his hearing aid. Conversely, 3 cases show that large differences are associated with dissatisfaction. A Spearman's corrélation coefficient of 0,55 was recorded for correlation within this matrix.

These results show a general correlation between improved user satisfaction and smaller Delta FGs but they are disappointing. Hearing aid fitting using the POGO solely does not appear to be sufficient to ensure user satisfaction and supplementary methods of hearing aid evaluation are therefore indicated.

According to McCandless & Lyregaard (1983) in the final analysis it is the patient who has the last word in hearing aid fitting as it is he/she who must live with the hearing aid in daily life. Thus, from the above analysis we can tentatively suggest that a close approximation of hearing aid reponses to POGO results in a more satisfactory fitting.

		Satisfaction 0	Satisfaction 1	Row Total
Delta (Δ) Insertion Gain	0	4 80	1 25	5 55.8
	1	1 20	3 75	4 44.4
Column Total		5 55.6	3 44.4	9 100

Table 6. A Correlation matrix depicting the relationship between satisfaction and delta functional gain

CONCLUSIONS

Although the sample size was too small to allow any meaningful interpretation, there appears to be some correlation between the magnitude of difference in delta FG, scores obtained on word recognition tests and the user's satisfaction with the hearing device. It appears that as differences between functional and required FG decreases, so speech intelligibility and satisfaction improves.

In the light of the afore-mentioned statements, we can tentatively suggest that the application of POGO appears to result in more acceptable hearing aid fittings and that it is fulfilling a very necessary requirement. It seems to be best suited to providing the basis for further modifications, i.e., it is a starting point at which to prescribe frequency and gain characteristics of the hearing aid as one can intuitively assess that improvements in gain will result in better speech intelligibility and greater satisfaction. The weak trends, however, suggest that POGO cannot be used solely but should be used with supplementary methods of hearing aid evaluation. This is particularly true if the hearing aid is to be used in noisy situations for large periods of time.

In conclusion, "There is no single standard of hearing aid selection" (Pascoe, 1986). However, the Prescription of Gain/Output appears to be a valid predictor of the electroacoustic characteristics of a hearing aid, necessary for improved speech intelligibility and satisfaction. There are therefore direct implications for the introduction of this hearing aid fitting procedure to replace the Modified Carhart Comparative approach as a gross hearing aid selection procedure, at least in patients presenting with mild and moderate sensorineural hearing impairments. These results also suggest that POGO may be used on other hearing-impaired populations other than the one researched.

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APPENDIX 1 : HEARING AID ASSESSMENT QUESTIONNAIRE (Maclean, 1988, p.179)

Patient's Name : .... YES NO

1. Are you happy with your hearing aid?
2. Is it physically comfortable?
3. Do you have difficulties :
   a. installing it?
   b. operating it?
   c. cleaning it?
   d. with feedback (squealing or whistling)?
4. Do other people's voices sound pleasant?
5. Is the sound of your own voice okay?
6. Do you have difficulty with the phone?
7. Before you received the aid what was your most troublesome listening situation?
8. In that situation, has the aid helped?
9. Has the aid helped in other situations?
10. Which listening situations still pose problems?
11. Are you satisfied with battery life?
12. How many hours per day do you wear the aid?
13. In general are you getting good value for the money spent on the aid?
14. Would you recommend that a hearing handicapped friend or relative try one?
15. Additional comments.