Effects of Preferred and Prescribed Gain on Speech Perception in Noise - A Validation of Prescriptive Formulae

Minakshi Kusari & K Rajalakshmi*

Abstract

This study aimed at investigating the effects of prescribed gain and preferred gain on speech perception in noise. Two widely used prescriptive formulae (NAL-NL1 & DSL- I/O) were employed in this study. Two groups of hearing impaired individuals with gradually sloping and steeply sloping loss served as subjects. REIG and SNR threshold measurements were carried out in each subject. The results showed that REIG measured at preferred and prescribed gain in NAL-NL1 as well as DSL-I/O were significantly different in most of the frequencies for both the groups. However, the amount and direction of difference was frequency dependent. In some frequencies the difference between preferred and prescribed gain was not significant. In SNR threshold estimation there were no significant differences between preferred and prescribed gains. The only exception was the gradually sloping hearing loss group, which revealed significant differences for both NAL-NL1 and DSL-i/o at 65 dB SPL.

Introduction

The introduction of digital technology and fully digitized amplifiers in hearing aids has vastly increased the possibilities for re-configuring sound for individuals who suffer from hearing impairment. In spite of these extensive technical advances, it does not appear that consumer satisfaction and market penetration have greatly improved (Haubold & Schweitzer, 2000). Evidences suggest that manufacturers are designing and producing technically better hearing instrument systems, it seems questionable to lay the blame for continuing complaints on them. Rather, suspicion may instead fall on the available means and methods of configuring and fitting hearing instruments to individual user preference. It might be a case of hearing instruments becoming "more mature" in technical sense but remaining 'immature' in the less technical aspects of user satisfaction.

Prescriptive formula, threshold based or suprathreshold based gives the first estimate of gain requirements. There may be inter-subject differences in loudness growth and preferred sound quality even when two subjects have the same audiogram configuration. Fine-tuning is the correction for individual variation from the mean. There is literature support for the view that the preferred gain settings differ from the settings recommended by fitting formula (Arlinger, Lyregaard, Billermark & Oberg 2000; Berger & Hagberg, 1982; Byrne & Cotton, 1988; Marriage, Moore & Alcantara, 2004). These authors have also discussed the effect of hearing aid experience on the difference between prescribed and preferred gain.

* Reader in Audiology, All India Institute of Speech and Hearing, email:rajrose2000@yahoo.com

Speech in noise measures have been used limitedly in quantifying difference between preferred and prescribed gain, except for few reports (Cunningham, Williams & Goldsmith, 2002). Apart from subjective and qualitative evidences empirical evidences in favor of fine-tuning is also required which has direct implications in clinical practice. Individuals with sensorineural hearing loss are more sensitive to noise masking effects than the normal hearing individuals listening to speech processed through a hearing aid. The benefits of fine-tuning of hearing aids, in terms of speech understanding in noise are little known as there is dearth of literature. It is necessary from both theoretical and clinical stand point to establish if the prescribed and preferred gains affect various aspects of hearing such as speech perception in noise. Comparison of the prescribed gain with individual preferred gain is one of the important ways to determine the efficacy of fitting formulae. Such a method though recommended in literature has not been extensively used to validate hearing aid prescriptions (Dillon, 2001). The continued need to verify which formula among (NAL-NLI & DSL (I/O) gives a close match with preferred settings will eventually also be addressed, as this study will use two frequently used prescriptive formula.

Therefore the present study has the following aims:

1. To determine if there is a significant difference between prescribed gain and preferred gain for two non linear hearing aid fitting formulae
2. To determine whether there is any difference in speech perception in noise due to prescribed and preferred settings
3. To determine the differences if any depend on the formulae
4. To determine the differences if any depend on configuration of hearing loss

Method

A. Subjects

Twenty individuals (mean age: 41 years; range: 23 to 56 years) with bilateral sensorineural hearing loss served as subjects for this study. Ten subjects had gradual sloping and ten had steeply sloping hearing loss configuration in the test ear. The mean pure tone average of the gradual sloping and steeply sloping hearing loss subjects were 53 dB (SD=7) and 59 dB (SD=7) respectively. They were native speakers of Kannada language and new users of hearing aid. The aided speech identification scores of the participants were 75% or more in the test ear.

B. Instrumentation and test set up

A calibrated dual channel audiometer (MAICO MA 53) with two hi-fi sound field speakers (MAICO) was used for hearing aid testing. The channel one of the audiometer, with input from a DVD player (Philips), was used to deliver recorded speech material. The channel two of the audiometer was used to deliver speech shaped noise from audiometer. A FP40D hearing aid analyzer was used to check the electro-acoustic characteristics of the hearing aid and also for the Real Ear Insertion Gain (REIG) measurements. All the testing, both for selecting subjects and for experimental purposes were conducted in an air conditioned, acoustically treated single or double room set up. The ambient noise levels inside the test room were within the permissible limits (re: ANSI S3.1 1991, as cited in Wiber 1994).

C. Hearing aid fitting

The Siemens Music Pro behind-the-ear hearing aid was used in this study. The Music Pro has fine-tuning option in which manufacturer's recommended solutions are available for complaints encompassing loudness of sound, loudness of speech, speech intelligibility and acoustic feedback. The hearing aid was programmed using NAL-NL1 and DSL [I/O] fitting formula using the Connexx software version v 5.0 through NOAH 3.0 version and Hi-Pro.

D. Test material

The phonetically balanced list in Kannada developed by Yathiraj and Vijaylakshmi (2005) was used in this study.

E. Procedure

The subjects fulfilling the stated criteria were included in the study. The hearing aid was programmed using the Connexx software version v 5.0 through NOAH 3.0 version and Hi-Pro. Prior to hearing aid fitting the electro-acoustic performance of the aid was measured using FP 40D hearing aid test system following standard audiological protocol. For every new user the hearing aid was programmed with two independent prescriptive procedures: NAL-NL1 and DSL [I/O]. No fine-tuning was allowed for the purposes of comparisons. The gain, frequency shaping and compression parameters were kept in records. The hearing aid fitting in new users were fine-tuned through frequency shaping option of the NOAH program (version 3.0) to determine the preferred gain settings. The hearing aid fine-tuning was performed following standard audiologic protocol. The fine-tuning parameters included audibility, intelligibility, comfort and sound quality, and were programmed using routine questionnaires. The questions were asked on one-to-one basis and with normal vocal effort at 4 ft to 5 ft distance. The low cut, high cut gains and the cut-off frequency values were then manipulated depending upon the subjects' responses. After programming the hearing aid according to each of the fitting formula, REIG were measured at 65 dB SPL with digi-speech input signal using FP 40 D hearing aid analyzer. The values from 250 Hz to 6000 Hz were recorded. The minimum signal to noise ratio (SNR) that is needed to correctly identify and repeat the words presented in noise with a 50% criterion was measured. The SNR threshold measurements were performed at two levels, 55 dB SPL (soft level) and 65 dB SPL (average level). The SNR threshold measurement for each subject was done at prescribed and preferred hearing aid settings for each prescriptive formula, NAL-NL1 and DSL-[i/o]. The speech material was presented at 0° azimuth while speech shaped noise was presented at either 45° or 315° azimuth depending on the test ear. The speakers were placed one meter away from the subjects (re: nose). The SNR threshold was measured using an adaptive procedure. The speech was presented at a constant level of 55 dB SPL. The noise level was set at 15 dB below the signal and varied systematically to measure SNR threshold, where individuals had to repeat correctly minimum 3 words in a set of 6 words. The same process was also carried out for SNR measurements at 65 dB SPL. Similarly SNR thresholds were measured in aided conditions for the other prescriptive formula at both levels. The procedure was further repeated with preferred settings of two prescriptive formulae at each input level. Thus there were total of 8 SNR thresholds measured for each subject. The order of SNR measurements and word list presentations were randomized.

Results and Discussion

The data was appropriately tabulated and statistically analyzed using SPSS (10.0 version) software. Four-way ANOVA (Analysis of Variance) for repeated factors was carried out in both REIG & SNR measurements.

1. Real Ear Insertion Gain (REIG): Both main and interaction effects were statistically significant. To study the interactions, separate analysis was carried out for REIG measurements using paired t-tests. Mean REIG measurements were done at preferred gain and prescribed gain for NAL-NL1 & DSL-i/o

i) NAL-NL1 prescriptive formula

a. Gradually Sloping Hearing Loss: Mean REIG at preferred gain was significantly greater than prescribed gain at 1 KHz, 2 KHz & lesser at 4 KHz. As the listeners were new users, it is assumed that they might have preferred more gain for ease of listening. They might have given more preference to audibility than intelligibility while determination of their preferred gain. This is supported by a review done by Braida, Durlach, Lipman, Hicks, Rabinowitz and Reed, cited in Leijon, Eriksson-Mangold and Bench-Karlsen (1984) in which it was shown that prescriptive methods of fitting the frequency gain characteristics were usually designed and evaluated with the user's ability to understand speech as the sole criteria. However some users may primarily want to adjust the aid so that they can listen at a comfortable spectral balance, if there is a conflict between these goals. At the high frequency (4000 KHz), lesser gain was preferred than prescribed to the subject. Though NAL-NLI acts on a desensitization factor, that is, it gives lower gains at frequencies with more severe losses compared to other frequencies to maximize speech intelligibility; even lower gains were preferred at 4 KHz. There are evidences from previous research (Munro & Lutman, 2005) that some subjects do not like the initial tonal quality of high frequency amplification and describe it as "shrill", "tinny" or "metallic". It is often assumed that this is due to the fact that the subject has not heard the high frequencies for many years. It was also advocated that it could be due to the reason that prescription targets are based on average values and may not be ideal for a specific subject. Findings of this study are in contradiction with earlier studies (Humes, Wilson, Barlow & Garner, cited in Smeds, 2004; Leijon, Eriksson-Mangold & Bench-Karlsen (1984) and Leijon, Lindkvist, Ringdahl & Israelsson, (1990)), which showed that the overall preferred gain by sensorineural hearing loss subjects was lower than the prescribed gain.

In the study by Leijon et al. (1990) it was demonstrated that users clearly used less insertion gain than recommended by NAL formula in the frequency range 1-2 KHz, and the difference was statistically significant. Factors like the subjects selected the type of hearing aid, its electroacoustic features and the procedure used to determine the preferred gain might have contributed to the differences noted in the present study and previous studies. The results may vary largely even if small differences in the above mentioned factors are present. In the study by Humes et al. (2002) linear amplification was used for the subjects, which will give higher than normal loudness for a higher-level input for a person with loudness recruitment. But Smeds (2001) have indicated that subjects without previous hearing aid experience provided with level dependent gain also preferred less overall gain than prescribed by some of the current threshold based prescriptive methods for wide dynamic range compression hearing aids (NAL-NLI, CAMEQ & DSL-i/o). In the study done by Leijon et al. (1990) the subjects were prescribed according to NAL recommendation in a linear hearing aid. The subjects were allowed to make volume control adjustments for about 12 to 15 dB above the recommended values. They were given a trial period to judge the sound quality in their daily life listening situations and answer a questionnaire. However in the current study long trial periods were not given. This could not be a potential factor for the difference because in the previous study even experienced users showed similar preferences. Though subjects in both the studies had similar hearing loss configurations, the subjects in the previous study were elderly listeners, which might be one of the reasons of preferring lesser gain, to avoid tolerance problems. In the previous study the gain at 250 and 500 Hz were almost 0 dB due to direct leakage of the sound. Moreover in the previous study the measurement probe was inserted between the ear mold and the skin. This might have caused additional ventilation and an underestimation of gain at 1 KHz and below. Only real ear insertion gain was measured in the previous study and no speech perception measures were used. Also, in the previous study, the subjects were given several trial periods with the preferred settings and the gains were adjusted on the basis of difficulties faced by the subject in daily listening tasks. In this study no such listening practice was given. So at the first perception, the clients might have preferred ease of listening compared to intelligibility.

b. Steeply Sloping Hearing Loss: At all frequencies mean REIG measured at preferred gain was greater than the mean REIG at prescribed gain. The preference of more gain at low and mid frequencies can be accounted for more audibility and hence ease of listening. They also preferred more high frequency gain which is in contrast with hearing loss desensitization factor, employed by NAL-NL1 where higher frequencies are given less emphasis, especially if the loss is more at high frequencies. It is because the high frequency does not contribute to speech intelligibility much. Most of the subjects of this group had severe to profound loss at high frequencies. So it might be that as high frequencies were not heard at all they preferred more gain to hear those sounds again, whereas in gradual sloping subjects, the subjects did not enjoy the high frequency sounds and hence preferred lesser gain.

ii) DSL-I/O prescriptive formula

a. Gradually sloping hearing loss: Mean REIG measured at preferred gain was significantly lower than REIG measured at prescribed gain for 4000 Hz and 6000 Hz. At 1000 Hz, 2000 Hz and 3000 Hz mean REIG measured at preferred gain were significantly greater than REIG measured at prescribed gain.

The greater preference of gain in mid-frequencies can be explained again with ease of listening explained in the previous section. All the subjects preferred to listen at a comfortable level and gave preference to audibility. Again the preference of lesser gain at high frequency can be explained by the fact that subjects might not have liked the high frequency amplification. Moreover, it can be explained from underlying rationale of DSL- I/O, which includes concept of extended dynamic range rather than normal dynamic range. This extended dynamic range is mapped on to the hearing impaired dynamic range, thus resulting in more gain frequency response than NAL-NLI for all hearing loss. Therefore subjects preferred lesser gain at the higher frequencies when DSL- I/O was used. This preference of less high frequency gain supports previous study by Munro and Lutman (2005) in which subjects were provided with less high frequency gain (16 dB reduction at 4000 Hz) in comparison to DSL (prescribed gain). They preferred reduced gain for overall comfort and this gain was preferred in overall conditions.

However the authors also demonstrated that lesser gains were preferred at low and mid frequencies, which is in contradiction to the present study.

b. Steeply sloping hearing loss: Mean REIG measured at preferred gain was significantly lower than that measured at prescribed gain for frequencies 500 Hz and 1000 Hz. At 2000 Hz and 3000 Hz the mean REIG measured at preferred gain was significantly greater than that measured at prescribed gain. The subjects preferred less gain at the low frequency where DSL- I/O prescribes a higher gain. At 500 Hz the low frequency gains were not essential for the subjects as a higher gain would have masked the mid and high frequency information The lesser gain preference at 1000 Hz may be accounted to preference of the subjects. Again for ease of listening and comfortable hearing, the subjects preferred more gain at 2000 and 3000 Hz. There was no significant difference found at 4000 and 6000 Hz. Though the DSL- I/O is known to give more high frequency gain compared to other formula (Sehgal, 2001; Keidser & Grant, 2001), the listener's preferences were not more or less than the prescribed setting. They might have preferred the audibility in high frequency region where there was severe hearing loss.

c. Gradually sloping hearing loss: The mean difference in REIG between preferred and prescribed gain in case of NAL-NLI were significantly different than mean difference in DSL-I/O. The mean difference in REIG between preferred and prescribed gain was significantly higher in DSL-I/o than in NAL-NL1 at the frequencies 500 Hz, 1000 Hz and 6000 Hz. However at 4000 Hz the difference was more for NAL-NL1. The trend of difference in REIG was same for both the formula. That is, preferred gain was more than prescribed gain at 500 and 1000 Hz. It was less at 4000 Hz and 6000 Hz. At 3000 Hz though not statistically significant the mean difference in REIG at preferred and prescribed gain was larger for DSL-I/o. The type of frequency gain responses prescribed by each formula can explain this. The differences at 6000 Hz are explainable from frequency response characteristics of each formula. DSL- I/O prescribes almost same gain as NAL-NLI at low and mid frequencies but greater gain at higher frequencies. Sehgal, (2005) and Keidser et al (2001) reported that for gradually sloping hearing loss cases the mean REIG at low and mid frequencies were almost equal for NAL-NL1 and DSL-I/O. However at high frequencies NAL-NL1 prescribes less gain than DSL-I/o. Though this explains the difference at 6000 Hz, the difference at 500 Hz and 1000 Hz remains unanswered. It might be accounted for the perceptual differences.

d. Steeply sloping hearing loss: In this DSL-I/o prescribed gain gives a close match to the subject gain preferences. Moreover, the way and amount by which the preferred gain differs from the prescribed one are not identical for NAL-NLI and DSL-I/O. There are some trends maintained by each. In case of NAL-NLI, the preferred gain was significantly higher than prescribed gain at all the frequencies, whereas in DSL-I/o the preferred gain was significantly lower at 500, 1000 and 6000 Hz than prescribed gain and preferred gain was higher at 2, 3 and 4 KHz. Though the difference was not significant at 4 and 6 KHz this can be explained partly by rationale of each formula. The NAL-NLI and DSL-I/o give identical frequency gain response in the mid frequency range and in both formulae more gain is preferred than prescribed whereas in case of lower frequencies, the NAL-NLI prescribes low gain and DSL- I/O prescribed more gain than that. So users while listening with NAL-NLI prefer more gain than prescribed and in case of DSL-I/O the case is reverse. Sehgal, (2005) and Keidser et al. (2001) report that for steeply sloping hearing loss both the formula do not show much variation in gain for low and mid frequencies. The difference in gain becomes larger after 3000 Hz for all the frequencies. NAL-NL1 prescribes lesser gain at higher frequency and gain drops as frequency increases.

2. Speech to noise ratio measurements: Few main and interaction effects were statistically significant. To study the interactions separate analysis was carried out for SNR threshold measurements using paired t-tests.

a. Gradually sloping hearing loss

There was no significant difference between mean SNR thresholds measured at preferred gain and prescribed gain at 55 dB SPL. It can be inferred that a greater audibility could not produce a significant change in speech perception. As explained in the previous section, the hearing impaired subjects must have preferred greater audibility for ease of listening but that was not sufficient to overcome masking effects of noise and improve intelligibility at soft speech input levels. Tillman, Carhart and Olsen (1970) reported that even though the speech is sufficiently amplified, the individuals with SNHL fail to understand speech. It has been shown by investigators that benefits of providing audible speech to listeners with SNHL have limitation. Turner and Cummings (1999) and Turner and Brus (2001) provided similar evidence that maximizing the amount of audible speech was not always the beneficial strategy for patients with SNHL. For 65 dB SPL at the preferred gain, the subjects had approximately 5 dB lower mean SNR thresholds than at prescribed gain. So the increased mean insertion gain in preferred setting at 1 and 2 KHz and reduced gain at 4 KHz were favorable to improve speech perception in noise at average speech input levels. The results of the current study support findings of Ching, Dillon and Byrne (1998) and Turner and Brus (2001), who demonstrated that for lower frequency regions of speech range amplifying speech to audible levels consistently, provided benefit to all patients. The findings of the current study also support results obtained by Turner and Henry (2002) who showed that providing audibility in frequencies with more loss, high frequency regions, gives an advantage to speech recognition in the presence of background noise. They suggested that there are some easier cues for manner and even place that can be perceived by listeners with even severe hearing losses in the high frequency region. In their study it was also shown that the improvement noted in recognition in response to additional high frequency bands of speech were usually not large. However, Ching, Dillon and Byrne, (1998) have shown that for listeners with hearing losses greater than mild degree the amount of information that can be extracted from a speech signal is not proportional to the amount of audibility. Further, in both the gains the SNR thresholds were significantly lower at 65 dB SPL than at 55 dB SPL. This shows individuals with a SNHL are more sensitive to masking effects of noise when listening to speech processed through a hearing aid and this is more marked at soft input speech levels. It supports findings of Sehgal, (2005) who reported similar findings when mean SNR thresholds were compared at two levels within the same formula (NAL-NL1 or DSL- I/O).

SNR measured at preferred vs. prescribed gain at 55 and 65 dB SPL in DSL-I/O:

There was no significant difference between mean SNR threshold measured at preferred and prescribed gain at 55 dB SPL. Though the REIG at preferred gain was lesser than that at prescribed gain, it was not sufficient enough to produce a change in speech perception at 55 dB SPL. The mean SNR at preferred gain was 1 dB lesser than at prescribed gain in the presence of background noises. The lower speech input levels are more affected than higher speech input levels when intelligibility was measured in the presence of noise. In contrast to 55 dB SPL, the

SNR thresholds at preferred gain were significantly lesser than at prescribed gain at 65 dB SPL. It was on the order of 4 dB at preferred gain than prescribed gain. Moreover, within the same gain settings, both preferred and prescribed, the mean SNR thresholds measured at 55 dB SPL were significantly more than that at 65 dB SPL. So the lower speech input levels are more adversely affected by presence of noise as compared to higher input levels.

In the study by Cunningham, Williams and Goldsmith (2001) there were no differences on measures of aided hearing aid benefit (COSI; APHAB), speech perception in noise, sound quality, satisfaction or number of hours worn, between the control and treatment group. In the treatment group post fitting fine-tuning was done. The post fitting fine tuning was carried out in several periodic sessions; though there were subject driven changes in real ear insertion response in the range of 1 to 10 dB over time, there were no significant changes in perceived benefit or speech in noise measures. The results cannot be directly compared with the results of current study as no trial session was given to the subjects in the present study.

b. Steeply Sloping Hearing Loss:

i. SNR measured at preferred vs. prescribed gain at 55 and 65 dB SPL in NAL NL-1:

There was no significant difference between SNR measured at preferred and prescribed gain for both the levels. This shows the increase in REIG at preferred gain across all the frequencies was not sufficient to improve or worsen the SNR thresholds. That is, though a greater gain was provided after fine-tuning according to listener preference, it was not increasing or reducing the masking effects of noise. The past research has shown that providing high sensation levels at frequencies where the hearing loss was severe or profound did not always improve speech intelligibility (Ching et al. 1998; Hogan & Turner, 1998). So it can be extrapolated that greater gain at the higher frequencies will not contribute much to speech intelligibility. Moreover some reports also suggest that providing amplification to individuals with SNHL, especially at the higher frequencies, may deteriorate the speech perception in noise (Ching, et al.1998; Hogan & Turner 1998; Turner & Cummings 1999; Turner & Brus 2001). Further, the hearing loss desensitization factor, employed by NAL-NL1 also suggests that increasing audibility especially at the high frequency does not maximize speech intelligibility. So it can be concluded that greater gain at the higher frequencies did not contribute much to speech intelligibility. There is reduced usefulness of audibility with increased hearing loss (hearing loss desensitization) and this is more marked at high frequencies than at lower frequencies. As compared to gradually sloping loss, wherein there was a significant difference between preferred and prescribed gain at 65 dB SPL, the same was not true in cases with steeply sloping hearing loss. If we look at the rationale of NAL-NL1 it provides less high frequency gain as these have minimal contribution to SII. In the present study though listeners with steeply sloping hearing loss preferred greater gain at low, mid and high frequency region, the speech intelligibility was not affected, neither had it improved nor did it deteriorate. This implies that fine-tuning at the first session can be carried out in response to subject's complaints without affecting the speech intelligibility. However, to validate the fine-tuning procedure sound quality judgment tasks could be included along with speech perception measures. Even though the speech is sufficiently amplified the individuals with SNHL fail to understand speech (Tillman, Carhart & Olsen, 1970). It has been shown by investigators that benefits of providing audible speech to listeners with SNHL have limitation. Turner and Cummings (1999), Skinner (1980), and Turner and Brus (2001) provided similar evidence that maximizing the amount of audible speech was not always the beneficial strategy for patients with SNHL. Further, the effect of level when analyzed gave similar results as in subjects with gradually sloping hearing loss.

ii. SNR measured at preferred and prescribed gain within each level in DSL i/o:

There was no significant difference between mean SNR threshold measured in prescribed and preferred gain at both levels. The differences in REIG were not sufficient enough to bring in changes in speech perception in noise. As observed in the REIG measurements the subjects with steeply sloping hearing loss preferred more gain at mid frequencies and high frequencies. But this increased audibility did not improve or deteriorate the SNR thresholds. However it is reported (Ching et. al., 1998; Hogan and Turner 1998; Turner and Cummings 1999; Skinner 1980; and Turner and Brus 2001) that increased high frequency audibility did not increase speech perception in noise, though few authors (Turner and Henry 2002) suggested improvements to be present. As there were no significant changes in SNR thresholds, not even deterioration, it can be concluded that the amount of change relative to DSL-i/o prescribed settings does not bring about change in speech perception in noise. So this amount of fine-tuning can be done in response to subject's complaints without the fear of incorrect amplification.

3. Effect of formula on SNR measurements: There was no significant difference between mean SNR measured threshold for NAL-NL1 and DSL-i/o when compared within same level and gain (preferred and prescribed) for both the configurations. In case of SNR threshold measurements no significant difference was found between preferred and prescribed gain at 55 and 65 dB SPL. The perceptual preferences by the subject at low, mid and high frequencies were not sufficient to bring about changes in the SNR thresholds. Though the effect of both formulae is significantly different in REIG measurements in both the configuration of hearing loss, the same is not true in case of SNR measurement. The trends of difference between prescribed and preferred gain in each formula are not reflected on SNR threshold measurement. It might be argued that as the adjustments were done in the same hearing aid with same signal processing, the differences in SNR threshold measurement were not evident across both the formula as well within each formula.

Summary and Conclusions

Real Ear Insertion Gain measurements and Speech to Noise Ratio thresholds were established at preferred and prescribed gain settings of each formula in each group of subjects. REIG measured at preferred and prescribed gain in NAL-NL1 as well as DSL-I/o were significantly different in most of the frequencies for both the groups. However the amount and direction of difference was frequency dependent. In some frequencies the difference between preferred and prescribed gain was not significant. The difference between REIG at preferred and prescribed gain in each formula was computed to investigate the effect of formula. It was found that each of the formula maintained a trend for each group. The NAL-NL1 prescribed settings were close to the preferred settings in case of gradually sloping hearing loss subjects. However for DSL-i/o the differences were large. In case of steeply sloping hearing loss, the trend was reversed; DSL-i/o gave a close match to the preferred settings. Thus, it can be concluded that the listeners in both the groups showed deviant preferences from the prescribed settings when using each formula. In most of the cases, the listeners preferred higher gains at mid frequencies, showing that they enjoyed listening at a comfortable level whereas at high and low frequencies the preferred gain was lower than the prescribed gain. However, in steeply sloping hearing loss group there was a preference for higher gains than prescribed throughout the frequency range when NAL-NL1 was used.

In SNR threshold estimation there was no significant difference between preferred and prescribed gain. The only exception was the gradually sloping hearing loss group which revealed significant differences for both NAL-NL1 and DSL-I/o at 65 dB SPL.

Hence it can be concluded that the trend of difference between prescribed and preferred gain in each formula observed in REIG measurement was not reflected on SNR threshold measurement. So the changes done in the overall gain and frequency shaping parameters in response to subjective impression were not affecting the speech perception in noise in most cases, with the exception being gradually sloping hearing loss group at 65 dB SPL.

The future directions implicated by the present study are that quality judgment tasks along with real ear and speech perception measures should be included for quantifying the difference between preferred and prescribed gain. Moreover the preferred gain was obtained in quiet situation. It is suggested that the protocol to determine preferred gain settings should also encompass listening in noisy situations with varying SNR and speech input levels. The validations should be carried out in varying listening situation as the preferences can vary with circumstances and listening situations as well. Further research should be carried out using subjects with other configurations of hearing loss and on larger population.

References

Arlinger, S., Lyregaard, P.E., Billermark, E. & Oberg, M. (2000). Fitting hearing aids to first time users. *Scandavinian Audiology*, 29, 150-158.

Berger, K.W. & Hagberg, E.N. (1982). Gain usage based on hearing aid experience and subject age. *Ear and Hearing*, 3(4), 235-237.

Byrne, D. & Cotton, S. (1988). Evaluation of the National Acoustic Laboratories – New hearing aid selection procedure. *Journal of Speech and Hearing Research*, 31, 178-186.

Ching, T.Y.C., Dillon, H. & Byrne, D (1998). Speech recognition of hearing-impaired listeners: Predictions from audibility and the limited role of high frequency amplification. *Journal of the Acoustical Society of America*, 103 (2), 1128-1140.

Cunningham, D.R., Williams, K.J. & Goldsmith, L.J. (2001). Effects of providing and with-holding post fitting fine-tuning adjustments on outcome measures in novice hearing aid users: A pilot study. *American Journal of Audiology*, 10, 1-11.

Dillon, H. (2001). Hearing Aids. Turramurra: Boomerang Press.

Haubold, J. & Schmeitzer, C. (2000). Fitting for an 'Auditory life'. *The Hearing Review,* 7 (9), 42-51.

Hogan, C.A. & Turner, C.W. (1998). High frequency audibility: Benefits for hearing-impaired listeners, *Journal of the Acoustical Society of America,* 104 (1), and 432-441

Keidser, G. & Grant, F. (2001). Comparing loudness normalization (IHAFF) with speech intelligibility maximization (NAL-NL1) when implemented in a two-channel device, *Ear & Hearing*, 22 (6), 501-515.

Leijon, A., Eriksson-Mangold M. & Bench-Karlsen, A. (1984). Preferred hearing aid gain and bass-cut in relation to prescriptive fitting. *Scandavinian Audiology*, 13:157-161

Leijon, A., Lindkvist, A., Ringdsahl, A. & Israelsson, B. (1990). Preferred hearing aid gain in everyday use after prescriptive fitting. *Ear and Hearing*, 11 (4), 299-305.

Marriage, J., Moore, B.C.J. & Alcantara, J.I. (2004). Comparison of three procedures for initial fitting of compression hearing aids. III. Inexperienced versus experienced users. *International Journal of Audiology*, 43, 198-210.

Munro, K.J. & Lutman, M.E. (2005) Sound quality judgments of new hearing instrument users over a 24-week post fitting period. *International Journal of Audiology*, 44, 92-101.

Sehgal, A. (2005). *A comparative study of proprietive and generic prescriptive procedures for non-linear hearing aids*. Unpublished master's dissertation. Mysore: University of Mysore.

Smeds, K. (2004). Is normal or less than overall loudness preferred by first-time hearing aid users*? Ear & Hearing*, 25, 159-172.

Tillman, T.W., Carhart, R. & Olsen, W.O. (1970). Hearing aid efficiency in a competing speech situation *Journal of Speech and Hearing Research*, 13, 789-811.

Turner, C.W. & Brus, S. (2001). "Providing low and mid-frequency speech information to listeners with sensorineural hearing loss. *Journal of the Acoustical Society of America*, 109, 2999-3006

Turner, C.W. & Henry, B.A. (2002). Benefits of amplification for speech recognition in background noise. *Journal of the Acoustical Society of America*, 112 (4), 1675-1680

Turner, C.W. & Cummings, K.J. (1999). "Speech audibility for listeners with high-frequency hearing loss." *American Journal of Audiology*, 8, 47

Wilber, L.A. (1994). Calibration, pure tone, speech and noise signals. In J. Katz (Eds.). *Handbook of Clinical Audiology* (4^{th} Edn.) (Pp. 73-97). Baltimore: Williams and Wilkins.