Comparison of hearing aid acclimatization in individuals using Receiver in the canal (RIC) and Behind the ear (BTE) hearing aids

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This Dissertation is submitted as partfullfillment for the Degree of Master of Science in Audiology University of Mysuru, Mysuru

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Certificate

This is to certify that this Masters dissertation entitled '**Comparison of hearing aid acclimatization in individuals using Receiver in the canal (RIC) and Behind the ear (BTE) hearing aids.**' is a bonafide work in part of fulfillment for the degree of Master of Science (Audiology) of the student with Registration Number 14AUD021. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other Universities for the award of any Diploma or Degree.

Mysuru,
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Declaration

This Masters dissertation entitled **'Comparison of hearing aid acclimatization in individuals using Receiver in the canal (RIC) and Behind the ear (BTE) hearing aids'** it is the result of my own study and has not been submitted to any other university for the award of any other Diploma or Degree.

Mysore **Registration No. 14AUD021**

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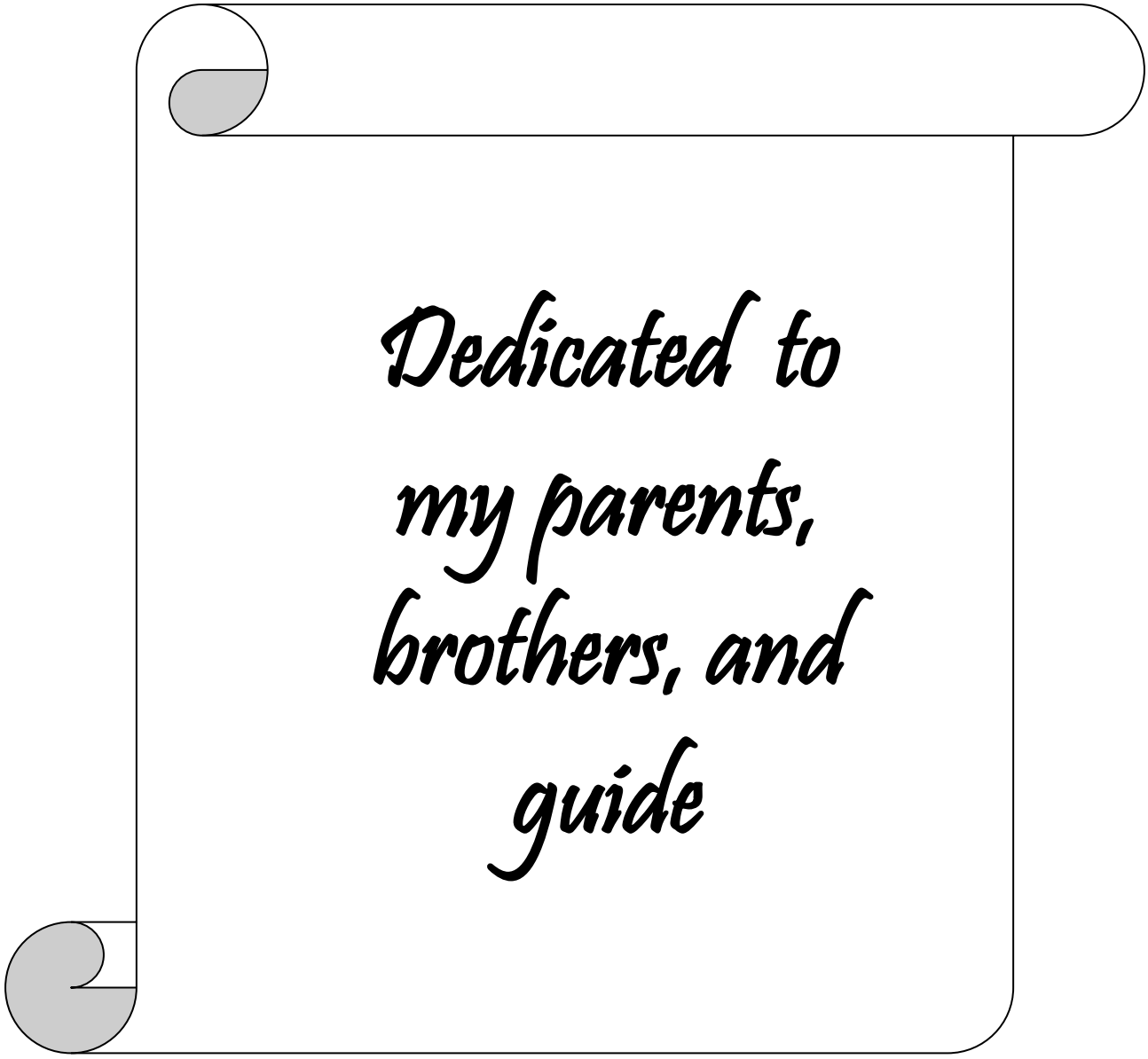
Dedicated to
my parents,
brothers, and
guide

Acknowledgments

Thanks to God for giving me strength, knowledge and courage. No love is greater than Mom's love and no care is greater than Dad's care. Yes I cant thank you both enough for the love, care and trust you have shown on me. Without your blessings, I could not have been in the position where I stand today. I will assure you that I will fulfill all your dreams about me and will always try to be a good daughter.

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Abstract

Background: It was hypothesized that magnitude of acclimatization while using Receiver in the canal (RIC) hearing aids could be higher than that of Behind the ear (BTE) instruments. This could be due to increased bandwidth in the high frequency region and better access to high frequency information in RIC hearing aids. Additionally, the acclimatization effect should be observed in both quiet and noise. **Aim:** The present study assessed hearing aid acclimatization in quiet and noise in individuals with sloping sensorineural hearing loss who were naive users of RIC and BTE hearing aids. **Methods:** There were 10 participants in the age range of 47 to 82 years, who had mild to moderately-severe sloping sensorineural hearing loss involved in the study. Five of the participants were naive users of RIC hearing aids and the remaining five were naive users of BTE hearing aids. Perception of high frequency words, sentence identification in the presence of noise were evaluated at two different time intervals. Initial testing was carried out at the time of hearing aid fitting and a follow up evaluation was carried out after 1 month of uninterrupted hearing aid usage. Additionally, hearing aid benefit questionnaires was also administered. **Results:** It was found that both RIC and BTE hearing aid users showed significant aided benefit in both high frequency word test and sentence identification in noise. However, no significant difference in test results was found between RIC and BTE hearing aid users. Similarly, bjective questionnaire rating showed no significant difference between RIC and BTE hearing aids. **Conclusion:** In individuals with sloping sensorineural hearing loss the acclimatization effect was seen in both quiet and noise. Further, the amount of acclimatization was similar for both RIC and BTE hearing aid users.

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Chapter 1

Introduction

One of the important aspects in rehabilitation of individuals with hearing impairment is providing amplification through hearing aids. With the provision of amplification, the rehabilitation program should also involve procedures that help the individuals to get accustomed to the amplification over a period of time (Gatehouse, 1992). Bentler, Holte, and Turner, (1999) defined acclimatization as the improvement in speech recognition abilities over a course of time, probably due to the amplification and the learned use of newly available speech cues. This acclimatization can be measured objectively using speech recognition tests as well as subjectively using self-reported questionnaires (Cox & Alexander, 1992). The underlying physiology behind acclimatization is the plasticity (Robinson & Gatehouse, 1995) where in anatomical and physiological changes will be seen in the auditory cortex over a period of time with altered input to the auditory system.

Though many studies have demonstrated an acclimatization effect (Gatehouse, 1992; Surr, Cord, & Walden, 1998; Yund, Roup, Simon, & Bowman, 2006), a few have failed to show considerable amount of hearing aid acclimatization (Bentler, Bender, Niebuhr, & Anderson, 1993; Gabrielle & Kathleen, 1997). The difference in the results obtained in these studies could be because of the limitations in their methodology. Gabrielle and Kathleen, (1997) found no evidence of acclimatization over the first 3 months of hearing aid use evaluated using CID W- 1 spondee word list and Hearing in Noise Test. They acknowledged that the test materials used were not high frequency

weighted and thus were less sensitive to measure changes in high frequency region. Similar results were found by Neuman et al.(1997). Hence, it was suggested by Bentler et al.(1999) that to expect acclimatization, the subjects must be selected with enough high frequency hearing loss, must have audibility returned to them and tested using high frequency stimulus.

Deterioration in unaided scores over a period of time might have resulted in aided improvement that cannot be attributed to acclimatization. A study conducted by Cox , Alexander, Taylor, and Gray (1996) evaluated the benefit of behind the ear (BTE) hearing aids in 22 older individuals in the age range of 60-82 years. Speech intelligibility testing was carried out over 12 weeks after fitting the hearing aid. Though there was an improvement seen for the group as a whole at the beginning of 6 weeks, only 3 subjects showed marked improvement, while the magnitude of improvement was small in others. However, long term follow up showed increasing benefits in some individuals but it was clearly accredited to the decline in the unaided performance.

In recent times, open-fit receiver in the canal (RIC) hearing instruments are favoured by audiologists and patients alike, because of their small size, discreet appearance and their ability to minimize occlusion. RIC instruments are also capable of a broader bandwidth than receiver in the aid instruments (Kuk & Baekgaard, 2008) and may present lowered feedback risk because of the distance between the microphone and receiver, and increased maximum gain before feedback (Hoen & Fabry, 2007; Hallenbeck & Groth, 2008). Increased bandwidth in the high frequency region may

provide better access to high frequency information and lead to faster/higher acclimatization to amplification.

Recently, Mondelli, Garcia, Hashimoto and Rocha (2015) compared the performance on speech perception in 20 individuals using receiver in the aid (RITA) and receiver in the ear hearing aids (RITE). Their participants were above 18 years of age having mild to moderate sloping sensorineural hearing loss. Speech perception was assessed using Hearing in noise test (HINT) and also using a questionnaire (satisfaction with amplification in daily life). The authors could not find any significant improvement in scores post 6 months hearing aid fitting when compared to the results obtained at the time of fitting. The results obtained could be due to the use of stimuli that were not high frequency concentrated. The authors also found no significant difference in speech perception between the two types of hearing aids. It was inferred that similar speech perception in these two hearing aids could be because of the similar output characteristics in RITA and RITE hearing aids as revealed by the probe microphone measurements in the study.

Need for the study:

Hearing aid acclimatization has not been systematically studied with respect to RIC instruments. Although Mondelli et al.(2015) compared BTE and RIC hearing aids there was no acclimatization effect found in these two types of hearing aids. Aided speech perception in individuals using RITA and RITE hearing aids evaluated using Hearing in noise test (HINT) and also using a questionnaire (satisfaction with amplification in daily life). HINT sentences were also presented in quiet situation. It was

found in quiet environment that there was a significant improvement in the aided performance over the unaided condition in both the types of hearing aids. However, the performance between 2 aided conditions i.e., at the time of fitting and 6 months post fitting, did not show any significant difference. Similar results were obtained in the presence of noise. The results obtained could be due to the low frequency dominance in Hearing in noise test (HINT). These stimuli were not sensitive enough to demonstrate the learnt use of new acoustic information available to the listeners in the high frequency region. Further, identical results found between two hearing aid types. This could be because of the similar gain provided by both the hearing aid types as depicted by probe microphone measurements wherein the gain from the hearing aid in all the participants matched to the target according to NAL-NL1. In addition, the participants included were limited to moderate degree of hearing loss.

Similarly, earlier studies on hearing aid acclimatization have used test materials that assess mainly the low frequency information (Gabrielle & Kathleen, 1997). Further, Bentler et al.(1999) suggested that acclimatization could be evident among individuals having high frequency hearing loss and have audibility returned in those frequencies. Thus, there is a need to investigate hearing aid acclimatization in individuals having high frequency sloping loss using a high frequency test material.

Aim of the study:

To compare hearing aid acclimatization in individuals using BTE and RIC hearing aids.

Objectives of the study:

To study impact of two different types of hearing aids on acclimatization using

- Word recognition scores using high frequency word list in Kannada.
- Speech perception in noise using sentence test in Kannada.
- Performance in real life situation using Hearing Aid Benefit questionnaire for adults

Chapter 2

Review of literature

The amount of benefit from hearing aids vary across individuals depending on the type, degree of hearing loss, the age of hearing aid fitting, type of hearing aid and time course of hearing aid usage. Auditory acclimatization refers to an orderly change in the auditory performance over a period of time, associated with the change in the acoustic information accessible to the individual using hearing aid. This includes betterment in the perception which cannot be accredited solely to the effects of task, procedure or training (Arlinger et al.,1996).

There are several studies that reported auditory acclimatization after a short/long term hearing aid use. Long term benefit was studied by Humes, Wilson, and Barlow, (2002) and Bentler et al. (1993). The benefit from short term usage of hearing aids was studied by Gatehouse (1993), Surr, Cord, and Walden, (1998) and many others as given in the further part of the review. Studies on hearing aid acclimatization have mainly focused on the change in speech perception performance overtime. Majority of the studies reported improvement in speech perception abilities resulted from acclimatization (Gatehouse, 1992; Cox et al., 1996; Humes et al., 2002; Yund, Roup, Simon, & Bowman, 2006) . However, there are a few reports that showed little effect from acclimatization (Bentler et al., 1993; Gabrielle & Kathleen, 1997).

Gatehouse (1992) evaluated the hearing aid acclimatization in four individuals with bilateral symmetrical sloping sensorineural hearing loss. The age of the participants ranged from 57 to 70 years and they were fitted with BTE hearing aid monoaurally. They

were tested on the first day of hearing aid fitting and further 9 sets of evaluations were carried out until 12 months post fitting. Insertion gain and speech perception in presence of noise was tested in each of the visit. Word identification in presence of noise was carried out using four alternative auditory feature (FAAF) test in free field condition as well as monoaurally through headphones, where in the frequency response of the hearing aid was presented through headphones for both aided as well as unaided ear. Results of the study revealed that the difference between aided and unaided conditions were similar for both the ears initially e.i., 3-4 weeks post fitting. Following 6-12 weeks after the hearing aid fitting the scores in the aided ear increased significantly when compared to the unaided ear. However, the author reports that this improvement cannot be attributed solely to acclimatization. He states that the participants may become more motivated with the use of hearing aids to concentrate more on the presented speech.

Since the previous study was carried out only on four individuals, Gatehouse (1993) conducted a similar study on 36 individuals with bilateral symmetrical sensorineural hearing loss. The mean age of the subjects was 64 years. They were fitted with monaural BTE hearing aids. All the participants were initially fitted with prescriptive formula based on UK NHS fitting and used the aid for 12-15 weeks. Later they were fitted using NAL prescriptive formula so that the frequency response of the hearing aid was changed. The gain provided by the hearing aid at high frequencies was less with the UK NHS fitting. Then the subjects were assessed for their speech perception abilities soon after the fitting and follow-up at 8 and 16 weeks. Four alternative auditory feature test was used to evaluate the word identification in noise. Sentence verification

test was also carried out. The performance was similar with both the prescriptive formulas at the initial testing phase. Whereas the scores were significantly higher with the fitting based on NAL prescriptive formula at 8 and 16 weeks after the new fitting. The author concluded that the subjects require time to get acclimatized to the new frequency response before seeing any improvement.

Cox et al.(1996) studied the acclimatization to hearing aids in 22 older adults in the age range of 60 to 82 years. All the participants had bilateral sloping sensorineural hearing loss ranging from mild to moderate degree. They were fitted with unilateral BTE hearing aids. The hearing aids were programmed using NAL prescriptive formula and insertion gain measurements were also carried out to see the agreement between the two. Connected speech test (CST) and Speech pattern contrast (SPAC) were carried out both in unaided and aided conditions. The evaluations were carried out at the time of fitting and further 4 subsequent testings were done with 3 month interval between the evaluations. The scores on CST were significantly better in aided condition after 12 weeks of hearing aid fitting when compared to the day of fitting. The authors also conducted similar evaluations in subjects who were not prescribed hearing aid serving as controls. There was no difference noted in the control group even after 12 weeks of hearing aid fitting. Thus the authors conclude that the improvement seen is solely due to acclimatization effect.

Surr et al.(1998) evaluated and compared short term and long term benefits from the hearing aids. Fifteen subjects in the age range of 55-75 years were selected for the study. The participants had gradually sloping sensorineural hearing loss of moderate to

severe degree bilaterally. All the individuals were successful users of linear amplification. Later they were fitted with wide dynamic range compression (WDRC) and the acclimatization to the same was evaluated. Connected speech test (CST) and Profile of Hearing aid benefit (PHAB) were performed at 6 weeks and 1 year post fitting. The results of the study showed that there was no added benefit seen after 1 year of hearing aid use. The scores obtained at 6 weeks and 1 year after the hearing aid fitting was similar. Thus the authors conclude that 6 weeks period is sufficient for acclimatization.

Similarly, long term benefit was studied by Humes et al.(2002). They assessed 134 individuals over a period of 1 year. Forty nine of these participants were also followed up after 2 years of hearing aid fitting. The age of the subjects ranged from 60 to 89 years. Individuals with flat or gradually sloping moderate sensorineural hearing loss were recruited for the study. In the ear (ITE) hearing aids were prescribed to all the individuals bilaterally. The Nonsense syllable test (NST) and Connected sentence test (CST) were performed at initial fit, 2 weeks, 1 month, 6 months and 1 year after the fitting. In addition, subjective evaluation was carried out using Hearing aid performance inventory (HAPI) and Hearing handicap inventory for the elderly (HHIE). The results showed a significant improvement in scores after 1 month of post fitting as revealed by subjective and objective measures. The amount of improvement in the later evaluations was minimal and it was similar at 1 year and 2 years after the hearing aid fitting.

Reber and Kompis, (2005) evaluated the hearing aid acclimatization in 23 individuals with sensorineural hearing loss. Age of the participants ranged between 40-76 years. They were allowed to choose between Completely in the canal (CIC), In the

canal (ITC) or In the ear (ITE) hearing aids. The individuals were divided into three groups: audiologist driven (AD), patient driven (PD) and set-to-target (STT) group. In the first two groups, the gain adjustments were done by the audiologists and patients respectively. In the STT group, the gain was set completely based on NAL-NL1 prescriptive formula. Real ear measurements and speech perception measures in quiet and noise were performed at the time of fitting. Later the subjects were assessed for their speech perception abilities at 2, 4, 6,8,12 and 24 weeks after the initial fit. Gain adjustments were done if required. There aided speech recognition scores improved significantly between 2 weeks and 6 months after fitting for AD and STT group. This trend was not seen for the PD group. The authors conclude that the PD gain fitting may not be appropriate and hence much benefit was not evident.

The effect of multichannel compression on hearing aid acclimatization was studied by Yund et al.(2006). Thirty nine individuals between 43-84 years of age with bilateral symmetrical sloping sensorineural hearing loss were recruited for the study. All the participants were naive ITC hearing aid users. Half of the participants were fitted with wide dynamic range multichannel compression (WRDMCC) and the remaining half with linear amplification (LA). Nonsense syllable test (NST) was administered at the time of fitting and 1, 2, 4, 8, 16 and 32 weeks post fitting. Subjective evaluations were also done using profile of hearing aid benefit (PHAB) and hearing aid performance inventory (HAPI) questionnaires at 2,8 and 32 weeks. After 32 weeks of usage of hearing aids, there was a switch between WDRMCC and LA. Again the evaluations were performed at 2, 4 and 8 weeks after the switching. In terms of consonant identification, the

improvement seen over the duration was significantly more in individuals using WDRMCC than with LA. But the same effect was not seen after the switch between the two. There was no difference obtained between the WDRMCC and LA as revealed by the two questionnaires. The authors reported that the subjects get consistent speech information related to frequency-intensity relationship by using WDRMCC than LA. Thus the acclimatization was seen more in individuals using WRDMCC which was not very evident through LA.

Prates and Iório, (2006) evaluated the hearing aid acclimatization over first 3 months of hearing aid use. Eighteen participants ranging from 31-69 years were considered in the study. Their hearing loss ranged from mild to moderately severe degree of sensorineural type in both ears. Speech perception evaluation was carried out using perceptual index of speech recognition (PISR) and speech recognition threshold (SRT) in noise. Subjective assessment included International outcome inventory for hearing aids (IOA-HA). The evaluations were carried out at the initial fit and 1, 2 and 3 months after the fitting of hearing aids. For both the tests the scores were significantly better at 2 and 3 months post fitting than initial fit. But similar acclimatization effect was not seen by using the subjective questionnaire. The authors conclude that the questionnaires were not sensitive enough to tap the subtle changes taking place due to acclimatization.

A series of evaluations were performed by Bentler et al.(1993) to study the hearing aid benefit over a period of 1 year. The study included 65 individuals in the age range of 21-84 years (mean age, 63.8years) with moderate and moderately severe hearing loss. The configuration of hearing loss was flat, gently falling and steeply falling. 70% of

the subjects were fitted with In the ear (ITE) hearing aids BTE were fitted for the remaining 30% of them. The performance was assessed using speech perception in noise (SPIN) and nonsense syllable test (NST). Insertion gain measurements were also carried out. The testings were done at the time of initial fitting and 1, 3, 6 and 12 months thereafter. However, there was no significant difference observed in any of the test scores over the course of time. No difference was noticed in terms of degree, configuration of hearing loss. The authors suggest that one of the possible explanation for the result could be the participants were allowed to change the volume control settings. So the subjects could have set it to a level that might sound as pleasant but might not be optimum to obtain all the speech cues and hence the scores did not improve as expected.

The benefit provided by hearing aid over the first 3 months of fitting was assessed by Gabrielle and Kathleen, (1997). There were 48 participants in the study among whom 24 were experienced hearing aid users and the remaining 24 were naive users of hearing aid. They had mild to moderate hearing loss of sensorineural type in both ears. All the participants were fitted bilaterally with BTE hearing aids. The evaluations wee performed soon after the fitting and follow-up was done at 30, 60 and 90 days post fitting. Speech recognition threshold was measured in quiet and noise using CID word list and HINT respectively. Real ear measurements were also carried out to calculate the articulation index (AI). All the hearing aids were providing sufficient gain at both low and high presentation levels as revealed by AI. There was no significant difference between the scores in both quiet and noise over the testing period. The authors reason out that one of the possible cause for not seeing the acclimatization effect is because of the test material

used in the study. Both the speech tests were tapping more of low frequency information. Thus the tests failed to reveal any effect of acclimatization on the high frequencies. Thus the authors suggest that acclimatization could be better studied using high frequency test material.

Recently, the acclimatization to receiver in the aid (RITA) and receiver in the ear (RITE) hearing aids in individuals with sloping sensorineural hearing loss was investigated by Mondelli et al.(2015). They compared the adaptation using the above mentioned types of hearing aid in 20 individuals. Their participants were above 18 years of age having mild to moderate sloping sensorineural hearing loss. Speech perception was assessed using Hearing in noise test (HINT) and also using a questionnaire (satisfaction with amplification in daily life). HINT sentences were also presented in quiet. The authors found that in quiet environment, there was a significant improvement in the aided performance over the unaided condition in both the types of hearing aids. However, the performances in 2 aided conditions i.e., at the time of fitting and 6 months post fitting, did not show any significant difference. Similar results were obtained in the presence of noise. The results obtained could be due to the use of stimuli which was not high frequency concentrated. Thus, the stimuli were not sensitive enough to demonstrate the learnt use of new acoustic information available to the listeners in the high frequency region. The results were similar across both the hearing aid types. This could be because of the similar gain provided by both the hearing aid types as depicted by probe microphone measurements wherein the gain from the hearing aid in all the participants

matched to the target according to NAL-NL1. In addition, the participants included were limited to moderate degree of hearing loss.

From the above review, it is clearly evident that studies on hearing aid acclimatization have shown either improvement or no improvement in the speech perception. The diverse results in these studies could probably due to their methodological limitations. In many of the above studies they have not utilized appropriate test stimuli that were sensitive to document acclimatization effect or the configuration of hearing loss was not taken care of. Another important aspect is the use of objective speech perception tests in evaluating acclimatization. It is not appropriate to comment about the acclimatization effects solely based on subjective questionnaires. Also few studies have not taken into consideration the unaided scores, which makes it difficult to interpret whether the improvement in the speech perception scores seen are due to increase in the aided performance because of acclimatization or the reduction in the unaided scores.

Chapter 3

Method

The present study aimed to compare the hearing aid acclimatization in individuals with sloping sensorineural hearing loss using Behind the Ear (BTE) and Receiver in the Canal (RIC) hearing aids. Aided perception of high frequency words and sentence identification in presence of noise was assessed in both unaided and aided conditions. In order to estimate the acclimatization effect a follow up testing was carried out for all the participants after 1 month of hearing aid use.

3.1. Participants

Ten participants with sloping sensorineural hearing loss (SNHL) between the age rang**e** of 47 to 82 years (Mean age: 67.5 years, SD= 12) participated in the study. Among them, five individuals were naïve RIC hearing aid users and the remaining five subjects were naïve BTE users. Participants fitted with monaural or binaural hearing aids were selected. All the participants were native speakers of Kannada. The demographic and audiologic details of the participants can be seen in Table 3.1

3.2. Procedure for the selection of participants

A structured interview was carried out to choose the participants who met the following criteria:

- No history of external or middle ear infection,
- No history of any speech and language problem,
- No gross neurological or cognitive dysfunction(Evaluated using Standardised Mini Mental Status Examination).

Table 3.1: Demographic and audiologic details of the participants

Sl.No	Age/ Gender	PTA (dBHL)		SIS(%)		Tympanogram (bilateral)	Acoustic Reflex (bilateral)	Hearing aid
		Right	Left	Right	Left			
1	47 Y/F	50	55	100	92	A	Present	RIC
2	66 Y/M	45	45	96	96	A	Present	RIC
3	82 Y/M	62.5	58.75	92	92	A	Absent	RIC
4	76 Y/F	32.5	36.5	92	96	A	Present	RIC
5	75 Y/M	50	50	88	88	A	Present	RIC
6	66 Y/M	60	65	92	92	A	Absent	BTE
7	76 Y/M	54	55	100	100	A	Present	BTE
8	74 Y/M	60	65	88	92	A	Absent	BTE
9	54 Y/M	45	50	100	92	A	Present	BTE
10	59 Y/M	60	58.75	92	92	A	Absent	BTE

PTA=Pure-tone average, SIS=Speech identification score

In addition to the above criteria, only participants who manifested the following findings were included in the study:

- Pure-tone hearing threshold in the range of mild to moderately severe sloping sensorineural hearing loss with 5-12 dB increase in threshold per octave (Silman & Silverman, 1991).
- Symmetrical hearing loss, where the difference in threshold between the two ears should not exceed 10 dB HL at any frequency (Figure 3.1),

- ‘A’ type tympanogram,

Prior to collection of data, detailed audiological evaluation was carried out for all the participants. Pure-tone thresholds were obtained via the modified Hughson and Westlake procedure (Carhart & Jerger, 1959), using a calibrated diagnostic audiometer. Calibrated immittance instrument was used to obtain tympanograms and acoustic reflex thresholds. Speech identification scores were obtained using a phonemically balanced word test in Kannada, developed by Yathiraj and Vijayalakshmi (2005).

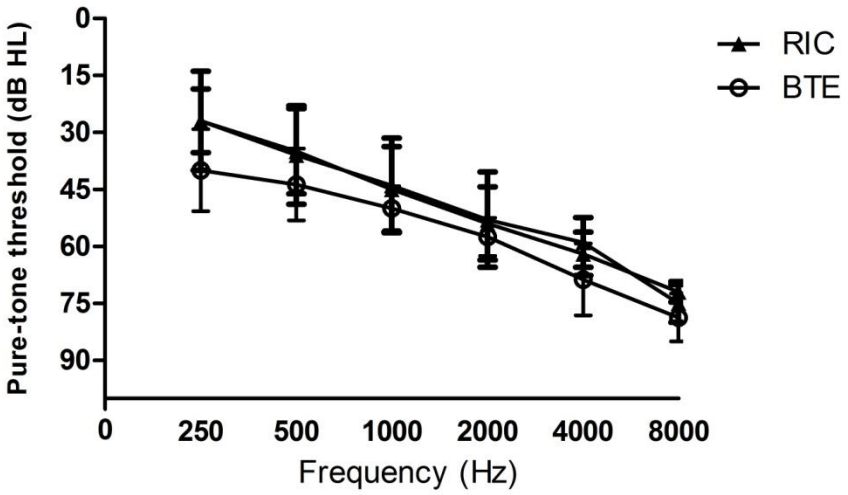

Figure.3.1. The mean and ±1SD of pure tone air conduction thresholds across frequencies in RIC and BTE hearing aid users.

3.3. Test stimulus

The stimuli used for the study include high frequency word list in Kannada (Kavitha & Yathiraj, 2002) and a sentence test in Kannada (Geetha, Kumar, Manjula & Pavan, 2014). The former stimuli were used to evaluate the ability of the participants to use the high frequency information and the latter was used to evaluate the speech perception performance in adverse listening conditions. Both word and sentence test were performed in the unaided as well as aided conditions. The high frequency word list in Kannada had three lists in it, each having 25 words. The recorded version of any of the three word list was presented at 40 dBHL and the percentage of correctly identified words was calculated.

Four lists of sentences were taken from the recorded sentence test in Kannada. Each list contained ten sentences and each sentence had five key words. All the sentence lists were phonemically balanced. The ten sentences in each list were mixed with speech shaped noise at different signal to noise ratios (SNR) ranging from 12 dB to -6 dB SNR in 2dB step-sizes. The speech shaped noise was generated by randomizing the phase of the Fourier spectrum of concatenated sentences of original signals using MATLAB software. The noise was added to the sentence based on root mean square (RMS) level. The stimuli were RMS normalized to maintain equal loudness. The SNR at which 50% of the sentences were perceived will be calculated using the Spearman–Kärber equation (Finney, 1952), which is as follows:

$$50\%\ \text{point} = \mathrm{I} + (0.5 \times \mathrm{d}) - \mathrm{d}\ (\#\ \text{correct})/\mathrm{w}$$

where, I is initial presentation level (dB SNR), d is the decrement step size (attenuation), and w is the number of words per decrement.SNR 50 was obtained from each participant in the unaided and aided conditions.

To assess the performance in real life situation Hearing Aid Benefit questionnaire for adults (Kanwer & Devi, 2011) was used. The check-list was administered to assess communication abilities of participants in the unaided and aided conditions. First two divisions of the questionnaire that assess the performance of participants in favourable (quiet) and unfavourable (noise) situations were utilized.

3.4. Test environment

The study will be carried out in an acoustically treated air-conditioned room with permissible noise level as per ANSI S3.1, (1999).

3.5. Hearing aid programming

A wide dynamic range compression BTE and RIC hearing aids with similar number of channels (4-6) as well as gain and compression characteristics was utilized for the study. BTE hearing aids were fitted using custom made soft ear moulds and the RIC hearing aids were fitted using domes of appropriate size. The hearing aids were programmed using a personal computer loaded with a NOAH software (version-4) and hearing aid specific software. Programming was done separately for each participant to provide appropriate output characteristics at first fit.

Real ear insertion gain measurement

All the participants were tested for their real ear insertion gain characteristics. Prior to the testing, otoscopic examination of the ear canal was performed. A loudspeaker was placed at a distance of 12 inches and 0^0 azimuth from the participants. A calibrated probe tube was placed within approximately 5 mm of the ear drum of the participants. Real ear insertion gain curves were obtained for each of the participants by subtracting the real ear aided and unaided gain curves. The procedure was same for both BTE and RIC except that the reference microphone was switched off in order to avoid artifacts caused by the feedback suppression technology in the RIC hearing aids. It was ensured through real ear measurements that appropriate gain was provided using both RIC and BTE hearing aids.

3.6. Test Procedure

Each participant was evaluated to assess both unaided and aided speech perception abilities. Speech perception abilities of each participant were assessed at two different time intervals. First evaluation was performed soon after fitting hearing aids. Another evaluation was performed 4-5 weeks after uninterrupted use of the hearing aid. Each participant was tested in their aided ear while blocking the unaided ear using ear mould impression material. The recorded versions of the word test as well as sentence test were utilized to evaluate their performance. The stimuli were played using a computer. The output of the computer was routed through a calibrated audiometer and heard by the participants through a loud speaker kept at a distance of 1 meter at 0^0azimuth. The stimuli were presented at 40 dB HL. No participant heard the same list

more than once to avoid any familiarity effect. The participants were instructed to repeat the stimuli and the responses were noted by the experimenter. The SNR was adjusted depending on the participant's response to obtain 50% response. Similarly, the word identification scores was calculated by counting the number of words identified correctly.

3.7. Analyses

The data obtained from 10 ears of 5 individuals using binaural RIC hearing aids and 8 ears (3 binaural and 2 monoaural hearing aid users) of BTE users were analysed using SPSS (version 20). Descriptive statistics, Wilcoxon Signed Rank test, Mann-Whitney U test were performed to analyse the data.

Chapter 4

Results

The present study compared the hearing aid acclimatization in individuals with sloping sensorineural hearing loss using RIC and BTE hearing aids. In order to quantify the acclimatization effect, speech perception abilities of the participants were evaluated in quiet and noise. Perception of high frequency words and sentence identification in noise (SNR-50) were carried out to evaluate the performance in quiet and noise respectively. Both the testings were carried out at the time of hearing aid fitting (trial 1) as well as after 1 month of hearing aid use (trial 2). Additionally, the participants were asked to fill a questionnaire on hearing aid benefit at the end of 1 month of hearing use.

4.1. Perception of high frequency words

In order to obtain the aided benefit using high frequency word list, the difference between aided and unaided scores was determined. This was carried out separately for trial 1 and trial 2. The mean and SD of unaided and aided scores for RIC and BTE hearing aids can be seen in table 4.1. Participants showed similar unaided scores in both the trials whereas the aided scores improved in trial 2.

Table 4.1: The mean and standard deviation for the unaided and aided scores using RIC and BTE hearing aids for trial 1 and trial 2

	Unaided scores		Aided scores	
Hearing aid type	Mean (Standard deviation)		Mean (Standard deviation)	
	Trail 1	Trail 2	Trail 1	Trail 2
RIC	3.70 (2.163)	3.70 (2.163)	14.10 (2.424)	19.30 (1.252)
BTE	1.75 (2.188)	1.75 (2.188)	13.75 (1.909)	17.75 (1.982)

The difference in the aided benefit between the two trials yielded the acclimatization effect. Table 4.2 shows the mean, median and standard deviation of aided benefit in both RIC and BTE hearing aid users. It is clearly seen that aided benefit obtained after 1 month of hearing aid usage was higher than that obtained at the time of hearing aid fitting. Wilcoxon Signed Rank test was carried out in both RIC and BTE hearing aid users to determine the significance of improvement in speech identification scores. The results showed a significant improvement in speech identification for both RIC ($|z| = 2.821$, $p < 0.05$) and BTE ($|z| = 2.533$, $p < 0.05$) hearing aid users at the end of 1 month of hearing aid use. The difference in speech identification scores between two trials in RIC and BTE hearing aid users can also be found in Figure 4.1.

Table 4.2: The mean, median and standard deviation for the aided benefit using RIC and BTE hearing aids for trial 1 and trial 2

	Aided benefit					
Hearing aid type	Trial 1			Trial 2		
	Mean	Median	Standard deviation	Mean	Median	Standard deviation
RIC	10.0000	11.0000	3.33999	15.6000	15.0000	2.27058
BTE	12.0000	11.5000	3.46410	16.0000	16.0000	2.67261

In order to determine the acclimatization effect, aided benefit obtained on trial 1 was subtracted from trial 2. This was carried out separately for RIC and BTE hearing aid users. The mean, median and standard deviation of acclimatization effect in both RIC and

BTE hearing aid users can be seen in table 4.3. It is noted that the acclimatization effect obtained in the RIC users was slightly better than that of the BTE users.

Table 4.3: The mean, median and standard deviation of acclimatization effect for high frequency words in RIC and BTE hearing aid

Hearing aid type	Acclimatization effect		
	Mean	Median	Standard deviation
RIC	5.2000	5.0000	1.87380
BTE	4.0000	3.5000	2.20389

Further, Mann-Whitney U test was administered to check the significance of difference in the amount of acclimatization between RIC and BTE users. The results revealed no significant difference in the amount of acclimatization between the two types of hearing aids ($U= 25.00$, $p>0.05$).

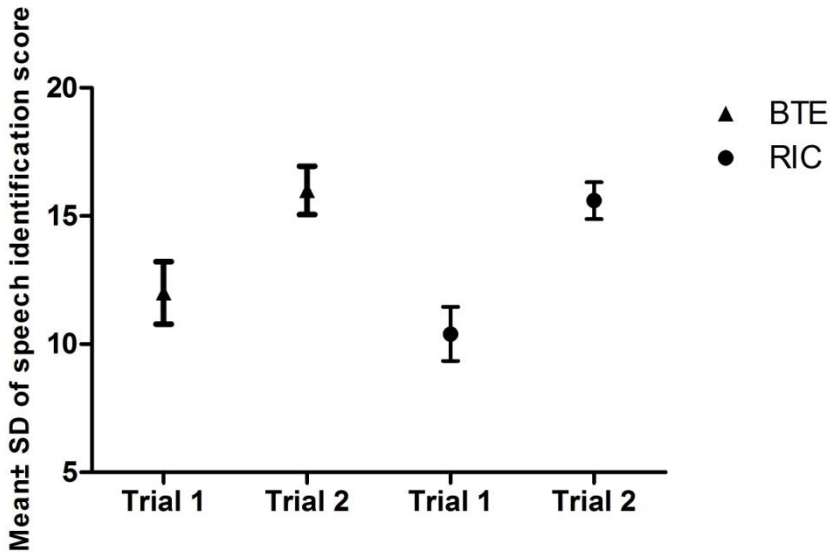

Figure 4.1: Speech identification score (mean and ±1SD) obtained using high frequency wordlist across two trails in BTE and RIC hearing aid users.

4.2. Sentence identification in noise

Sentence perception in noise was evaluated using aided SNR-50 in both trial 1 and trial 2. The mean, median and standard deviation for the aided SNR-50 in both the trials is depicted in table 4.4. It is evident in both BTE and RIC hearing aid users that SNR-50 obtained on trial 1 was poor compared to that of trial 2. Wilcoxon Signed Rank test was performed to assess the significance of difference in SNR-50 between the two trials. This was done separately for RIC and BTE hearing aid users. The results revealed that both RIC ($|z| = 2.807$, $p < 0.05$) and BTE ($|z| = 2.527$, $p < 0.05$) hearing aid users showed significant difference in SNR-50 between the two trials. The difference in SNR-50 between two trials in RIC and BTE hearing aid users can also be found in Figure 4.2.

Table 4.4: The mean, median and standard deviation for the SNR-50 in RIC and BTE hearing aids for trial 1 and trial 2

Hearing aid type	SNR-50					
	Trial 1			Trial 2		
	Mean	Median	Standard deviation	Mean	Median	Standard deviation
RIC	+8.6000	+8.7500	1.04881	+3.3500	+3.7500	1.70049
BTE	+8.4375	+8.0000	1.67838	+4.4375	+4.2500	2.11183

Acclimatization effect was determined by taking the difference in SNR-50 between the two trials. Table 4.5 shows the mean, median and the standard deviation for the acclimatization effect for SNR-50 in both the groups. Mann-Whitney U test was done to see the significance of difference in amount of acclimatization between the two types of hearing aid. As shown by the results, the amount of acclimation was not significantly different between BTE and RIC hearing aid users ($U= 23.00$, $p > 0.05$).

Table 4.5: The mean, median and standard deviation of acclimatization effect for SNR-50 in RIC and BTE hearing aid

Hearing aid type	Acclimatization for SNR-50		
	Mean	Median	Standard deviation
RIC	5.2500	5.0500	1.84466
BTE	4.0000	4.2500	1.60357

Figure 4.2: SNR-50 (mean and ±1SD) obtained across two trails in BTE and RIC hearing aid users.

4.3. Hearing aid benefit questionnaire

In order to assess the performance in real life situation Hearing Aid Benefit questionnaire for adults (Kanwer & Devi, 2011) was administered after 1 month of hearing aid use. Each question was answered with respect to unaided and aided condition in both quiet and noise. The mean and standard deviation of the same can be seen in table 4.6.

Table 4.6: The mean and standard deviation for the unaided and aided scores using RIC and BTE hearing aids in both quiet and noise

	Quiet		Noise	
Hearing aid type	Mean (Standard deviation)		Mean (Standard deviation)	
	Unaided	Aided	Unaided	Aided
RIC	16.56 (12.675)	68.13 (12.431)	7.20 (6.195)	57.22 (12.205)
BTE	6.25 (1.276)	64.47 (2.352)	2.77 (2.266)	47.57 (1.291)

The differences between the aided and unaided scores were calculated. Table 4.7 shows the mean, median and standard deviation of aided benefit on both the subscales. It is clear that both RIC and BTE hearing aid users showed aided benefit on both the subscales.

Table 4.7: The mean, median and standard deviation of aided benefit in BTE and RIC hearing aid users in quiet and noise subscales

Hearing aid type	Aided benefit Quiet			Aided benefit Noise		
	Mean	Median	Standard deviation	Mean	Median	Standard deviation
RIC	51.5630	46.8750	11.10295	50.0140	51.3900	9.41790
BTE	58.2156	58.5938	1.50919	44.7925	45.1400	8.51572

Mann-Whitney U test was administered to see if there was significant difference in the aided benefit between RIC and BTE hearing aids. On both the subscales i.e., quiet ($U= 8.00$, $p > 0.05$) and noise ($U= 8.50$, $p > 0.05$), there was no significant difference in aided benefit in both RIC and BTE hearing aid users.

Chapter 5

Discussion

The present study compared the acclimatization in individuals with sloping sensorineural hearing loss using RIC or BTE hearing aids. The results of the study showed significant acclimatization effect in both RIC and BTE hearing aid users. However, there was no significant difference in acclimatization between the two types of hearing aids. This was evident through both speech perception tests as well as subjective measures.

5.1. Perception of high frequency words

The results of the high frequency word test revealed that the perception of high frequency words improved significantly at the end of 1 month of hearing aid usage in both RIC and BTE hearing aid users. Perceptual improvement in high frequency word scores accounts for the acclimatization effect in quiet. Due to high frequency sloping hearing loss, the study participants were unable to access the high frequency information in the unaided condition. After fitting hearing aid that provided sufficient gain in the high frequency region, the participants were able to make use of the high frequency information that helped them to perceive high frequency cues better. Moreover, we used the test stimuli that tap the perception of high frequency information. Similarly, previous work on hearing aid benefits by Gatehouse (1992; 1993) and Yund et al.(2006) have also showed significant acclimatization effect. In these studies they used test materials such as four alternative auditory feature (FAAF) and nonsense syllable test (NST), which tap more of high frequency content. In contrast, Gabrielle and Kathleen (1997) did not show

significant acclimatization effect. The reason they attributed for lack of acclimatization was the test material that did not tap the high frequency perception. Thus, they suggested the use of stimuli that taps the high frequency perception while assessing the acclimatization in individuals with sloping sensorineural hearing loss. Thus, significant acclimatization in the current study participants who had sloping sensorineural hearing loss could be attributed to access to newly available high frequency cues that were evaluated using appropriate test stimuli.

The study also indicated that there was no significant difference in the amount of acclimatization between RIC and BTE hearing aids. This could be because both RIC and BTE hearing aids were efficient in providing adequate high frequency gain. This was confirmed using real ear measurements. Similar results were found by Mondelli et.al. (2015) where in the authors reported no significant difference in acclimatization between RIC and BTE hearing aid users.

5.2. Sentence identification in noise

Perception of sentences in noise represents the aided performance in the presence of noise. It can be seen that the SNR-50 improved significantly at the end of 1 month post acclimatization in both RIC and BTE hearing aid users. However, the amount of improvement was not significantly different between the two types of hearing aids.

It could be expected that with acclimatization, individuals learn to use newly available speech cues in the high frequency region and this might have resulted in the improved performance in the presence of noise. Similar results on speech perception in noise were obtained by Prates and Iório, (2006). However other studies by Gabrielle and

Kathleen, (1997) and Mondelli et al. (2015) reported that no significant acclimatization effect on speech perception in noise while using SPIN and HINT stimuli respectively.

In many aspects the present study is comparable to the one conducted by Mondelli et al.(2015). Both the studies had individuals with sloping sensorineural hearing loss, they used similar types of hearing aids (RIC and BTE) and similar tasks i.e., perception of sentences in noise. In spite of these similarities, study by Mondelli et al.(2015) failed to show significant acclimatization effect even after 6 weeks post hearing aid fitting. However, the present study showed significant acclimatization effect in both the types of hearing aids. The possible reason for the difference in the findings could be because of the frequency content of the stimuli as revealed by the long term average speech spectrum (LTASS). Earlier study used HINT sentences which were concentrated majorly on low frequencies with the roll off starting at 1000 Hz (Nilsson, Soli & Sullivan, 1994). In contrast, the present study used sentences which had more high frequency concentration compared to HINT. Even though, major concentration of the stimuli was in the low frequencies, the roll off started at a much higher frequency at about 10000 Hz (Geetha, Kumar, Manjula & Pavan, 2014). Thus, in the present study, significant acclimatization was seen since the stimuli tapped high frequency information.

The present study also revealed that there was no significant difference in the amount of improvement in the SNR-50 between the two types of hearing aids. The results are in accordance with the study conducted by Mondelli et.al. (2015), which is the only study that compared acclimatization in BTE and RIC hearing aids. The authors reasoned

that both the types of hearing aids provide adequate high frequency gain and thus the results did not show any significant difference in terms of acclimatization.

5.3. Hearing aid benefit questionnaire

The intention of administering the subjective questionnaire was to see whether the participant's subjective rating was more in favour of one of the hearing aid types. The above results of the objective evaluation are in accordance with the subjective measures as revealed by the hearing aid benefit questionnaire. The first subscale i.e., aided benefit in quiet revealed that there was an improvement in the aided condition when compared to unaided condition in both RIC and BTE hearing aid users. However, there was no significant difference in the amount of improvement between the two types of hearing aids.

Similarly, the subscale representing the aided benefit in the presence of noise, showed benefit in aided condition over unaided condition. However, no significant difference in the amount of benefit was obtained with both the types of hearing aids. Since both the types of hearing aids provided similar gain, the subjective rating might not have revealed any significant changes between RIC and BTE hearing aids. However, the questionnaire was administered only once after the acclimatization period and hence we are unable to get information regarding the effect of acclimatization on parameters in the questionnaire.

Overall results of the present study showed that both RIC and BTE hearing aids provide significant benefit for speech perception both in quiet and noise. The improvement with the hearing aids was evident on both the speech perception tests as

well subjective questionnaire. However, none of the two types of hearing aids proved to be significantly better over other type of hearing aid. This may be due to the similar gain provided by both the types of hearing aids. Thus, in individuals with sloping sensorineural hearing loss both RIC and BTE hearing aids showed similar amount of acclimatization probably due to their identical gain characteristics.

Chapter 6

Summary and Conclusion

The present study evaluated and compared the acclimatisation to RIC and BTE hearing aids in individuals with sloping sensorineural hearing loss. Ten individuals with mild to moderately severe sloping sensorineural hearing loss were included in the study. Ten ears of 5 individuals with RIC hearing aids and 8 ears of 5 individuals using BTE hearing aids were tested for the speech perception abilities in quiet and noise. All the participants were naive users of hearing aid.

Perception of high frequency words (Kavitha & Yathiraj, 2002) was evaluated in both unaided and aided conditions at the time of hearing aid fitting and after an acclimatization period of 1 month. Aided sentence identification in the presence of noise (Geetha, Kumar, Manjula & Pavan, 2014) was also assessed in both the time intervals. Four lists of sentences were taken from the recorded sentence test in Kannada and were mixed with speech shaped noise at different signal to noise ratios (SNR) ranging from 12 dB to -6 dB SNR in 2dB step-sizes. The SNR at which 50% of the sentences were perceived was calculated. To assess the performance in real life situation, first two subscales (quiet and noise) of the Hearing Aid Benefit questionnaire for adults (Kanwer & Devi, 2011) was used. The check-list was administered to assess communication abilities of participants in the unaided and aided conditions.

For the high frequency word perception, the aided benefit was found out by taking the difference between aided and unaided scores in both the trials. Wilcoxon signed rank test was administered to see whether significant acclimatization was present and the

results showed that both RIC and BTE hearing aid users showed significant acclimatization effect. However, Mann- Whitney U test revealed no significant difference in the amount of acclimatization between the two types of hearing aids.

Aided SNR-50 was determined in both the trials in both the study groups. Results of Wilcoxon signed rank test revealed a significant acclimatization seen in RIC and BTE aid users. Further, Mann-Whitney U test showed no significant difference in the amount of acclimatization between two types of hearing aids. The results of both the speech perception tests are in agreement with the findings from the subjective questionnaire used in the study. For both the subscales (favourable and unfavourable), a significant acclimatization effect was present for RIC and BTE hearing aid users. However, the amount of acclimatization did not differ significantly between the two types of hearing aids.

Overall, it is clear from the present study that both RIC and BTE hearing aids resulted in significant improvement in speech perception abilities in individuals with sloping sensorineural hearing loss. The results were similar in both quiet and in the presence of noise. The results were supported by the findings of the hearing aid benefit questionnaire.

Clinical implications

The present study showed that significant acclimatization is seen in both RIC and BTE hearing aids and the speech perception scores improved significantly after 4 weeks of hearing aid fitting. Thus the individuals need time to utilize the newly available cues

with the amplification and hence the time course of acclimatization should be taken into consideration while fitting hearing aid., .

Future directions

The present study revealed that there was no significant difference in the amount of acclimatization in individuals with sloping sensorineural hearing loss using RIC or BTE hearing aids. However, all the individuals had gradual sloping configuration in the present study. Testing with different slopes of hearing loss configuration might lead to better understanding about the amount of acclimatization between RIC and BTE hearing aids.

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