Comparison between preferred gain and NAL-NL1 prescribed gain formulae in naïve adult hearing aid users

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CERTIFICATE

This is to certify that this dissertation entitled **"Comparison between preferred gain and NAL-NL1 prescribed gain formulae in naive adult hearing aid users"** is the bonafide work submitted in part fulfilment for the Degree of Master of Science (Audiology) of the student with Registration No: 10AUD005. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this Master's dissertation entitled **"Comparison between preferred gain and NAL-NL1 prescribed gain formulae in naive adult hearing aid users"** is the result of my own study under the guidance of Dr.Vijaya Kumar Narne, Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in other University for the award of any Diploma or Degree.

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CHAPTER 1

INTRODUCTION

Cochlear hearing loss can vary in terms of degree and configuration. This necessitates tailor made fitting of the hearing aid for every client. Widely practiced approach in the clinics is to use a prescriptive procedure, to provide approximate target amplification. The prescriptive approach for hearing aid fitting is, one in which the amplification characteristics are calculated from some of the hearing characteristics of the individual. This is based on the assumption that certain amplification characteristics suit certain type, degree and configuration of hearing loss. The prescriptive methods were changed over the years due to advancement in technology, better understanding of hearing characteristics and other factors affecting hearing aid performance.

Prescriptive procedures for nonlinear hearing aids are based upon different underlying rationales. The fitting procedures use either threshold or supra threshold measurements as input data (Dillon, 2001). Threshold based procedures are namely NAL-NL1 (National Acoustics Laboratory – Non-linear 1), (Dillon, 1999), FIG6 (Killion&Fikret-Pasa, 1993), and partly DSL [I/O] (Desired Sensation Level Input-Output, linear compression version), (Cornelisse, Seewald& Jamieson, 1995). Supra threshold procedures are LGOB (Allen, Hall &Jeng, 1990), IHAFF (Independent Hearing Aid Fitting Forum) (Cox, 1995) and partly DSL [I/O] (Desired Sensation Level Input-Output, curve linear compression version) (Cornelisse, Seewald& Jamieson, 1995). Among the procedures named above, most commonly used procedure for prescribing hearing aids is NAL-NL1 (Dillon, 2001). The prescriptive formulae, threshold based or supra threshold based, give the first approximation of gain required. Clinical experiences with prescriptive methods show that the methods cannot eliminate the need for individual adjustments i.e., fine tuning of hearing aid (Dillon, 2001). However, one should bear that fine tuning of gain settings in the hearing aids is performed on prescribed gain. The prescribed gain should be a good approximation to preferred gain, which reduces the trial and error done by the clinician and also saves time (Dillon, 2001).

Many investigators have reported that gain provided by NAL-NL1 was not appropriate for new hearing aid users (Mueller & Powers, 2001). Further studies conducted on western population demonstrated that new hearing aid users prefer less gain than that prescribed by NAL-NL1 (Keidser, Brien, Carter, Mc Lelland, &Yeend, 2008; Smeds, 2004). Ankit and Manjula (2008) studied in Indian population and showed opposite results that Indian populations prefer higher gain than that prescribed by NAL-NL1. Hence, the studies in this direction are needed to know the deviation in gain parameters between preferred and NAL-NL1 settings in naïve hearing aid users.

1.1 Need for the study

The gain preferred by naïve hearing aid users is lesser than that preferred by experienced users (Humes, Wilson, Barlow & Garner, 2002; Smeds, 2004). The new hearing aid users require lesser gain than that prescribed by NAL-RP (Byrne & Cotton, 1988; Cox & Alexander, 1992; Horwitz& Turner, 1997; Humes, Wilson, Barlow, Garner, 2002, Smeds, 2004). Many investigators from western countries (using English speaking individuals) compared NAL-NL1 formula in naive and experienced hearing aid users (Keidser et al, 2001, 2004, 2006, 2008 &Humes et al., 2002). They observed that NAL-NL1 provides 3 to 6 dB higher gain than that preferred by cochlear hearing loss individuals.

Most of the above studies comparing preferred and prescribed gain were performed on western population. On contrary, Indian population, Ankit and Manjula (2008) showed opposite results, that is Indian populations prefer higher gain than that prescribed by NAL-NL1. However, the studies done by Ankit and Manjula (2008) considered overall gain from hearing aid software program. The difference that is noted between NAL-NL1 and preferred gain mayn't be appropriate because the target formula selected as NAL-NL1 in programming software gives a lesser gain of 10dB than the target gain noted from REIG values. So, further studies are needed to confirm the results of the previous study. There are only limited studies available on comparing preferred gain and prescriptive gain settings in naive hearing aid users in Indian context. Further, general opinion among the clinicians in India is that, majority of the clients prefer different gain settings than that prescribed by NAL-NL1. Hence, it becomes all the more important to compare the prescribed and preferred gain settings in new hearing aid listeners. These deviations can be studied using REIG and speech perception measures.

It is important to use REIG measurements because it provides the true gain in the ear canal. Aazh and Moore, (2007) have demonstrated that, the currently available programming software provides an inappropriate gain in the ear canal than that prescribed by the prescriptive procedures (Aazh& Moore, 2007; Swan & Gatehouse, 1995). This can only be identified and adjusted using REIG measures. Hence, measuring this is an essential tool while fitting the hearing aid.

Many researchers have used speech perception measures to check for the acceptance of hearing aid gain characteristics. Some have used continuous discourse with noise (Keidser et al., 2005) and a few others have used speech recognition threshold (Moore, Alcantara& Marriage, 2001). The mentioned studies demonstrate that scores were different between preferred and prescribed condition. Prescriptive formula provides maximum emphasis to speech; it thus becomes an important tool to study the difference in speech perception using preferred and prescribed condition.

1.2 Aim of the study

The aim of the present study is to find the deviation in gain parameters, at three different input levels (soft, moderate and loud level) between preferred and prescribed (NAL NL-1) fitting strategy in naïve hearing aid users.

CHAPTER 2

REVIEW OF LITERATURE

Most hearing aids fitted today are programmable and the audiologists are required to program these instruments according to established prescriptive fitting methods, such as NAL-NL1, DSLv4.1 etc. The reason for programming the hearing aids to a given prescriptive method is that substantial research has indicated that this fitting philosophy is most appropriate for the average patient, given the patient's specific audiometric configurations. Most appropriate can mean maximizing speech intelligibility, obtaining superior speech quality, restoring normal loudness perception ,or some combination of these or other factors. Given the multiple settings required in today's hearing aids for gain, output and compression, it is necessary to have an automated starting point for the hearing aid fitting.

Prescriptive selection procedures have had a long history and their references can be found even during 1930s. Knudsen and Jones (1935) proposed that the gain needed at each frequency was equal to the threshold loss at the same frequency minus a constant. This is also known as mirroring of the audiogram, because the shape of the gain frequency response equals the inverse of the shape of the hearing loss. The mirroring procedure follows a pattern such that there is a 1 dB increase in additional gain given to overcome every 1dB increase in hearing loss. But it can be deduced by the pattern that the gain prescribed maybe more than necessary at certain frequencies, where the hearing loss and the loudness growth will not be similar for all individuals. Hence, for all higher levels, the amount of gain would be excessive if all gain prescription methods follow mirroring procedure.

Mirroring thus leads to excessive gain, especially for those frequencies with the greatest hearing loss (Dillon, 2001). The next step in this regard was to provide required gain based on the person's most comfortable level (MCL) rather than on their thresholds. Watson and Knudsen (1940) suggested that speech should he amplified sufficiently to make speech energy audible and comfortable. Although their specific formula, incorporated MCL, but did not take into account the variation of speech energy across frequency.In mid-1940's, half gain rule was proposed based on the observation that people chose the required gain which is approximately half of their hearing loss. In fact, half gain rule and raising speech to MCL are both very similar. In cases of mild to moderate sensor neural hearing loss, the threshold of discomfort is little different from that in normal hearing individuals. As MCL is approximately half way between threshold of hearing and discomfort, every 2 dB increase in hearing loss requires MCL to be raised by 1dB. This gain is approximately half of the hearing loss.But the primary aim is to raise speech to MCL, but the speech intensity across the frequency spectrum is not same, such as low frequency components are more intense than the high frequency sounds. Hence, half gain rule needs some modifications, like either increasing gain for high frequencies or by decreasing gain at low frequencies or both (Dillon, 2001). Moreover, the half gain rule also needs to be modified for severe and profound hearing losses. When hearing thresholds are greater than 60 dB HL, discomfort thresholds are significantly above normal. So the relationship between threshold, MCL, and discomfort does not remain the same. In this case, MCL is elevated by more than half of the hearing threshold loss. Hence, the gain to be provided must be more than half of the hearing loss (Dillon, 2001).

With all the previous data, it is very clear that even more than 50 years ago, the basis for prescription for gain was based mainly on two auditory attributes, hearing threshold and supra-threshold loudness percept (such as MCL). The link between these is made clear in some procedures where threshold and discomfort levels are measured: but are used to estimate MCL by assuming that MCL bisects the person's dynamic range (Dillon, 2001).

2.1 Prescriptive procedures

This complex and inter twining relationship between threshold and loudness perception provides the base for most current procedures for advanced non-linear hearing aids. So far, prescription procedures for non-linear devices can be broadly classified into two categories.

1. **Loudness Based procedures** : A few of them being Loudness Growth in Octave Bands (LGOB) (Allen, Hall, &Jeng, 1990), Independent Hearing Aid Fitting Forum (lHAFF) (Cox, 1995), ScalAdapt (Kiessling, Schubert &Arehut, 1996).

2. **Threshold Based procedures**: Some of them being National Acoustic Laboratory Non-Linear, version 1 (NAL-NL1) (Dillon, 1999), F1G6 (Killon&Fikret-Pasa, 1993), Desired Sensation Level (input/output) (DSL [i/o]) (Cornelisse, Seewald, &Jamiason, 1995)

Nonlinear prescription can be viewed as specifying the gain-frequency response for several levels of input. Both, average gain and frequency response vary with input level. Alternatively, this can be viewed as specifying input-output curve at many frequencies. However, it is totally impractical to prescribe a hearing aid solely based on prescriptive methods as evaluation of the end results, such as fine tuning of the device according to individual needs is essential in all cases (Dillon, 2001). The following section deals with the various prescriptive formulae.

Loudness growth in half-octave bands (LGOB)

LGOB aims to normalize loudness. Here, the client has to rate the loudness of narrow-band noises on a 7-point rating scale. The average level corresponding to each loudness category in a hearing impaired person is compared to levels needed in a normal hearing person. Now, for each input level, the gain needed to normalize loudness is found out and applied.

FIG6

This procedure specifies how much gain is required to normalize loudness, especially at medium and high-level input sounds. This is not based on individual measures of loudness but on hearing threshold. Rather, it uses loudness data averaged across a large population with similar degree of hearing loss. Gain is prescribed at input levels of 40, 65 & 95dB SPL and is interpolated for the rest. Generally, for low-level input sounds (40dB SPL), the basis for prescription of gain is that for mild-moderate degree of hearing loss patients should have aided thresholds 20dB above normal hearing threshold. For comfortable level (65dB SPL) input signals, the amount of gain prescribed for any degree of hearing loss is equal to the MCL of the normal hearing population. For high level (95 dB SPL) input signals, the gain prescribed is equal to the boost required to make it equally loud as in a normal hearing person (Dillon, 2001).

CAMEQ

This procedure (Moore, Glasberg& Stone, 1999b) aims to place as much of the speech spectrum information as possible above absolute threshold for a given overall loudness. This is achieved by amplifying speech such that, on average, the loudness is similar for a frequency range between 500-5000Hz. The most specific goal is to make the loudness same in each critical band. This goal can be described as amplifying speech so as to give a flat loudness pattern across frequencies. This also aims to achieve equal across different input levels and achieve same overall loudness as normal for speech over a wide input levels.

CAMREST

This procedure (Moore, 2000) determines the gain needed to restore perception of loudness to normal for speech like stimuli. This not only attempts to restore overall loudness to normal but also makes the relative loudness across frequency bands the same as normal. This also aims at normalizing loudness for speech over a wide range of input levels.

In the current day technology, most hearing aids are non – linear, multichannel. They mostly use prescriptive procedures such as NAL NL–1 and DSL [i/o]. The following section will describe these two formulae in detail.

DSL [i/o]

This fitting strategy is just like its predecessor DSL and is based on loudness equalization or normalization. Loudness normalization means that sounds that appear soft to a normal hearing person should be audible soft, after amplification, to the hearing-impaired person. Similarly, sounds that are comfortable or loud, for the normal hearing person should be comfortable or loud, respectively, after amplification for the hearing aid user. There are basically two aspects of normalization. First, the overall loudness of sounds is normalized. This means for any input level and frequency, the sound would be equally loud for a normal hearing individual and to a hearing impaired person after amplification Second; the relative loudness of each frequency components of complex sounds will be preserved. By equalization, it means that all frequency bands of speech will be amplified sufficiently to produce equal loudness of speech.

The name DSL [i/o] stands for Desired Sensation Level [Input/Output] and was first described by Cornelisse, Seewald and Jamieson (1995). DSL [i/o] method provides prescriptive targets for the fitting of wide-dynamic-range compression hearing aids. DSL [i/o]'s goals were to have loud sounds not exceeding the individual's uncomfortable listening level, make speech undistorted and audible across a wide range of input levels without discomfort, and to normalize loudness (Cornelisse et al. 1995). DSL [i/o] utilizes low-compression thresholds to increase audibility of softer speech sounds. The DSL [i/o] method has the goal of fitting "the acoustic region corresponding to the extended normal auditory dynamic range into hearing-impaired individual's residual auditory dynamic range" (Cornelisse et al. 1995). The method is based on complete compensation for recruitment, which in turn means restoration of dynamic range to normal and complete restoration of audibility of speech sounds.

NAL NL-1

The name NAL-NL1 stands for National Acoustics Labs, Non-linear, version 1 and was first described by Dillon in 1999. The underlying assumptions behind this procedure like its predecessors NAL-R and NAL-RP is to maximize speech intelligibility subject to the overall loudness of speech at any level being not more than perceived by a normal hearing person. The main objective of developing NAL-NL1 was to determine the gain for several input levels that would result in maximal effective audibility. This is neither based on loudness normalization nor equalization. However in this procedure the loudness of the signal is varied to such an extent where speech intelligibility is maximized.NAL NL-1 is based on two models: Loudness model (Moore &Glasberg, 1997) & Speech Intelligibility Index (SII), (ANSI, 1997). The only information required is the hearing thresholds and the speech spectrum levels input to the ear after amplification. One of the main criterions is that the loudness of an amplified speech should not be louder than that perceived by someone with normal hearing. If the lower levels result in higher SII, gain on the hearing aid will be reduced to achieve higher SII.

NAL NL-1 is based on a complex equation that specifies insertion gain at each standard 1/3 octave frequencies from 125Hz to 8000Hz. For speech input at any level, gain at each frequency was systematically varied with a high speed computer until the calculated speech intelligibility was maximized, but without the calculated loudness exceeding that loudness calculated for normal hearing people listening to speech at the same level. This procedure was repeated for many representative audiograms and the optimized gains for each audiogram, for each input level were found. As this was a very time consuming process, even for a single audiogram at a single input level, an equation was fitted to the complete set of optimized gains. This equation thus summarizes all the optimizations and can be applied to any audiogram. Alternately, the aid can be prescribed in terms of real ear aided gain (REAG). REAG is deduced from insertion gain by adding the adult average real ear unaided gain (REUG) to the insertion gain target (Dillon, 2001).

The NAL – nonlinear software program displays the results as either gain curves at different levels, or I/O curves at different frequencies. These curves can be for a 2 – cc coupler, an ear simulator, or the real ear. In case of real ear prescription, the gains can be either insertion gain or REAG. For multichannel hearing aids, crossover frequencies, compression thresholds, compression ratios and gains for 50, 65 and 80dB SPL input levels were also recommended by NAL-NL1 programming software.

Amplification requirements for people with mixed losses are fulfilled in two steps. First, by applying the gain formula to the sensorineural part of the person's hearing loss (i.e. the bone conduction thresholds) and then calculating the gain equivalent to 75% of the conductive part of the loss (i.e., the air bone gap) and then adding them (Dillon, 2001).

2.2 Comparison of different prescriptive procedures

In the following section, an attempt has been made to compare amongst the various prescriptive methods and preferred gain settings. It can be said that even though there are a lot of fitting strategies for non-linear hearing aids, it is very difficult to definitely ascribe any one of them as the best. Also, it is important to know which rationale works best when listening to a range of input levels that hearing aid users are exposed to in real life situations. Here is a brief summary regarding the few studies that have been conducted in this regard.

Byrne, Ching, Katsch, and Keidser (2001) has made an attempt to compare NAL-NLI with DSL (i/o), FIG6 and IHAFF for flat, reverse slope, moderately sloping and high-frequency hearing loss for a range of input levels i.e., 50, 65 and 80 dB SPL. Results showed that, NAL-NLI prescribes less low frequency gain for flat and upward sloping hearing loss, while it prescribes less high-frequency gain for moderately sloping and steeply sloping high frequency loss, when compared to other procedures. The relative differences in gain prescribed are different as expected as they are based on different principles. As already mentioned, NAL-NLI attempts to make the spectral balance in the speech signal, which is required to maximize calculated speech intelligibility. As it is a well-known fact that low frequency parts of the signal contribute to the loudness of the signal than the high frequencies, NAL-NL1 gives low cut while prescribing gain, which is not so for other procedures. The other procedures attempt to normalize loudness at each frequency. NAL NL-1 procedure never attempts to produce a high sensation level at the frequencies with the greatest loss, because the ear's ability to extract information at those frequencies would have decreased. However, it is unclear that in spite of the fact that all three procedures have similar rationales, they prescribe different gain for various configurations of hearing loss. This may be because of the slight differences in their rationale and in the normative data they utilize (Dillon 2001).

Ching, Scollie, Dillon, andSeewald (2010) compared the relative effectiveness of the NAL-NL1 and the DSL v.4.1 prescription procedures for children with mild to moderately severe hearing loss. 48 subjects were taken for this study and this study was being conducted simultaneously in Australia and Canada. Evaluations for this study included speech perception tests, loudness ratings, paired comparison judgements of intelligibility, and children's preferences and performances in real-world environments. This study was divided into various trial periods. During the first trial period, half of the participants received the NAL-NL1 and the other half the DSL v.4.1 prescription fitting. This was carried on for 8 weeks after which, each participant received the other prescription for the second trial period of another eight weeks. During the third and fourth trial periods, both prescriptions were put into separate programs in their respective hearing aids, using a remote control for access by the participants at all times. Each of the third and fourth trial periods were for duration of four weeks. At the end of each trial period, battery of tests was administered for assessment. Results indicated that the DSL v.4.1 procedure prescribed higher gain (0.5 to 4 kHz) than the NAL-NL1 prescription on average by about 10 dBs It was also noted that across trials 1 and 2, more negative comments about noise disturbance was associated with DSL v.4.1 than with NAL-NL1, and positive comments about loudness comfort was associated with NAL-NL1 than with DSL v.4.1. They also reported that across trials 3 and 4, more positive comments about listening to soft speech and speech from a distance or behind were associated with DSL v.4.1 than with NAL-NL1. The authors concluded that, the findings imply that the gain requirements of children in real-life situations are not met prescribed either by NAL-NL1 or the DSL v.4.1 prescription. Hence, to achieve optimal audibility of soft speech, children need more gain than what is prescribed by NAL-NL1 and to achieve listening comfort in noisy places, children need less gain than what is prescribed by DSL v.4.1.

Stelmachowicz and Dalzell (1998) using Resound 2-channel fast acting WDRC hearing aid compared the gains for input levels of 50 and 80 dB SPL prescribed by DSL[i/o], FIG6 and a proprietary algorithm. They reported that DSL [i/o] procedure over-prescribed gain at 500, 2000 and 4000 Hz at both input levels. FIG6 under-prescribed gain for mild and moderate hearing losses, particularly at the 80 dB input level, but over prescribed gain for severe to profound losses. The manufacturer's algorithm provided a closer approximation to the gain actually used by the adults in this study. That is not too surprising, as the proprietary formula was a statistical summary of the gains actually used by wearers of precisely this type of hearing aid. It is however possible that the gains used by the subjects were influenced by the gains they were fitted with, which in turn were influenced by the proprietary fitting formula.

Humes and Christensen (1999) compared a two-channel WDRC device prescribed using DSL [i/o] to a linear hearing aid prescribed using NAL-R. The WDRC instrument gave superior speech intelligibility, particularly at lower input levels and was preferred by 76% of the subjects in field trial. One possible interpretation is that DSL [i/o] prescribed a more appropriate gain-frequency response for mild-level inputs than did NAL-R. For high frequency sounds, both prescribed lesser than required because of the differences in the two prescriptions and the mean high-frequency gain achieved for the WDRC instrument was closer to NAL-R than to the DSL [i/o] prescription procedure.

Moore, Alcantara, andMarraige (2001) compared the effectiveness of the CAMEQ, CAMREST and DSL [i/o] fitting procedures in experienced hearing aid users fitted bilaterally. Immediately after fitting with a specific procedure and one week after fitting, the gains were adjusted by minimal amount necessary, if required .The same process was carried out for all the fitting procedures. On average, the gain adjustments were smaller for the CAMEQ followed by CAMREST and largest tor DSL [i/o]. The authors conclude that DSL [i/o] provide more high frequency gain than preferred by adult users. Overall, the CAMEQ and CAMREST procedures give more satisfactory initial fits than DSL [i/o] for experienced adults. But there is no mention if the subjects have used the same prescriptive formula previously.

In a similar study that involved experienced hearing aid users but fitted unilaterally, Alcantara, Moore, andMarraige (2004) showed similar results as that of previous one. The authors commented that CAMEQ and CAMREST procedures provide a more initial fitting than DSL [i/o] even far unilaterally, experienced hearing aid wearers. Also, comparisons with the previous study based on bilateral findings suggest that the gain preferences were found to be same for unilateral and bilateral fittings.

Zakis, McDermott, and Dillon (2007), conducted a study wherein they divided the hearing aid users into two groups. One group was given a hearing aid in which they could manipulate amplification parameters (compression threshold, gain prescribed below the compression threshold, compression ratio, and noise suppression strength) and the other group received hearing aids in which they could not manipulate any of the settings. They compared the preferences by the hearing aid users across various situations while using hearing aids. The results indicated that the subjects preferred the hearing aid in which the settings could be manipulated and it had been advised to use this in real-life listening situations by the clients.

Keidser and Grant (2001) compared two-channel WDRC hearing aids fitted according to NALNL - l and IHAFF protocol. Preferences under free field condition and in the laboratory condition both strongly favoured NAL NL-1, particularly in presence of background noise. Speech identification scores in the laboratory also favoured NAL-NL1, particularly in background noise.

Keidser, O'Brien, Carter, McLelland, andYeend (2008) conducted a study aimed at determining if gain adaptation occurs, and if it occurs, at which frequency bands do they occur, among new hearing aid (HA) users. Fifty new and 26 experienced HA users were taken for the study and were fitted with three listening programs (NAL-NL1 and NAL-NL1 with low- frequency and NAL-NL1 with high-frequency cuts) in the same hearing instrument family. Real-life gain preferences and comfortable loudness levels were measured at one month, four months and at 13 months post-fitting for the new HA users, and at one month post-fitting for the experienced HA users. The results indicated that new HA users prefer progressively less overall gain for average input levels than do experienced HA users with a similar degree of hearing loss. This was true even when the hearing loss increased. It was observed that the gain reduction from the NAL-NL1 prescription varies from -2 dB for those with a 4 frequency average (250Hz, 500Hz, 1000Hz & 2000Hz) hearing threshold of 25 dB HL down to-9 dB for those with a 4 frequency average (250Hz, 500Hz, 1000Hz & 2000Hz) hearing threshold 55 dB HL. It was also noted that for experienced hearing-aid users, NAL-NL1 generally overprescribed overall gain by about 3 dB for an input level of 65 dB SPL. And about half of both new and experienced hearing-aid users preferred a high-frequency cut in the gain-frequency response.

In most of the earlier mentioned studies, the outcome measures are measured via many parameters and the most common amongst them is REIG. As stated earlier, REIG can be a very important tool to check if the gain prescribed in the hearing aid is accurate and the necessary changes that have to be made to achieve the target.

In a study conducted by Swan and Gatehouse (1995), to check if the real ear gain closely matches the prescribed gain and they found out that 57% of the subjects failed to come within 10 dB of the target gain at one or more frequencies between 250 Hz to 3 kHz. After appropriate changes 85% achieved a satisfactory gain.

Aazh and Moore (2007) conducted a similar study with the main aims of (1) determining whether routine real ear insertion gain (REIG) measurement is necessary in fitting digital hearing aids; and (2) assessing the extent to which modifying the frequency-gain response of an aid can lead to better matches to the target in cases where the target gain was not initially achieved. The target formula was selected as NAL-NL1 in the programming software of four types of digital hearing aids. REIG measurements on 42 ears showed that 64% of cases failed to come within ±10 dB of the target at one or more of the following frequencies: 250 Hz, 500Hz, 750 Hz, 1000 Hz, 1500 Hz, 2000 Hz and 4 kHz. After adjusting the frequency-gain response of the aids, based on the REIG results, 83% of cases came within ±10 dB of the target. The results indicate that REIG measurements can and should be used to achieve more accurate fittings but that accurate adjustments are difficult with some aids. This study clearly states the need to make use of REIG.

There are few Indian studies comparing the preferred gain and that prescribed by NAL-NL1. Ankith and Manjula (2008) evaluated the deviations in gain parameters from that prescribed by NAL-NL1 after a period of hearing aid use. The study included twenty naïve hearing aid users (5 individuals with Mild to Moderate hearing loss and 8 and 7 subjects with Moderately Severe and Severe hearing loss respectively). The deviation in gain parameters were noted during initial fit and 45 days after hearing aid use between the preferred and that prescribed by NAL-NL1. The results of the study indicate that naïve hearing aid users with Moderate and Moderately Severe hearing loss preferred 2-5 dB lower gain that prescribed by NAL-NL1. But, individuals with Severe hearing loss preferred 4-5 dB higher gain relative to NAL-NL1.

Achaiah and Narne (2011) compared the outcomes using preferred gain and prescribed gain formulae in experienced adult hearing aid users. The study included 10 experienced hearing aid users with pure tone average ranging between 30 and 91.6dB.

The result of the study indicates that on an average 10 dB higher gain is preferred compared to NAL-NL1 fitting formulae. Therefore, from the above studies we can clearly infer that most of the times, there is a discrepancy between the prescribed gain and the preferred gain settings. This discrepancy is seen mostly due to the programming software and also due to the fact that gain prescribed is not favourable to the participant's needs & modification might be required. The most appropriate way to check for these discrepancies is to use REIG values and Speech perception measures.

CHAPTER 3

METHOD

3.1 Participants

33 participants (n=33 ears), in the age range of 30 to 80yrs (mean age of 59.2yrs.), with mild to severe cochlear hearing loss and using digital BTE hearing aid were participated in the present study. The participants were native speakers of Kannada (A Dravidian language spoken in a southern state of India), having post-lingual onset of hearing loss and were naive hearing aid users (with duration of Hearing aid use not more than 3 months). The Pure-Tone Average (PTA) ranged from 36.6 dB to 85 dB. The participants were divided into 3 groups namely, Group I, Group II and Group III based on the degree of hearing loss. Group I included 13, Group II and Group III included 10 participants with Mild to Moderate, Moderately severe and Severe hearing loss respectively. It was ascertained from a structured interview that none of these participants had any history of neurologic disorders. The demographic and audiologic data of all the participants, including degree of hearing loss, speech identification score and the hearing aid being used is provided in table 3.1. The mean and standard deviation of pure-tone thresholds at octave frequencies for all the 3 individual groups is plotted in figure 3.1.

Table 3.1: *Demographic and Audiologic data of all the papticipants*

Sl.no	Age/Gender	Ear	Pure tone Average	Speech Identification Scores	Hearing Aid Model
Group 1					
1	51/F	Right	45	88%	Phonak Una SP
2	30/M	Left	36.6	92%	Phonak Una SP
3	48/M	Left	50	52%	Phonak Una SP
4	57/M	Right	41.6	92%	Phonak Extra 411 AZ
5	63/F	Right	50	92%	Phonak Una SP
6	71/F	Left	55	96%	Phonak Una SP
7	65/M	Right	45	52%	Phonak Una SP
8	44/F	Left	48.3	72%	Phonak Una SP
9	67/M	Left	48.3	92%	Phonak Una SP
10	51/F	Right	53.3	88%	Phonak Una SP
11	62/M	Left	53.3	76%	Phonak Una SP
12	54/M	Right	50	60%	Phonak Una SP
13	72/F	Left	43.3	80%	Phonak Una SP
Group 2					
1	61/M	Left	65	72%	Phonak Una SP
2	42/F	Left	58.3	88%	Phonak Una SP
3	80/M	Right	56.6	76%	Phonak Extra 411 AZ
4	57/F	Left	70	72%	Phonak Una SP
5	73/M	Right	70	52%	Phonak Una SP
6	72/M	Left	56.6	68%	Phonak Una SP
7	38/M	Right	68.3	72%	Phonak Una SP
8	76/M	Left	70	40%	Phonak Una SP
9	53/F	Right	61.6	76%	Phonak Una SP
10	44/F	Left	63.3	76%	Phonak Una SP
Group 3					
1	62/M	Right	85	60%	Phonak Una SP
2	42/M	Right	73.3	80%	Phonak Una SP
3	53/F	Left	75	72%	Phonak Una SP
4	66/F	Right	80	56%	Phonak Una SP
5	71/F	Left	83.3	56%	Phonak Una SP
6	45/M	Left	73.3	72%	Phonak Una SP
7	65/M	Right	75	68%	Phonak Una SP
8	60/F	Left	85	48%	Phonak Una SP
9	70/M	Right	81.6	40%	Phonak Una SP
10	60/F	Left	73.3	60%	Phonak Una SP

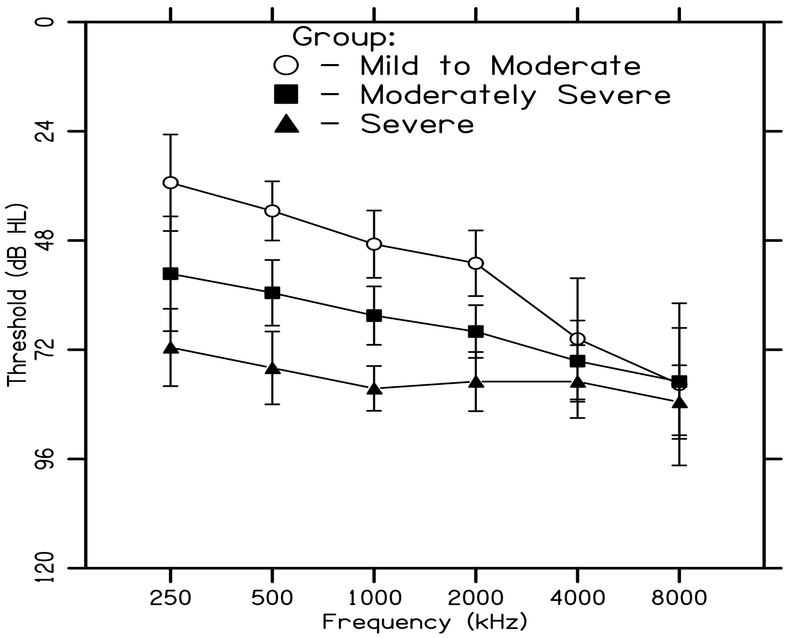


Figure 3.1:Mean and standard deviation of pure-tone thresholds for 3 individual groups

3.2 Instrumentation

- Orbiter OB-922 (Madsen Electronics, Denmark), a two channel diagnostic audiometer calibrated as per ISO 389 with loudspeakers placed at 0 degree azimuth was used to assess the speech identification scores.

- A personal computer with NOAH-3 and hearing aid specific software with Hearing Instrument Programmer (HI-PRO) interface to program the hearing aids

- FONIX 7000 (Frye Electronics Inc, USA) hearing aid analyser was used to perform real ear Insertion gain (REIG) measurements.
- A questionnaire for fine tuning of hearing aid (fitting assistant questionnaire) was used (given in Appendix -A)

3.3 Test Environment

All the testing was conducted in an air conditioned, acoustically treated double room set up.

3.4 Procedure

The experiments were conducted in two phases. In the phase 1 hearing aid was programmed to NAL-NL1 settings, which was followed by measurements of speech Identification Scores. In phase 2, hearing aid was programmed to the participant's preferred setting, which was followed by measurements of speech Identification Scores.

3.4.1 Phase 1

Initially the hearing aid was programmed according to the gain parameters prescribed by NAL-NL1 fitting formula as given by hearing aid fitting software. 'First fit' settings were obtained by using the participant's hearing thresholds and selecting NAL-NL1 prescriptive formula.It has been noted by number of researchers that the hearing aid programming software provides an inappropriate gain than that prescribed by the NAL-NL1 prescriptive procedure (Aazh& Moore, 2007). So, REIG was performed to attain appropriate gain parameters of NAL-NL1 by matching REIG values to gain curve generated by FONIX 7000 hearing aid analyzer for NAL-NL1 target. However, it was not possible to achieve the perfect match to the target in all the participants. The relationship between the achieved and NAL-NL1 prescribed 4 frequency averages (4FA) i.e. 500, 1000, 2000 and 4000 Hz for all the participants is given in figure 3.2.

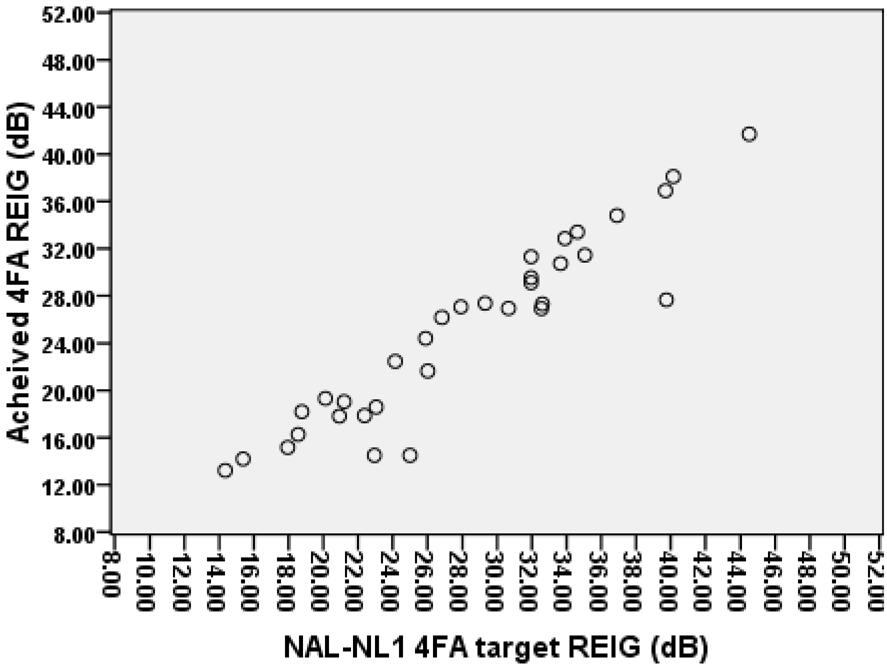


Figure 3.2: The relationship between the achieved and NAL-NL1 prescribed 4 frequency averages (4FA) for all the participants.

From the figure it can be inferred that there wasn't much difference between achieved and target REIG values. The mean difference between the achieved and target REIG values for 4FA is 3 dB. The average fit was closer to target at mid frequencies than in low and high frequencies. After approximating the REIG values to FONIX target curve, these values were considered as the NAL-NL1 gain prescribed. Following this Speech Identification Score (%) was measured.

3.4.2 Phase 2

The hearing aid was programmed as per the preference of the clients. Initially, the automatic fine tuning of the hearing aid was carried out using 'feature activation' or 'Fitting Assistant' designed specifically for hearing aid fitment. Later, 'manual fine tuning' was done by narrating a passage in Kannada at moderate and loud intensity levels. With this, all or few of the hearing aid parameters (listed below) were manipulated as preferred by the participants. The parameters that varied were (1)

Overall gain, (2) Gain at individual Frequency Bands (4 for Phonak Una SP and 6 for Phonak Extra 411 AZ), (3) Enhanced Bass Boost and (4) Global Compression. The adjustment of overall gain and individual frequency bands gain was performed at 65 dB input level only. It was noted that the gain of 50 dB and 80 dB were also varied while fine tuning the gain for 65 dB input level. Thus, the gain at 50 dB and 80 dB was not changed individually. After, fine tuning of the hearing aid for preferred hearing aid settings, REIG and speech identification scores (%) measured once again.

3.5 Speech Identification Scores

The open set Speech Identification Scores in quiet were obtained through monitored live voice presentation. Word lists for adults developed by Yathiraj and Vijayalakshmi (2005) was used to obtain the speech identification scores. This test material consisted of 4 phonemically balanced word lists with 25 words each.

Procedure

The participants were seated comfortably in a double-walled, acoustically treated room. The speech stimuli were presented through the loudspeaker (C 115 Martin Audio) of the audiometer kept at a distance of one meter at 0° azimuth. Speech stimuli were presented at 40 dBHL. None of the lists was repeated for any of the listeners, as there were four lists. The order of presentation of conditions was randomized across the listeners. Listeners were instructed to repeat the speech token heard. The speech recognition scores was calculated by counting the number of words correctly repeated.

3.6Real Ear Insertion Gain (REIG)

REIG, as defined by ANSI (1997), is the difference in decibels as a function of frequency between the real ear aided gain (REAG) and real ear unaided gain (REUG), obtained with the at same measurement point and similar sound field conditions. Before the REUG is measured, levelling of the probe system of the hearing aid analyzer instrument was done using the reference microphone placed above the ear to ensure the smooth frequency output from the hearing aid analyser.

3.6.1 Measurement of REIG

The participants were seated at 1 foot distance and at 45 degree azimuth from the loudspeaker of real ear analyser. Real Ear Unaided Gain (REUG) was measured for the subjects without wearing the hearing aid by using Digispeech as the stimuli at 65dBSPL as the input. To ensure proper insertion depth of the probe tube, the probe tube was placed in the ear canal, so that the tube will rest along the bottom of the canal part of the ear mold, with the tube extending at least 5 mm past the ear mold. The stimulus was presented and the output was represented in the form of graph on screen and once the graph on screen is stabilized for more than 10 seconds, the input was stopped.

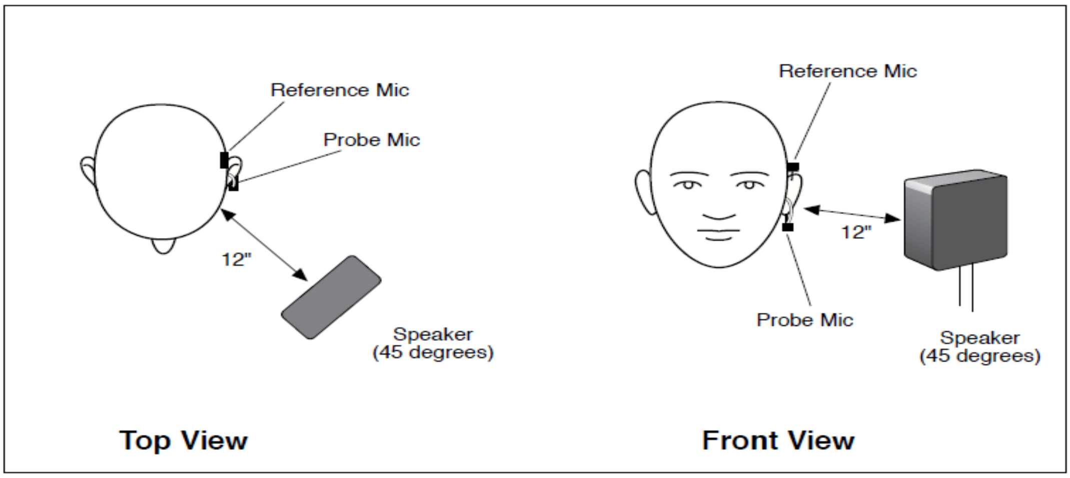
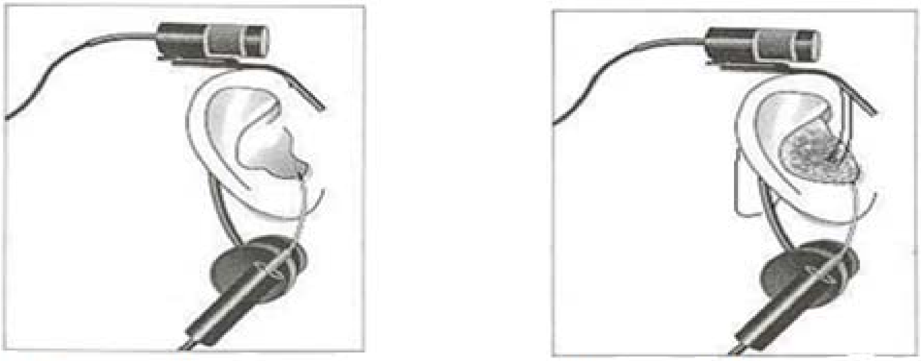


Figure 3.3: Position of participant and loudspeaker for real ear measurements

For measuring REAG, the hearing aid was placed into the participant's ear while holding the probe tube so that its position in the ear canal is not disturbed. Then, hearing aid is turned on for measuringReal Ear Aided Gain (REAG). The probe tube microphone measures the dB SPL in the ear canal as delivered by the hearing aid. The REAG was displayed as a curve with frequency (Hz) versus Intensity (dB).



Location of the reference microphone and probe tube microphone for REUR

Location of the reference microphone and probe tube microphone along with hearing aid for REAR

Figure 3.4: Illustration for measurement of insertion gain (REIG)

REIG

The real ear analyser automatically displayed the REIG across frequencies. This was done by the instrument by subtracting REUG from REAG. The values of REIG were noted across 250 Hz, 500 Hz, 700 Hz, 1k Hz,1.5k Hz,2k Hz,3k Hz, 4k Hz, 6k Hz frequencies for each participant. The REIG was also calculated at 3 different input levels i.e., 50, 65 and 80 dB SPL.

CHAPTER 4

RESULTS

The present study was carried to find the difference in gain between preferred and prescribed (NAL NL-1) strategies in naïve hearing aid users at three different input levels (50, 65 & 80dB). The REIG data at three input levels (50, 65 and 80 dB levels) were collected, tabulated and subjected to data analysis. Statistical analyses were carried out using SPSS Statistics Package (version 17).

4.1 Comparison of preferred and prescribed Real Ear Insertion Gain (REIG) values

Majority of previous studies have compared results for overall gain (4FA), LFA (250, 500 and 1000 Hz) and HFA (2000, 3000 and 4000 Hz) at 65 dB input level for different degree of hearing loss. Hence for ease of comparison only 65 dB input level is considered for the analysis of overall gain (4FA), LFA & HFA.

4.1.1 Relationship between preferred 4FA gain relative to NAL-NL1 and the pure tone average (PTA).

Figure 4.1 gives the relationship between the preferred 4FA gain relative to NAL-NL1 and the pure tone average (PTA) for all the participants. It can be inferred from the figure 4.1 that with increase in hearing loss, there was increment in gain deviation i.e. the gain deviation was higher for greater degree of hearing loss.

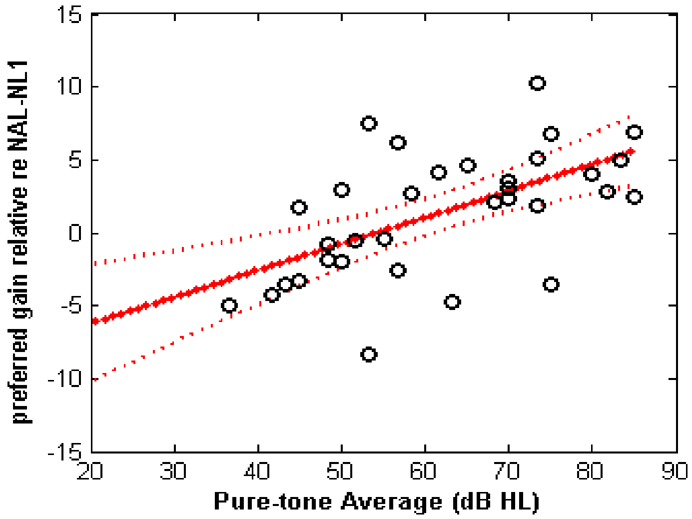


Figure 4.1: Shows the relationship between the preferred 4FA gain relative to NAL-NL1 and the pure tone average (PTA). The dotted lines show the regression line and 95% confidence bands.

4.1.2 Comparisons between preferred 4FA, LFA and HFA gain relative to NAL-NL1 between three groups

From the REIG measurements, gain deviation of preferred from the NAL-NL1 for a 65 dBSPL input was calculated in terms of overall gain (4FA), LFA and HFA for individual groups. The mean and standard deviation of this for three individual groups is given is Figure 4.2. It can be noted from the figure that the average gain preferred is around 2 dB lower for group 1, whereas group 2 and group 3 preferred is 2 to 4 dB higher gain than that prescribed by NAL-NL1.

Mixed ANOVA was performed to compare the conditions (LFA, HFA & Overall (4FA) across the three groups. Analysis showed no significant main effect of conditions, indicating that mean difference did not reach significance between conditions ($F_{(2, 30)}$=0.7, P= 0.40). But there was significant main effect across groups ($F_{(2, 30)}$ =5.09, P<0.05). Bonferonni's Post hoc analysis revealed group 1 is significantly different from group 2 and group 3 (p <0.05). But mean difference between group 2 and group 3 did not reach significance.

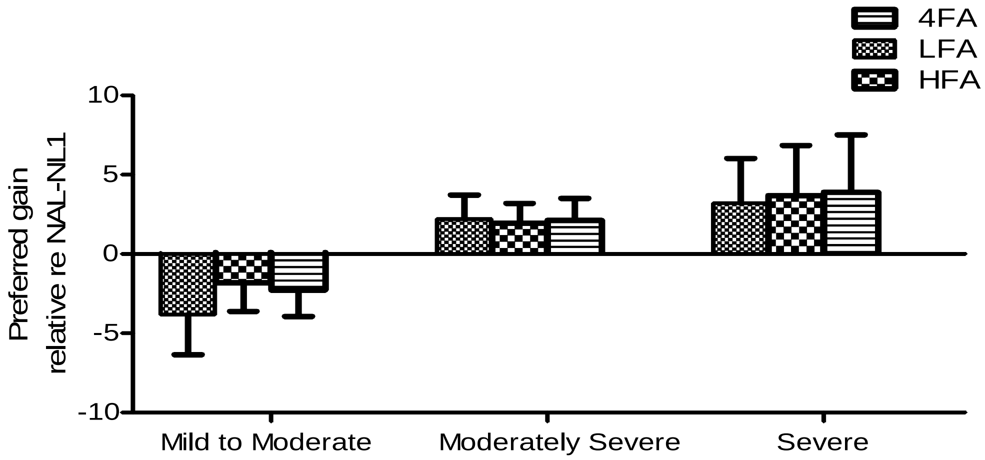


Figure 4.2: Preferred gain deviation from the NAL-NL1 for a 65 dBSPL input in terms of 4FA, LFA and HFA across groups

4.1.3 Difference in preferred gain and prescribed gain across frequencies

Further to know the difference in REIG between preferred and that prescribed by NAL-NL1 at each frequency across three groups for different input levels a separate analysis was done.

Group 1-Mild to Moderate HL

Figure 4.3 shows the preferred and prescribed REIG data across frequencies for group 1. It can be noted from the figure that for 50 dB and 65dB input levels, individuals with Mild to Moderate hearing loss preferred a gain 5-8 dB lower than that prescribed by NAL-NL1 at mid frequencies. However, at 80 dB input level, preferred and prescribed gains were almost similar. Further, it was also noted that there was no difference in mean REIG values at low and high frequencies for all 3 input levels.

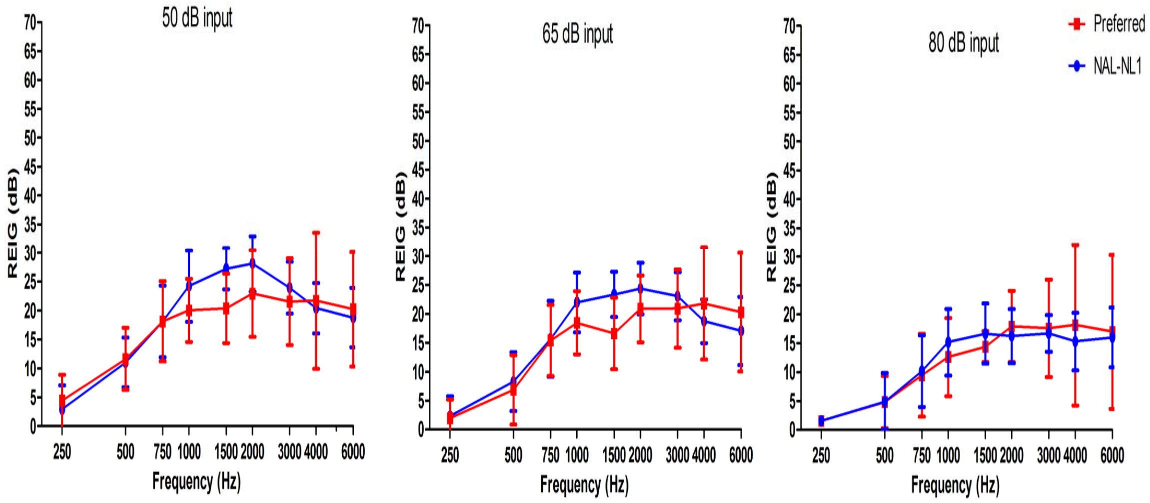


Figure 4.3: Shows the comparisons of REIG values at 3 input levels for group 1

Repeated measure ANOVA was performed to compare the gain between conditions (preferred and NAL-NL1) at three input levels (50, 65 &80dB) across the frequencies. Analysis showed significant main effect frequency ($F_{(2.9,\ 106.7)}$ =133.5, p<0.01) and level ($F_{(2,\ 36,)}$ =7.5, p<0.01) but no significant main effect of condition ($F_{(1,\ 36)}$ =3.59, p=0.06). Interaction analysis revealed significant interaction between frequency and condition ($F_{(3.2,\ 36)}$ =8.01, p<0.01), but other two way and three way interactions were not significant. Following this a Paired sample‘t’ -test was performed to assess at which frequencies, difference between conditions reaches significance for three different input levels separately. The results of ‘t’ test ,degrees of freedom and level of significance are depicted in table 1.It can be noted from the table 4.1 that for 50 and 65dB input level there was significant difference between preferred and prescribed conditions at 1000,1500 and 2000Hz only. But, there was no significant difference across frequencies for 80dB input.

Table 4.1: *Shows the 't' values and level of significance for three input level across frequencies for group 1.*

Frequency(Hz)	Input Level		
	50dB t value	**65dB** t value	**80dB** t value
250	1.08	-0.65	-0.06
500	0.44	-1.51	-0.08
750	0.0	-0.24	-0.54
1000	-2.97*	-3.3*	-1.78
1500	-4.3*	-4.7*	-1.83
2000	-3.2*	-2.4*	1.19
3000	-1.18	-1.42	0.44
4000	0.42	1.28	1.23
6000	0.62	1.46	0.45

**p<0.05*, Note *df was 12 for all 't' values*

Group 2- Moderately severe Hearing loss

Figure 4.4 gives the preferred and prescribed REIG data across frequencies for group 2. It can be noted from the figure that for the input level of 50 dB, 2-3 dB higher gain is preferred at low and mid frequencies than that prescribed by NAL-NL1. Whereas for input levels of 65dB and 80 dB, gain preferred is 5-6 dB higher than NAL-NL1 at mid frequencies.

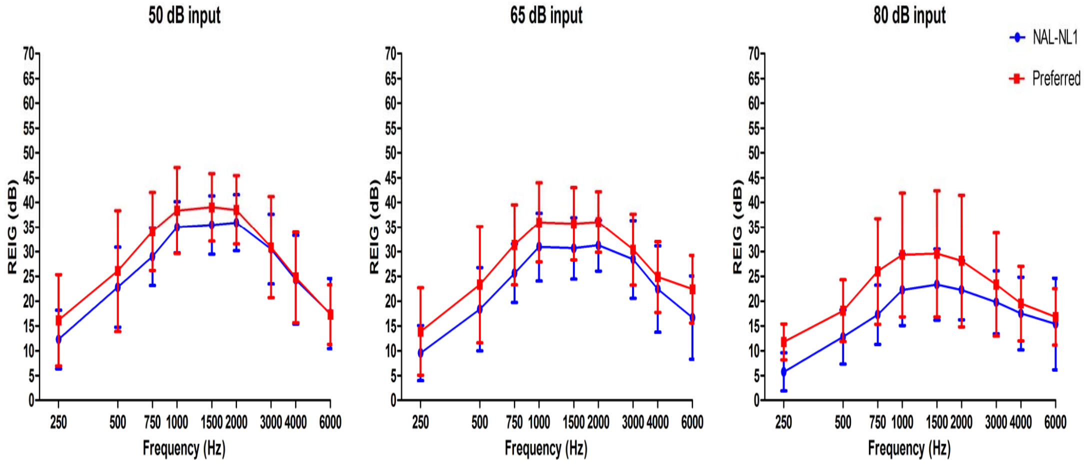


Figure 4.4: Shows the comparisons of REIG values at 3 input levels for group 2

Repeated Measure ANOVA was performed to compare the gain between conditions (preferred and NAL-NL1) at three input levels (50, 65 & 80dB) across the frequencies. Analysis showed significant main effect frequency ($F_{(8,\ 20)}$ =202.6, $p<0.01$), condition ($F_{(1,\ 27)}$ =13.15, $p<0.01$) and level ($F_{(2,\ 27,)}$ =6.4, $p<0.05$). Interaction analysis revealed significant interaction between frequency and condition ($F_{(3.04,\ 82.2)}$ =3.05, $p<0.05$), but other two way and three way interactions were not significant. Following this a Paired sample't' test was performed to assess at which frequencies difference between conditions reached significance for three different input levels. The results of't' test, degrees of freedom and level of significance are depicted in table 2. It can be noted from the table 4.2 that there was significant difference across 750, 1000, 1500, 2000, 6000 Hz for 65dB input level and 250, 750, 1000, 1500, 2000Hz for 80dB input level between preferred and prescribed conditions. However, for 50 input levels there was significant difference at 750Hz only.

Table 4.2: *Shows the 't' values and level of significance for three input level across frequencies for group 2*

Frequency(Hz)	**Input Level**		
	50dB t value	65dB t value	80dB t value
250	1.66	1.74	2.92*
500	0.90	1.41	2.08
750	2.38*	2.68*	3.27*
1000	1.23	2.38*	2.73*
1500	1.62	2.32*	2.51*
2000	1.09	2.95*	2.40*
3000	0.13	0.75	1.60
4000	0.14	1.45	1.08
6000	-0.08	3.20*	0.53

**p<0.05*, Note *df was 12for all 't' values*

Group 3-Severe Hearing Loss

Figure 4.5 gives the preferred and prescribed REIG data across frequencies for group 3. It can be noted from the figure that the preferred gain was higher than that prescribed by NAL-NL1 for all the 3 different inputs. For 50dB and 65dB input, 5-6 dB higher gain is preferred at mid frequencies but, for 80dB input the gain of 7-8 dB higher is preferred at mid frequencies**.**

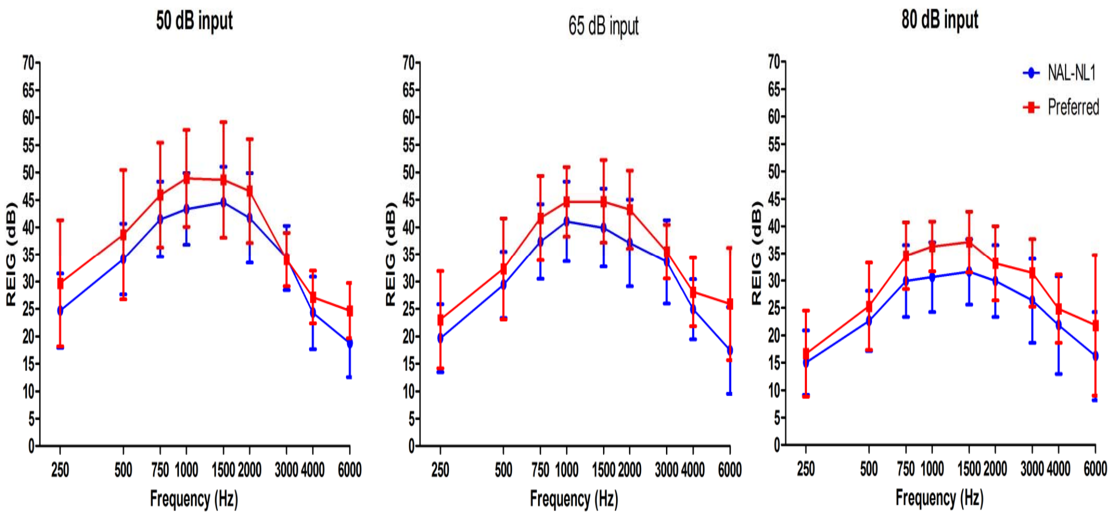


Figure 4.5: Shows the comparisons of REIG values at 3 input levels for group 3

Repeated Measure ANOVA was performed to compare the gain between conditions (preferred and NAL-NL1) at three input levels (50, 65 &80dB) across the frequencies. Analysis showed significant main effect frequency ($F_{(1.6, 45.08)}$ =72.3, p<0.01), level ($F_{(2, 27)}$ =10.4, p<0.01) and condition ($F_{(1, 27)}$ =42.56, p<0.01). Interaction analysis revealed no significant interaction between any conditions. Following this a Paired sample‘t’ test was performed to assess at which frequencies difference between conditions reaches significance for three different input levels. The results of ‘t’ test ,degrees of freedom and level of significance are depicted in table 4.3..It can be noted from the table 3 that for 50 input level there was significant difference between preferred and prescribed conditions at 750, 1000, 2000 & 6000Hz

. However, there was significant difference across 750, 1500, 2000, 4000, 6000 Hz for 65dB input and 750, 1000, 1500, 3000Hz for 80dB input.

Table 4.3: *Shows the 't' values and level of significance for three input level across frequencies for group 3.*

Frequency(Hz)	**Level**		
	50dB t value	65dB t value	80dB t value
250	1.74	1.47	0.58
500	1.58	1.30	1.22
750	2.28*	4.36*	4.76*
1000	3.09*	2.01	4.33*
1500	2.15	2.72*	4.31*
2000	2.34*	3.96*	1.40
3000	-0.14	0.91	2.35*
4000	1.69	2.37*	1.31
6000	3.81*	3.9*	1.80

**p<0.05* , Note *df was 12 for all 't' values*

4.2 Comparisons of Aided Speech Identification Scores (%) between preferred and prescribed conditions.

Figure 4.6 shows the comparison of Aided Speech Identification Scores (%) between prescribed and preferred settings across three groups. It can be noted from the figure that there is 5% increase in SIS in preferred gain than in NAL-NL1 settings in Moderately Severe and Severe Hearing Loss individuals. But, there was no difference noted in the mean of Mild to Moderate Hearing Loss group.

Repeated Measure ANOVA was performed to compare the Aided Speech Identification Scores (%) between conditions (preferred and NAL-NL1) across three groups. Analysis showed no significant main effect between conditions ($F_{(1, 30.1)}$ =3.1, p=0.27) and groups ($F_{(2, 40.2)}$ =0.75, p=0.4). Bonferonni's Post hoc analysis revealed there is no significant difference between groups.

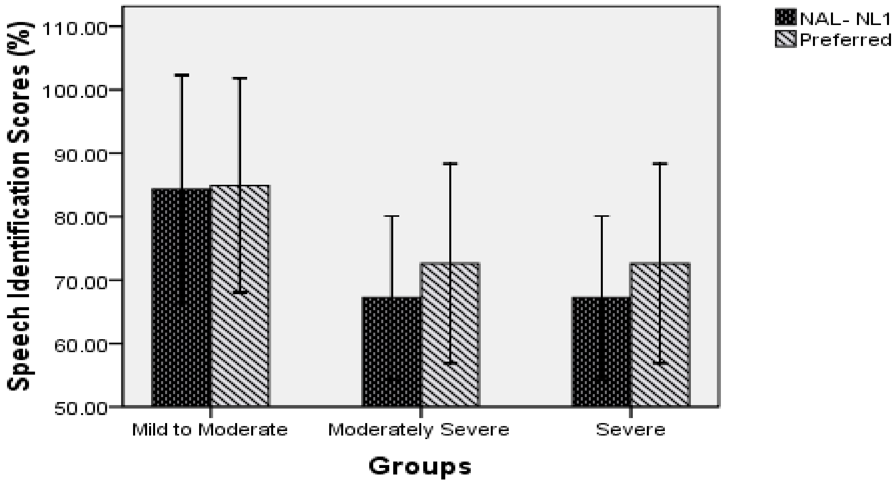


Figure 4.6: Shows the comparison of Aided Speech Identification Scores (%) between prescribed and preferred settings across three groups

CHAPTER 5

DISCUSSIONS

The aim of the present study is to find the deviation in gain parameters, at three different input levels (soft, moderate and loud levels) between preferred and prescribed (NAL NL-1) gain in naïve hearing aid users. This was investigated by comparing REIG values and Speech Identification Scores (%) between preferred and NAL-NL1 settings.

The summary of the results are as follows

- The gain preferences relative to NAL-NL1 is different for different degree of hearing loss. Individuals with Mild to Moderate hearing loss preferred 3-4 dB lower whereas individuals with Moderately Severe and Severe hearing loss preferred 4-8 dB higher gain than that prescribed by NAL-NL1.
- The preferred gain differences relative to NAL-NL1 across frequencies revealed greater deviations in mid frequencies than in low and high frequencies.
- The differences in preferred gain relative to NAL-NL1 increased with increase in degree of hearing loss.
- There was no significant differences in aided Speech Identification Scores (%) between preferred and that prescribed by NAL-NL1.

5.1 Comparison of preferred and prescribed Gain

The present study compared REIG values between preferred and NAL-NL1 for different degrees of hearing loss. The results of overall gain showed individuals with Mild to Moderate preferred 3-4 dB lower but Moderately Severe to Severe hearing loss preferred 4-8 dB higher gain than that prescribed by NAL-NL1. Ankith and Manjula (2008) compared the preferred and prescribed gain in naive hearing aid users. They reported individuals with Moderate and Moderately Severe hearing loss prefer 2-5 dB lower but severe hearing loss preferred 4-7 dB higher gain than that prescribed by NAL-NL1. The results of the present study are in accordance with those reported by Ankith and Manjula (2008). However, they demonstrated individuals with Moderately Severe hearing loss preferred lower gain of 2-5 dB but in the present study higher gain of 3-6 dB was preferred. The precise reason for the difference is not known. Difference between studies may be due to methodological differences. One potential methodological reason could be in the present study REIG was matched to FONIX 7000 hearing aid analyser target for NAL-NL1 but this was not done in Ankith and Manjula (2008).

In the contrary to the present study, Keidser et al., (2001; 2004; 2005; 2008) reported that naive hearing aid users requires -2 to -6 dB lesser gain with reference to gain provided by NAL-NL1. The difference in gain preferred with reference to NAL-NL1 among these studies may be due to the subject population. Keidser et al (2001; 2004; 2008) investigated on western population and showed that preferred gain is lower than that prescribed by NAL-NL1. In contrary, studies conducted in Indian population showed that gain preferred is higher than NAL-NL1 (Ankith&Manjula, 2008; Achaiah&Narne, 2011).Achaiah and Narne (2011) reported on an average 10 dB higher gain is preferred compared to NAL-NL1 fitting formula in experienced hearing aid users. Higher difference noted between present study and Achaiah and Narne (2011) study may be because they have considered experienced hearing aid users. In addition to that they have not matched REIG values to FONIX 7000 Hearing Aid analyser for prescribed NAL-NL1 gain settings. These results are in agreement with clinical observation made by majority of the clinicians in Indian population. The precise reason for needing a higher gain is not known. Probable reason could be that, as Studebaker & Sherbecoe (1993) reported that frequency importance functions vary widely across the languages and hearing aid prescriptive formulae were derived from the frequency importance function. Probably, the frequency importance functions for Indian languages are different which would have led to this difference.

The analysis was carried across three different frequency averages (LFA, HFA, and 4FA (overall gain) for three groups. It was noted that the overall gain preferred by Moderately Severe and Severe hearing loss subjects were 3-4 dB higher than that prescribed by NAL-NL1. Whereas, Mild to Moderate degree of hearing loss preferred -4 dB lesser gain than that prescribed by NAL-NL1. In order to understand which frequencies were showing the difference in REIG between preferred and prescribed by NAL-NL1, further analysis was carried out. The results of these analysis revealed the gain differences were noted only in mid frequencies. There was no consistent gain difference in low and high frequencies. These may be attributed to frequency importance function of Indian languages.

In addition to the gain differences noted at 65 dB input level, the gain differences were also observed in 50 dB & 80 dB input levels. To our knowledge there were no studies that have compared the gain differences at 50 dB & 80 dB input level. One logical reason for gain difference noted was because gains at other input levels were also modulated by varying the gain at 65dB input level in the hearing aid programming software, which would have led to these differences.

Present study also analysed the relationship between the pure tone average and preferred gain relative to NAL-NL1. It was noted that with the increase in degree of hearing loss, the preferred gain relative to NAL-NL1 increased. This finding are contrary to the findings of Keidser et al (2008), who reported gain preferred relative to NAL-NL1 was lower with increase in hearing loss. These difference in findings noted in Keidser et al (2008) study may be because majority of subjects considered were individuals with Mild to Moderate hearing loss but in the present study, the subjects were evenly distributed between different degree of hearing loss.

5.2 Speech Identification Scores

The Aided Speech Identification Scores (%) between prescribed and preferred settings across three groups were subjected to analysis. It is observed that there is only a 5% mean difference among the group in SIS (%) scores in group 2 and group 3. However, there is no significant differences observed between these groups, this could be attributed to less number of subjects and greater variability (as indicated by large standard deviation). Though there was no significant difference in preferred and NAL-NL1 gain condition on SIS (%), yet the subjects preferred different gain settings over that prescribed by NAL-NL1, for the overall enhancement in speech quality.

CHAPTER 6

SUMMARY AND CONCLUSIONS

The present study was carried out to find the deviation in gain parameters, at three different input levels (50, 65 & 80 dBSPL) between preferred and prescribed (NAL NL-1) fitting strategy in naïve hearing aid users. 33 participants (n=33 ears), in the age range of 30 to 80yrs (mean age of 59.2yrs.), with mild to severe sensory-neural hearing loss and using digital BTE hearing aid were participated in the present study. The participants were native speakers of Kannada (A Dravidian language spoken in a southern state of India), having post-lingual onset of hearing loss and were naive hearing aid users (with duration of Hearing aid use not more than 3 months). The Pure- Tone Average (PTA) ranged from 36.6 dB to 85 dB. The participants were divided into 3 groups namely, Group I, Group II and Group III based on the degree of hearing loss. Group I included 13, Group II and Group III included 10 participants with Mild to Moderate, Moderately severe and Severe hearing loss respectively. Individuals using either of the two types of hearing aids were participated in the present study namely Phonak Una SP and Phonak Extra 411 AZ.

For all these participants, the experiments were conducted in two phases. During the phase 1, programming the hearing aid to NAL-NL1 settings was done, which was followed by Speech Identification Scores (%) measurements. Then in phase 2, programming the hearing aid to participant's preferred setting was done, which was followed by Speech Identification Scores (%) measurements.

The main findings of the present study are summarized here

- The gain preferences relative to NAL-NL1 is different for different degree of hearing loss. Individuals with Mild to Moderate hearing loss preferred 3-4 dB lower whereas individuals with Moderately Severe and Severe hearing loss preferred 4-8 dB higher gain than that prescribed by NAL-NL1.
- The preferred gain differences relative to NAL-NL1 across frequencies revealed greater deviations in mid frequencies than in low and high frequencies.
- The differences in preferred gain relative to NAL-NL1 increased with increase in degree of hearing loss.
- There was no significant differences in aided Speech Identification Scores (%) between preferred and that prescribed by NAL-NL1.Yet, the subjects preferred different gain settings over that prescribed by NAL-NL1, for the overall enhancement in speech quality.

Finally, it can be inferred from the results of the present study that for the Indian population, higher gain is required at mid frequencies, compared to western population for individuals with Moderately Severe and Severe hearing loss. This study also reflects on the importance of fine-tuning of hearing aids based on participant‘s preference because the results of this present study was based on the fine tuning changes made based on subjective preference and it was mostly in the mid frequencies which was consistent across all the participants. To conclude, there was gain deviations noted in preferred condition relative to NAL-NL1 in all degree of hearing loss. These deviations of preferred gain relative to NAL-NL1 increased with increase in degree of hearing loss.

Future implications

- The comparisons in the present study were done based on small group of subjects. Probably the study can be extended in large number of participants with varying configurations of hearing loss.
- If a definite trend is observed across the population, then it can be safely assumed that the differences are mostly seen in Indian population and this data can be used to develop a new prescriptive formula specifically for Indian population.

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Appendix A

FITTING ASSISTANT QUESTIONNAIRE

I. Sound quality

➡ Sounds are

- hollow, booming, echo effect, bass
- muffled
- harsh, sharp, metallic
- tinny, not fill
- not clear, not distinct
- poor for music

II. Intelligibility

➡ Poor intelligibility in quiet

- One to one conversation
- Watching TV, listening to radio
- In reverberant environments
- Using a telephone

➡ Poor speech Intelligibility in noise

- In a restaurant
- In large groups
- Ina car, in a bus, on a plane
- On the street

III. Loudness of sounds

➡ Overall loudness is

- too soft
- too loud

➡ Low levels (eg. Fan, leaves rustling)

- too soft
- too loud

➡High levels (eg, party)

- too soft
- too loud

➡ Low level, high pitch (birds chirping)

- too soft
- too loud

➡ Low level, low pitch (eg. Refrigerator)

- too soft
- too loud

➡ High level, high pitch (eg, Dishes falling)

- too soft
- too loud

➡ High level, low pitch (eg, Car door slamming)

- too soft
- too loud

IV. Loudness of speech

➡ Overall loudness

- too soft
- too loud

➡ Low levels

- too soft
- too loud

➡ Average levels

- too soft
- too loud

➡ High levels

- too soft
- too loud

➡ Distant speech

- too soft
- too loud

➡ Own voice

- too soft
- too loud

V. Feedback/Squeal

➡ Always