Efficacy of NAL-NL1 Prescription for the First-Time Hearing Aid Users: A Follow-Up Study

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Abstract

A prescriptive approach to hearing aid fitting is one in which the amplification characteristics are calculated from some of the hearing characteristics of an individual. NAL-NL1, one such generic formula, which aims at maximizing speech intelligibility, is widely in use. The aim of the study was to evaluate the efficacy with which NAL-NL1 prescribes the hearing aid parameters for persons with varying types and degrees of hearing loss. In addition to find out the changes in the amplification parameters preferred by the hearing aid users in terms of, after the first 6 to 8 weeks of hearing aid use. Further, the study also aimed at evaluating the extent of deviation of the amplification parameters from the target prescribed by NAL-NL1. For this, a follow-up study was undertaken, in which participants (N=20) were tested under three conditions of hearing aid program. The three hearing aid programs were one with NAL-NL1, second with preferred setting and third with fine tune setting. Both subjective (aided thresholds, Speech reception scores and uncomfortable level) and objective (real ear insertion gain and real ear saturation response) measurements were carried out to compare performance of the participants in the three conditions. The results indicated an improved performance in subjective measures with fine tune settings compared to the other two conditions. These findings were supported by the objective test results also. These findings prove that fine tune program provides better results when compared to NAL-NL1. Re-programming according to individual's listening needs can enhance the benefit that one derives from the hearing aid. Hence, follow-up of the hearing aid users for fine tuning of the hearing aid should be considered as an integral part of hearing aid prescription procedure for greater user satisfaction and continued hearing aid use.

Key words: *aided threshold, speech recognition scores, uncomfortable level, real ear measurement*

Introduction

A prescriptive approach to hearing aid fitting is one in which the amplification characteristics are calculated from the hearing characteristics of an individual. This is based on the assumption that certain amplification characteristics suit certain types, degrees and configurations of hearing loss (Byrne, 1986). There are several prescriptive procedures for hearing aid selection, some for linear hearing aids such as Prescription Of Gain and Output (POGO), National Acoustic Laboratories formula-Revised (NAL-R) and others for non-linear hearing aids such as Desired Sensation Level-input/output (DSL-i/o), Figure 6 (FIG6), NAL - Non Linear 1 (NAL-NL1).

The first prescriptive formula by National Acoustic Laboratories (NAL) was published in 1976 (Byrne & Tonnison, 1976). NAL procedure is a threshold-based prescription for linear hearing aids that aims at maximizing speech intelligibility. The procedure is based on three principles, viz. preferred insertion gain at 1 kHz equals 0.46 times the loss at 1 kHz, speech bands according to the long-term average speech spectrum should be perceived equally loud, and equal loudness at a most comfortable level is modelled using the 60-phon equal loudness contour curve by listeners with normal

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hearing. As its predecessor NAL, NAL-R (Byrne & Dillon, 1986) is also a threshold-based procedure for prescribing the gain-frequency response in linear hearing aids with the aim of maximizing speech intelligibility.

NAL-NL1 evolved as a compression based method for non-linear hearing aids in 1998, from the older NAL-R method for linear hearing aids. The NAL-NL1 fitting method presents with some other interesting features, which are based in part, on the original underlying philosophy of the whole NAL "family" of fitting methods (NAL, NAL-R, NAL-RP). This includes *equalization*, rather than *normalization* (preservation) of the loudness relationships among the speech frequencies. The reason the NAL-NL1 method deviates from the approach of preserving the unaided loudness relationships among the different frequency elements of speech is because the "preserving" approach has not been shown to improve speech intelligibility (Dillon, Byrne, Ching, Katsch, Keidser and Brewer, 2000).

A question that might come to mind is whether the hearing aid users appreciate and accept the hearing aid that is programmed to NAL-NL1 targets. Can a user always accept the levels that would theoretically maximize their speech intelligibility? Killion and Revit (1993) have cautioned that even accurate calculations, carefully computed coupler transfer functions, and rigid standards of manufacturing the hearing aid might not yield the perfect results when measured on an individual probe microphone.

The present study aims at evaluating the efficacy with which NAL-NL1 prescribes the hearing aid parameters for persons with varying types and degrees of hearing loss. It also aims at finding out the changes observed in the preferred amplification parameters by the hearing aid users after the first 6 to 8 weeks of hearing aid fitment, and the extent by which they deviate from the target prescribed by NAL-NL1.

Method

Participants

The study included 20 participants in the age ranging from 45 to 80 years (mean age = 60.9 years). The participants were divided into groups based on the degree and type of hearing loss.

A. Based on degree of hearing loss in the aided ear, three groups were formed, which were:

Groups	*Grouping Criteria*
Group A1 (N=5)	Participants with a Pure Tone Average (PTA) of 35 to 55 dB HL
Group A2	Participants with a Pure Tone Average (PTA) of 56 to 70 dB HL

(N=8)	
Group A3 (N=7)	Participants with a Pure Tone Average (PTA) of 71 to 90 dB HL

B Based on type of hearing loss in the aided ear, two groups were formed:

Group	*Grouping Criteria*
Group B1 (N=12)	Mixed hearing loss (Bone conduction thresholds >15 dB; ABG = 15 to 40 dB HL)
Group B2 (N=8)	Sensori-neural hearing loss (ABG < 10 dB)

All the participants were first-time hearing aid users and had no previous experience of hearing aid use. The data were collected after they used the hearing aid for a period of at least 45 days to six months. All the participants had post-lingual onset of hearing loss, with the duration of hearing loss not greater than five years, and they spoke Kannada fluently. All the participants of the study used only digital BTE hearing aid monaurally. The aided thresholds with the selected hearing aid programmed for these individuals were within the speech spectrum.

Instruments used

A calibrated two channel sound field audiometer with two loud speakers to perform the aided sound field testing. The loud speakers were located at 0^0 Azimuth and 180^0 Azimuth, at a distance of 1meter from the participant. A personal computer was connected to the auxiliary input of the audiometer for presentation of speech material through a CD. Personal computer was used along with HiPro, NOAH 3 and hearing aid fitting software for programming the digital hearing aid. A calibrated hearing aid analyzer was used for performing the insertion gain measurements. A questionnaire for fine tuning of hearing aid, the 'fine tuning questionnaire' was used. Participant's own hearing aid was used for the study. They either used model 'A' or 'B' or 'C'. All the three models of the hearing aid were manufactured by the same company and had the features as mentioned below:

- A two channeled fully digital BTE hearing aid suitable for hearing loss from mild to profound degree, with three programmable memories, Automatic Gain Control - Input (AGC-I) compression and output limiting

or

- A two channeled fully digital BTE hearing aid suitable for moderate to severe degree of hearing loss, with three programmable memories, AGC-I compression and output limiting

or

- A single channeled fully digital BTE hearing aid with two frequency bands, suitable for hearing loss of moderate to severe degree, with three programmable memories, AGC-I compression and output limiting

Speech Material

Recorded phonemically balanced Kannada bi-syllabic word lists on a CD, developed by Yathiraj and Vijayalakshmi (2005) were used. Four out of the eight lists in the test material were used. Each of the lists had 25 bi-syllabic words.

Procedure

The testing was carried out in a two room sound treated environment. The procedure was as given below in three phases for each participant. They are:

Phase I: Programming the participant's own hearing aid for three test conditions

Phase II: Measurement using subjective tests
A: Aided hearing threshold
B: Aided Speech Recognition Score (SRS)
C: Aided Uncomfortable level (UCL)

Phase III: Measurement using objective tests
A: Real Ear Insertion Gain (REIG)
B: Real Ear Saturation Response (RESR)

Phase I: Programming the participant's own hearing aid

For each of the participant, his/her own hearing aid model was programmed in three different settings as three different programs. The three hearing aid programs were:

a. *Program with NAL-NL1 setting*: This is the program which was generated as 'first fit' by the hearing aid fitting software. 'First fit' settings were obtained by using the NAL-NL1 prescriptive formula, and the participant's hearing thresholds. This was stored in Program 1 (herein after referred to as P1).

b. *Program with participant's preferred setting*: This was the modified program, modified at the time of hearing aid dispensing as per the participant's needs. The settings that were noted in the scoring sheet at the time of trial (before hearing aid prescription) were used for this purpose. This was saved in Program 2 (herein after referred to as P2).

c. *Program with fine tune setting*: The hearing aid program was modified based on a 'Fitting Assistant Questionnaire', designed specifically for hearing aid fitment. This was used to fine tune the hearing aid after at least a minimum of 45 days of hearing aid use. This program was stored in Program 3 (herein after referred to as P3).

During programming, the acclimatization level was kept at a constant value of two for the above mentioned programs, viz., P1, P2 and P3. The testing was then carried out with the other two phases with each of the above mentioned programs. Both objective and subjective measurements were performed with each of the programs for ten out of 20 participants. Only subjective testing was done for the rest of the participants (10/20). All testing were done using participant's own hearing aid and custom ear mould.

Phase II: Measurement using subjective tests

The subjective tests were carried out by measuring the aided thresholds, Speech Recognition Scores (SRS), and Uncomfortable Level (UCL) in the three aided conditions (P1, P2, and P3).

II A. Aided hearing thresholds

The aided thresholds in sound field were measured for Frequency Modulated (5% frequency modulation) tones at 250 Hz, 500 Hz, 750 Hz, 1 kHz, 2 kHz, 3 kHz, 4 kHz and 6 kHz. The tones were presented through the loud speaker located at 0^0 Azimuth and 1 meter distance from test ear of the participants. Bracketing method was used to arrive at the threshold.

The participant was instructed to indicate the presence of the tone, and to respond by raising the forefinger of the right hand even to the faintest tone heard by them. The lowest level in dB HL at each frequency detected by the participant was noted and tabulated as the aided threshold, with each program setting (P1, P2, P3). This was done for each participant.

II B. Aided Speech Recognition Scores (SRS)

The participants were seated in the calibrated position in the sound field (as mentioned in IIA), with the speech material being presented through the loudspeaker. The recorded word list was played through windows media player in the computer and was routed through the auxiliary input of the audiometer to the loudspeaker. The VU meter deviation was monitored to ensure that it did not exceed an average deflection of 0 dB on the scale. Care was taken to ensure that there was no effect of the order of the word list on SRS.

The participant was instructed to repeat the words that he/she heard. The presentation level was kept constant at 45 dB HL. During aided testing, it was ensured that this level was within the UCL of the participant. The responses were scored on a response sheet as the number of words correctly repeated. The maximum score was 25 as the list consisted of 25 words. The SRS was measured separately for each participant with the hearing aid programmed in three settings (P1, P2 & P3) and tabulated.

II C. Aided Uncomfortable Level (UCL)

Speech noise was presented through the loud speaker.

The level of speech noise was increased systematically from 45 dB HL in 5 dB steps. The participant was instructed to indicate the level at which the noise presented was uncomfortably loud. The instruction was to indicate the level at which the speech noise started to become uncomfortable and no longer tolerable to the participant.

The procedure was repeated two times. The average of highest values at which he/she could tolerate the noise was noted as the UCL, for each setting (P1, P2, P3), for each participant.

Thus, the aided thresholds, SRS, and UCL were established in each program setting (P1, P2 & P3) for all the 20 participants.

Phase III. Measurement using objective tests

Real ear measurements were carried out to evaluate the following, in each of the three hearing aid programs (P1, P2 & P3) for ten participants.

III.A. Real Ear Insertion Gain (REIG)

REIG is the difference in decibels, as a function of frequency, between the Real Ear Aided Gain (REAG) and the Real Ear Unaided Gain (REUG), obtained with the same measurement point and the same sound field conditions (ANSI, 1997).

Before the actual testing started, leveling of the probe system of the hearing aid analyzer was done using the reference microphone placed above the ear to ensure a smooth frequency output from the analyzer. The REIG was obtained by subtracting the REUG from REAG. The participant was seated at one foot distance and 45^0 Azimuth from the loudspeaker of the real ear analyzer.

Measurement of REUG

To ensure proper insertion depth of the probe tube, the probe tube was placed in the ear canal, so that the tube rested along the bottom of the canal part of the ear mold, with the tube extending at least 5 mm (1/5 inch) past the ear mold. The target curve was created in the real ear analyzer by entering the participant’s audiometric data into the instrument and selecting the NAL prescriptive procedure.

Protocol for REUG

- Type of stimulus: International Collegium for Rehabilitative Audiology (ICRA, a temporally modulated signal) digital speech signal.
- Level of stimulus: 60 dB SPL for REUG, REAG, and 90 dB SPL for RESR.
- Reference microphone: On
- Smoothing: Off
- Output limit: 125 dB SPL
- Test type: Insertion Gain

The probe tube microphone in the ear canal picked up and measured the sound in the unoccluded ear canal. The Real Ear Unaided Gain (REUG) was measured and displayed as dB at different frequencies.

Measurement of REAG

Probe tube was placed in the ear canal, so that the tube rested along the bottom of the canal part of the ear mold, with the tube extending at least 5 mm (1/5 inch) past the canal opening as explained in the REUG measurement. The hearing aid was fitted into the participant's ear while holding the probe tube so that its position in the ear canal was not disturbed.

The hearing aid was turned 'on'.

Protocol for REAG

- Type of stimulus: ICRA speech signal
- Level of stimulus: 60 dB SPL
- Reference microphone: On
- Smoothing: Off
- Output limit: 125 dB SPL
- Test type: Insertion Gain

For an ICRA speech signal presented at 60 dB SPL, the probe tube microphone measured the dB SPL in the ear canal as delivered by the hearing aid. The Real Ear Aided Gain (REAG) was displayed as a curve with frequency versus dB.

REIG

The real ear analyzer automatically displayed the REIG across frequencies. This was done by the instrument, by subtracting the REUG from the REAG. The values of REIG were noted down from the data table at 200 Hz, 500 Hz, 700 Hz, 1 kHz, 1.5 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, and 8 kHz, in each program setting (P1, P2, and P3), for each participant.

III B. Real Ear Saturation Response (RESR)

Location of the participant and the loud speaker of the hearing aid analyzer were the same as that for REIG. The placement of probe tube in the ear canal and the hearing aid was the same as that for REAG. The volume of the hearing aid was set to the highest position just before feedback or projected use setting.

Protocol for RESR

- Type of stimulus: ICRA speech signal
- Level of stimulus: 90 dB SPL
- Reference microphone: On
- Smoothing: Off
- Test type: SPL

The probe tube microphone measured the dB SPL in the ear canal as delivered by the hearing aid. The Real Ear Saturation Response (RESR) was displayed as a curve with frequency versus dB SPL. Values of RESR were noted down from the data table at 200 Hz, 500 Hz, 700 Hz, 1 kHz, 1.5 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, and 8 kHz for each program setting (P1, P2, and P3), for each participant.

Thus, the REIG and RESR were noted down for each of the ten participants, at three different hearing aid program settings, i.e., Program 1 (P1), Program 2 (P2), and Program 3 (P3).

Statistics

Statistical Package for Social Sciences, SPSS (version 15) was used for analysis of the data. To examine if there was any difference between these groups of participants an independent samples t-test was run initially. The results revealed no significant difference between performance of sensori-neural and mixed hearing loss groups, hence these two groups were considered as a homogenous group for the rest of the study.

Independent samples t-test was again run for the groups of participants with different degrees of hearing loss and the three groups were found to be statistically different for a few frequencies. Based on this result, the three sub-groups with different degrees of hearing loss have been considered separately for statistics. For all the sub-groups considered henceforth, Friedman's test was done initially to check if there was any significant difference between the three programs (P1, P2 & P3). If a significant difference existed, then the Wilcoxon's test was administered to know which of the three programs differed significantly from each other.

Results and Discussion

Comparison of the three programs (P1, P2 & P3) is done on subjective (aided thresholds, SRS and UCL) and objective (REIG and RESR) measures.

Aided Thresholds:

For all the groups of participants, viz. moderate, moderately severe and severe hearing loss, the aided thresholds for the lower frequencies were better and became progressively poorer at the higher frequencies in all the three hearing aid programs. This can be attributed to the greater hearing loss usually seen at higher frequencies than at the lower frequencies and also to the limited ability of the hearing aids to provide more amplification at the higher frequencies.

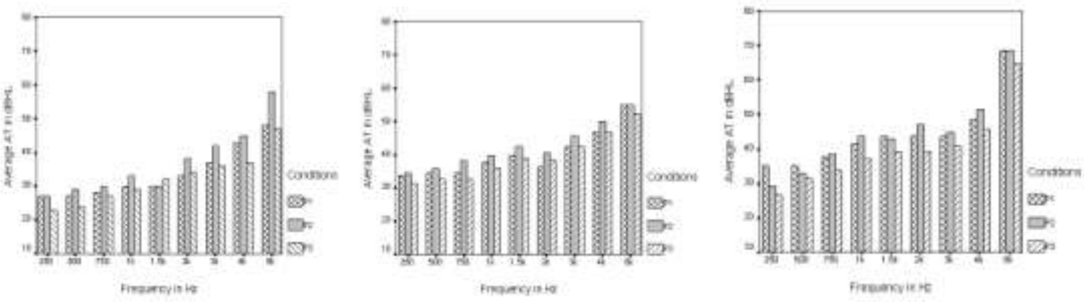

Fig. 1: Average aided thresholds at different frequencies for the groups with moderate, moderately-severe and severe hearing loss for P1, P2 & P3.

In all the three groups, i.e., moderate, moderately severe, and severe, P1 also showed equal or better thresholds than P2, though not statistically significant, for most of the frequencies (more so in the moderate and moderately severe groups), as can be noted from Figures 1. This goes on to prove that participants in the study, even with no previous experience, preferred a hearing aid setting that provided them with improved thresholds when compared to the NAL-NL1 setting, except at 250 Hz and 500 Hz.

Table 1: Programs which differed significantly from each other at various frequencies for the group with moderate hearing loss

Frequency (Hz)	Pairs which were significant from Wilcoxon's test		
	Moderate	Moderately severe	Severe
250	-	-	P1 & P3**
500	-	-	-
750	-	P2 & P3**	
1000	P2 & P3**	P2 & P3**	P1 & P3, P2 & P3**
1500	-	-	P1 & P3*
2000	-	-	P1 & P3*
3000	-	-	-
4000	-	-	-
6000	P1 & P2**	-	-

** p< 0.05, *p<0.1

Significant differences between P2 and P3 at various frequencies across the three groups (as shown in Table 1) indicated better performance from the participants with fine tuning of the hearing instrument rather than with the NAL-NL1 setting.

Speech Recognition Scores

Speech Recognition Scores (SRS) were also compared for P1, P2 and P3 across the three groups. Mean and Standard Deviation for SRS are given below in Table 2. From this table it can be observed that the SRSs were highest with P3 settings, in all the three groups.

Table 2: Mean and Standard Deviation (SD) of aided SRS across three hearing aid programs (P1, P2, & P3) for Moderate, Moderately- Severe and Severe hearing loss groups

Program	*SRS in Groups based on severity of Hearing Loss*					
	Moderate		*Moderately Severe*		*Severe*	
	Mean	*S.D.*	*Mean*	*S.D.*	*Mean*	*S.D.*
P1	22.40	1.14	22.00	1.77	22.57	1.51
P2	22.80	0.84	21.50	2.14	22.86	1.35
P3	23.80	0.45	22.75	0.89	24.00	1.00

However, Results revealed no significant difference in SRS across the three programs, even at 0.05 level of significance, except for SRS in those with severe hearing loss. In this group, the SRS was significantly higher with P3 than with NAL-NL1. This implied comparable speech recognition provided by the three program settings used in the experiment with all the three programs in groups with moderate and moderately-severe hearing loss.

This can also be attributed to 'ceiling effect', i.e., the hearing aids had reached their optimum performance with the first program itself and hence no statistically significant improvement was noted in SRS, though there were changes in aided threshold across programs. For the group with severe hearing loss, significant difference (at $p<0.1$ level) was seen in SRS between programs P2 and P3, indicating a significant improvement in SRS from P2 to P3, again displaying improved performance of participants with the fine tuned settings over NAL-NL1 setting.

Uncomfortable level:

Uncomfortable level (UCL), like SRS, was compared for P1, P2 and P3 across the three groups. The level at which the loudness was uncomfortable were higher in P3 than in P2 in all the groups of participants. These differences were not statistically significant as revealed by Friedman's test, implying that comparable uncomfortable levels were provided by the three program settings, i.e., P1, P2 and P3. The ceiling effect could have been a reason for this, as in SRS.

Also, unlike SRS, no trend in improvement of UCL was seen from P2 to P3 and the results remain inconclusive regarding the trend of UCL with the three programs, P1, P2, and P3 because the speech noise remained tolerable at the maximum limits of audiometer in all the three programs for all the participants.

Objective tests, i.e., REIG and RESR, were also carried out for 10 of the 20 participants. The Mean and SD of the REIG revealed variations across the three programs and across the tested frequencies.

Real Ear Insertion Gain (REIG):

The insertion gain provided by the hearing aid was greater at the mid frequencies than at the lowest or the highest frequencies in all the three program settings, i.e., P1, P2, and P3 for the three groups of participants, as shown in Figure 2. This shows the importance that is given to these frequencies for speech perception not just while calculating the generic formula (NAL-NL1, P2), but also by the participants themselves while selecting the tailor made program for their hearing aid (P1 and P3). This also reflects the lesser efficiency of the hearing aid in amplifying the low and high frequencies.

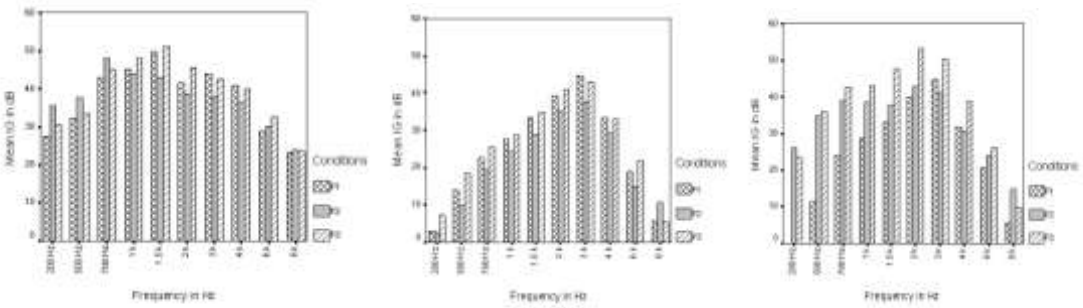

Fig. 2: Average REIG for groups with moderate, moderately-severe and severe hearing loss for P1, P2, and P3 at tested frequencies

Owing to the lesser number of participants in the moderate group (N=2), no statistical tool could be applied to check the influence of the three programs on REIG. However, as can be noted from Figure 2, the fine tune program gave higher insertion gain than the NAL-NL1 program through 1 kHz to 6 kHz, i.e., at frequencies, which are important for perception of speech.

For the group of participants with moderately-severe hearing loss the insertion gain again showed similar pattern, i.e., greater gain for the mid frequencies as compared to the lower and higher frequencies for P1, P2, and P3. However, in this group, no statistically significant difference was noted between P1, P2 and P3. This indicated that for the group with moderately severe hearing loss, the gain provided by the prescriptive formula, NAL-NL1, approximated the actual gain preferred by the participant, even after some days of hearing aid use.

Friedman's test was administered for the group of participants with severe hearing loss to examine if there was any significant difference in REIG at different frequencies. Significant difference was seen at 250 Hz and 8 kHz. Further, at 200 Hz, the Wilcoxon's test revealed a significant difference between the preferred setting (P1) and NAL-NL1 setting (P2). Also significant difference between preferred setting (P1) and fine tune setting (P3). Similarly, at 8 kHz, significant differences were noted between P1 and P2, and also between P2 and P3.

This difference, as can be noted from Figure 2, is in reverse direction, with NAL-NL1 program giving higher gain at both these frequencies than the preferred and fine tune programs. This implies that the NAL-NL1 formula over estimated the gain needed at these frequencies. For many participants, at 200 Hz the mean REIG for P1 approximated zero as for many participants in this group, the REIG was in negative values, which nullified the mean REIG. This is because the hearing aid does not significantly amplify at very low frequencies.

At other frequencies, though statistically insignificant, greater REIG was seen for P3 than P2 which shows that the insertion gain was higher with the fine tune program than that provided by the generic NAL-NL1 formula.

Real Ear Saturation Response (RESR):

As can be observed from Figure 3, no general pattern or behaviour could be attributed to the RESR across the various degrees of hearing loss. As in the case of REIG, here also greater output across the three programs was observed for frequencies of interest, though the difference between low, mid and high frequencies was not as pronounced as seen in REIG. The RESR was higher with P3 compared to P2 (NAL-NL1) except at frequencies below 700 Hz.

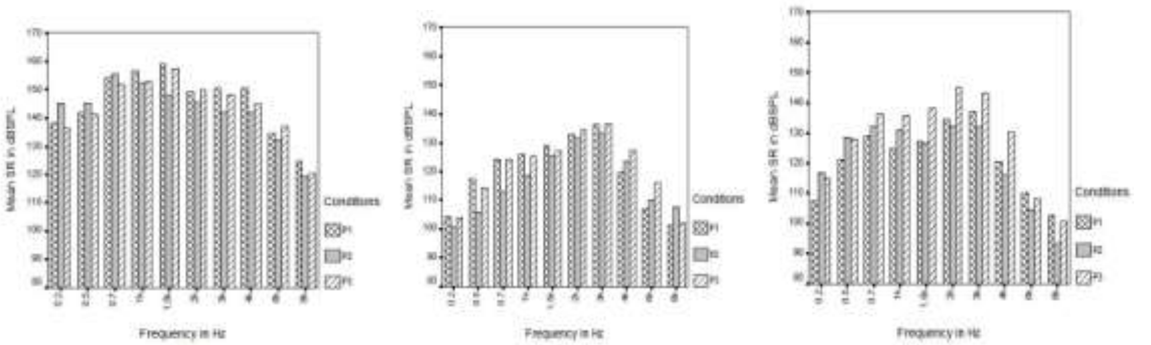

Fig. 3: Average RESR for group with moderate, moderately severe and severe hearing loss for P1, P2, and P3 at different frequencies

The RESR for the group with moderate hearing loss showed a similar trend as that of REIG responses in the same group. That is, the RESR was higher in the mid frequencies than at low and high frequencies, in all the three programs. The group with moderately severe hearing loss consistently showed greater RESR values across frequencies (except at 8 kHz) for P3 compared to P1, as can be noted from Figure 3.

This indicates that the hearing aids with fine tune programs are better equipped to work at higher input levels without causing discomfort to the wearer or causing feedback. Though visible from the figure, this difference was not statistically significant (on Friedman's test) throughout the entire frequency range.

The group of participants with severe hearing loss showed a clear advantage of P3 over P2, as evident from Figure 3. From this figure, it can be observed that the RESR was higher with P3 except at 8 kHz. However, statistically significant difference from Friedman's test in RESR across programs was revealed only at 4 kHz and 6 kHz. The fine tune setting gave the maximum values of RESR proving the efficacy of fine tuning procedure.

Comparison of aided threshold, REIG and SRS:

As can be noted from the results of REIG, the gain provided by the hearing aid was greater for P3 when compared to P1 and P2 for most of the frequencies and in all the three participant groups. This is comparable with the results for aided threshold and speech recognition scores. The performance was better for the P3 program when compared to P1and P2, thus indicating that fine tune setting gave higher insertion gain, resulting in improved aided thresholds and better speech recognition.

Comparison of UCL and RESR:

On examining the UCL values, one can notice higher UCL for all the three participant groups for P3, though not statistically significant, which comparable to greater RESR values is for the three groups of participants for P3 when compared to P2. This proves the advantage that P3 provided over P2. The RESR values have effect on UCL, i.e., higher the RESR, higher will be the UCL, and better will be the Dynamic Range (DR).

The overall results of this study stand at odds with the study by Keidser and Dillon (2006), where they reported NAL-NL1 as being too loud for the first time hearing aid users. As can be noted from REIG and RESR results, the insertion gain as well the saturation response at the time of initial fitting, i.e., with P1, was greater than the gain prescribed by NAL-NL1 (P2), indicating an acceptance of greater loudness than that prescribed by the generic formula in question. Though this difference cannot be proved statistically, which could be attributed to the lesser number of participants in the study, it is recommended that further research be carried out to confirm these results.

However, current study gains support from the work of Arlinger, Lyregaard, Billemark, and Oberg (2000), where they found no correlation between preference and audiological variables. The results of present study also support that reported by Stelmachowicz, Dalzell, Peterson, Kopun, Lewis, and Hoover (1998), who proved that a proprietary formula, which was a statistical summary of the gains actually used by wearers was more accurate than the generic formulae (DSL i/o, and FIG6), which either over- or under- amplified for the degree of hearing loss.

The three programming parameters across all the three groups revealed a negligible difference. However, these negligible changes in the programming parameters brought about some significant changes in the perception (as tested subjectively) and real ear measures (as measured objectively). These results are important as they show that even a minimal change in hearing aid programming parameters can either improve or adversely affect the performance of the hearing aid and can also affect the benefit that the hearing aid user receives from it. Thus, this may also have an effect on the continued use of the hearing aid. Keidser, and Grant (2001), in their study to compare the performance of NAL-NL1 and IHAFF, had reported that even when the difference between the two fittings was small, the subjects preferred and performed better with one program compared to other, proving that even an insignificant change in program is important in terms of subjective results and continued use of hearing aids.

As earlier discussed, most of the results are in favour of the fine tune setting as compared to the preferred settings and the NAL-NL1 setting. It can be safely concluded that the programming done using the ‘Fine tuning questionnaire’ for fine tuning hearing aids gives better results than the NAL-NL1 program.

Participant’s preferred program settings, at the time of first hearing aid trial, usually gave unsatisfactory results with lot of overshooting of the various parameters tested, which can be attributed to the inexperience on the part of the hearing aid user, as they tend to demand greater amplification at the time of first trial of hearing aid. This was observed as all the participants in this study were naïve hearing aid users. However, since only slight changes were present in the programming parameters and only at a few frequencies, the NAL-NL1 can still be considered as the base formula on which changes can be incorporated.

The findings of the present study prove that fine tune program provides better results when compared to NAL-NL1. Re-programming according to individual’s listening needs can enhance the benefit that one can obtain from the hearing aid. Hence, follow-up for fine tuning of hearing aid should be considered as an integral part of hearing aid prescription procedure for greater user satisfaction and continued hearing aid use. Also, these results can guide us in determining the possible changes in programming parameters, resulting in more client-oriented hearing aid setting on the first trial itself.

However, since only slight changes were present in the programming parameters and only at a few frequencies, the NAL-NL1 can still be considered as the base formula on which changes can be incorporated.

The findings of the present study have important clinical implications. The importance of follow-up and fine tuning can be emphasized for obtaining greater benefit from the hearing aid. The information on importance of fine tuning will be useful for hearing aid dispensing audiologists to enhance their knowledge on the probable changes that may occur in the programming over a period of time. Comparing and contrasting the changes occurring over time will endure continued use of the device.

The present study also has certain recommendations for future investigations. Extensive study with different types of hearing loss, and different degrees of hearing loss can help us identify the pattern of changes required in hearing aid parameters, which can be incorporated at the time of first fit itself, hence eliminating the disuse of hearing aid. Also, it is recommended to study such effects with different types of hearing aids, using different technologies. Such studies will help us to know if technology has an effect on the changes that occur in user preference with hearing aid usage for a period of time.

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