EFFECT OF NUMBER OF CHANNELS OF HEARING AIDS ON SPEECH PERCEPTION IN DIFFERENT DEGREES OF SLOPING HEARING LOSS CASES

Register No: 09AUD015

A Dissertation Submitted in Part Fulfillment of Final Year

Master of Science (Audiology)

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ALL INDIA INSTITUTE OF SPEECH AND HEARING,

MANASAGANGOTHRI, MYSORE – 570006

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CERTIFICATE

This is to certify that this dissertation entitled ***"Effect of number of channels of hearing aids on speech perception on different degrees of sloping hearing loss cases"*** is a bonafide work submitted in part fulfilment for the degree of Master of Science (Audiology) of the student (Registration number: 09AUD015). 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.

Dr.S.R.Savithri

Director

All India Institute of Speech and Hearing

Manasagangothri Mysore,

MYSORE,

JUNE, 2011

<u>CERTIFICATE</u>

This is to certify that this dissertation entitled ***"Effect of number of channels of hearing aids on speech perception on different degrees of sloping hearing loss cases"*** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier to any other university for the award of any other diploma or degree.

Guide:

Mr. Niraj Kumar Singh

Lecturer in Audiology

All India Institute of Speech and Hearing

Manasagangothri Mysore,

MYSORE,

JUNE, 2011

DECLARATION

I hereby declare that this dissertation entitled ***"Effect of number of channels of hearing aids on speech perception on different degrees of sloping hearing loss cases"*** is the result of my own study, and has not been submitted earlier to any other university for the award of Diploma or Degree.

RegisterNo.09AUD015

Mysore,

June, 2011

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To god:

या कुन्देन्दु तुषार हार धवला
या शुभ्रवस्त्रावृता ।
या वीणावरदंड मंडितकरा
या श्वेतपद्मासना ॥

ॐ वाक्देवय्यी च: विद्धमहे
विरिन्जि पत्निय्यी च: धीमहि
तन्नों वाणि प्रचोदयात् ।

To my babaji...

मनोजवं मारुत तुल्यवेगम्
जितेन्द्रियं बुद्धिमतां वरिष्ठम् ।
वातात्मजं वाणर यूथमुख्यं
श्रीरामदूतम् शरणं प्रपद्ये ॥

ॐ आञ्जनेयाय विद्धमहे
वायु पुत्राय धीमहि
तन्नो हनुमत् प्रचोदयात् ।

- ❖ Though only my name appears on the cover of this dissertation, a great many people have contributed to its production. I owe my gratitude to all those people who have made this dissertation possible and because of whom my post-graduation experience has been one that I will cherish forever. It is with deepest appreciation that I would like to thank all those who have extended their time, support, prayers, knowledge & efforts towards this dissertation. I will attempt to express my gratitude herein.

- ♣ My deepest gratitude is to my guide, His patience and support helped me overcome many tough situations and finish this dissertation. I cannot thank him enough. Sir, my sincere gratitude to you for being motivating and helping me to reach my destination. The best teachers teach from the heart, not from the book...The dream begins with a teacher who believes in you, who tugs and pushes and leads you to the next plateau, sometimes hurting you with a sharp stick called truth." SIR i am really thankful to you for helping me

- ♣ I extend my warmest gratitude to sujeet Sir, I am grateful to him for making my Statistics work a lot easier. Thank you sir

- ♣ To daddy : When I was born, you were there to make sure that everything should be perfect .When I said my first words, you were there for me, to teach me the whole dictionary. When I took my first steps, you were there to encourage me. When I had my first day at school, you were there with me in school for whole day sitting with me, giving me advice. I really can't forget the time, when I had a near death experience…that was very crucial times of my life and for our family. We really had gone through so much …and our relation had grown with time And I just want say my life is incomplete without you…and i know you will be there for me through all these times and more, the good and bad. Just want to say thank you to have trust on me, with all my heart. You are my personal confidence. So I just wrote this to say "your love made me do everything" I love you

- ♣ To mummy: It's very fairly said that god can't be there with everyone that's why he made mother to help you to save you & to be there for you…I had personally experienced it. Mummy you are the most wonderful person that I have ever known. You are the axis of our family. Without you I can never do or succeed in anything. Within our home, you are an abundance of love, discipline, fun, affection, strength, tenderness, encouragement, understanding, inspiration, support. You are always there when ever trials heavy and sudden fall upon me. When adversity takes the place of prosperity, when friends who rejoice with me in my sunshine deserted me; when trouble thickens around me, you are always there endeavour by your kind precepts and counsels to dissipate the clouds of darkness. You are an example of strength, hope and love… I wish to be like you so that i can handle tough situations. Love you with all my heart, this is for you mummy.

- ♣ To brother: Vicky to the outside world, we had grown old. But not to each other, we know each other as we always were. As a brother and sister, our tastes were pretty different but we know each other's hearts. We live outside the touch of time. I have wonderful memories with you and we will have more memories together. You were and you are always there for me through thick and thin and you will be there for me wheather i ask or not. I really miss the time we had together ...without your support and love I just can't do this. You are my best friend...who understands me more than anyone in this world. It takes a long time to grow an old friend...but its best and wonderful to grow old with your best friend...

- To all my bro and sis especially shwetha di, amit bhiya, anish bhiya,shilpi di ,atul, rima,satyam , and to anshu, without your love and support i could never be able to do this.
- To my forever friends
- Manish: A friend is like sunlight, filtering into the quite corners of ones heart, offering bright new mornings and fresh hope yet demanding nothing in return." "The greatest challenge in being a friend is not listening when words are spoken but hearing and feeling even though there is nothing but silence." "The happiest person has three things, a best friend, a true love and a best friend who is their true love. Our friendship has kept on growing and I'll be here for you to the end. You listen when I have a problem, and help dry the tears from my face. You take away my sorrow and put happiness in its place. I can't forget the fun we've had, laughing 'til our faces turn blue. Talking of things only we find funny. I guess this is my way of saying thanks, for catching me when I fall. Thanks once again for being such a good friend, and being here with me through it all.
- Madhuban: A friend is someone who can see the truth and pain in you even when you are fooling everyone else. You know me very well... You lifted me up when i could not lift up myself, you made me smile when i forgot how to, you were there for me in my times of need and you were there for me when I needed nothing at all. Tushi..love you for the way you are...
- Hemu: "A Friend is someone who knows all about you and loves you anyway!!!" "In loneliness, in sickness, in confusion-the mere knowledge of friendship makes it possible to endure, even if the friend is powerless to help. It is enough that they exist. Friendship is not diminished by distance or time, by imprisonment or war, by suffering or silence. It is in these things that it roots most deeply. It is from these things that it flowers." lucky to have you in my life...

- Nita: True friendship is a gift that is given without the expectation of anything in return. Instead the reward is the friendship itself. A person is only complete when she has true friends to understand her, share all her passions and sorrows with, and to stand by her throughout life..
- Pragnya: you are a wonderful person, and so you see, it's you and me together forever. Never apart, maybe in distance, but never in heart.
- To guptaji, preeti, sonia
- To priyanjali, tribal, Chai, Prabhash, Paggu,Shruthi, Ani and to all my classmates
- you people are wonderful...thank you all you people made me feel home like here...thank you for being there....
- And to all those wonderful people who were there, thank you.

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Chapter 1

Introduction

The sensorineural hearing loss results in loss of audibility, coupled with an uneven distortion of the audibility of the ear to different frequencies. Hearing aids are designed and fitted to lessen the problems faced by individuals with hearing impairment. A hearing aid is an electronic device that improves the audibility of sound thereby helping the individuals with hearing impairment in hearing sounds that otherwise would be inaudible to them. The hearing aid technology allows for the sound to be amplified alike across the frequencies, as in single channel, or different frequency components of sound to be amplified differentially, as in multichannel hearing aid.

In a single channel system, the dynamic range is optimised across the full range of frequencies by a single processor, which means that single-channel compression systems vary gain across the entire frequency range of the signal. Thus, they cannot accommodate variations in the listener's dynamic range that may occur for different frequency regions. For example, many listeners with a sloping loss have a normal or near normal dynamic range for low-frequency sounds but a sharply reduced dynamic range for high frequency sounds where hearing loss is more severe. In some single-channel systems, an intense low-frequency sound can decrease overall gain and cause high-frequency sounds to become inaudible (Kuk, 1996). A major disadvantage of this signal processing strategy is that it may be detrimental for listeners who exhibit variations in hearing thresholds and dynamic range across frequencies. This occurs because the reduction in overall gain may cause high-frequency sounds to become inaudible, which can reduce speech intelligibility.

Multi-channel hearing aids split the incoming signal into different frequency bands, and each band of signal passes through a different amplification channel. In multi-channel compression hearing aids, this dynamic range is optimised at discrete frequencies by using multiple compressors. In multi-channel compression, the gain compression is performed independently in each channel prior to summing the output of all channels. Hence, no such issue of inaudibility of one sound due to another sound is likely to come into the picture. In a multi-channel compression hearing aid, the incoming speech signal is filtered into two or more frequency channels. Compression is then performed independently within each channel prior to summing the output of all channels. Thus, the speech perception would still be better in the sloping hearing loss cases.

Need of the study

Most of the studies that have compared the performance between single and multi-channel hearing aids have used either higher degrees of hearing losses or have not specifically used sloping losses. Though some studies have proved that multi-channel hearing aids make unwanted changes in the stimulus spectrum (Bustamante & Braida, 1987; Drullman & Smoorenberg, 1997), it would be better to receive slightly distorted information at all the frequencies rather completely missing out in the high frequencies, which are more important for speech perception. Individuals with sloping hearing loss have differential audibility across channels and hence, likely to perform better with multi-channel hearing aids. The studies in literature are equivocal about the advantages and disadvantages of increasing the number of channels in the hearing aid. The above mentioned studies, using larger number of channels, show mixed results, although larger number of channels could be logically thought to be more advantageous when adequate frequency shaping is provided (Crain and Yund, 1995).

Aim of the study

To find the effect of number of channels of hearing aids on the speech perception in individuals with different degrees of sloping hearing losses.

Chapter 2

Review of Literature

Over the decades attempts have been made to investigate whether increasing the number of channels would help the individuals with hearing impairment in perceiving speech better. Moore and Glasberg (1986) compared two-channel and single-channel compression hearing aids. The two aids were chosen to be as similar as possible in other respects, and both were worn behind the ear. Both the aids improved the intelligibility of speech in quiet relative to unaided listening, particularly at the lowest sound level. Both aids incorporated slow-acting automatic gain control (AGC) operating on the whole speech signal. In addition, aid 'A' also incorporated two-channel syllabic compression. Eight subjects with bilateral sensorineural hearing losses took part in the trial which compared 1) listening unaided with 2)listening binaurally through the two types of hearing aid, aid 'A' (two-channel) and aid 'B' (single-channel). The questionnaires, that were administered, also indicated that aid 'A' gave better performance in noisy situations. The results strongly suggest that two-channel syllabic compression, can give superior results compared to single-channel, particularly in noisy situations.

Yund and Buckles (1995) measured speech discrimination for 8-channel compression and linear amplification system. As the signal to noise ratio (SNR) decreased, the speech identification became relatively better in multi-channel compared to linear amplification. Yund and Buckles (1995) reported an increase in speech identification scores with increase in the number of channels from 4 to 8. However, there was no significant variation in speech identification score thereafter up to 16 channels.

Villchur (1978) compared the single- and multi-channel compression. Contradictory findings in certain subjects were reported. In his experiment many compression hearing aids failed to improve speech intelligibility relative to linear amplification for which he proposed several possible explanations these included improper speech material, improper selection of subjects or poor post-compression frequency equalization. For most of the subjects, the multichannel compression was relatively better.

A multi-channel compression hearing aid may be better able to accommodate variations in hearing threshold at each frequency than a single-channel compression hearing aid (Venema, 2000). A few investigators have compared measured distributions of short-term RMS speech levels for linear and compressed speech (Verschuure et al., 1996; Souza and Turner, 1996, 1998, 1999). These studies have shown that the range depends on the compression parameters of the amplification system, most notably on the compression ratio, the release time, and the length of the measurement window. With multi-channel compression, the speech level distribution is reduced across frequency in accordance with compression ratio in each channel (Souza and Turner, 1999). In a review of published data on multi-channel amplification, Hickson (1994) concluded that the best results were obtained with compression systems having three or fewer channels. For speech intelligibility in general, recent data suggests that multi-channel systems with up to four channels are equivalent to, but not superior to, single-channel systems (Keidser and Grant, 2001; Van Buuren et al, 1999). Souza and Turner (1998) stated that compression with a maximum number of channels of four (and not three, as was suggested by the research available to Hickson) might give similar speech intelligibility as linear amplification (but not better than linear amplification). However, the result was attributed on increased audibility and not on the large numbers of channels itself. The higher the compression ratio, greater the effect on the speech level distribution. Even for a single-channel compressor, the speech level distribution is unevenly affected across frequencies (Verschuure et al., 1996).

Flynn, Davis & Pogash (2004) took twenty-one children with severe hearing loss for a study to compare their performance on measures of audibility, speech understanding (in quiet and noise) and listening situation between the children's current analog hearing aids and a test hearing aid with multiple-channel non-linear compression. Results were obtained from the children at two weeks, 8 weeks, 6 months and 12 months following the fitting of a multiple-channel non-linear hearing instrument. Compared with the children's own hearing instrument, the test instrument provided improved audibility, improvement in speech understanding in quiet and noise and an improvement in listening skills.

Yund and Buckles (1995) demonstrated improved nonsense syllable recognition in noise as the number of channels increased from four to eight. Comparison of consonant confusions and frequency response for different number of channels were consistent with improved high-frequency audibility. In this case, no additional improvement was seen with more than eight-channels, probably owing to the fact that eight-channel system already provided sufficient information for recognition of high-frequency consonants.

Similarly, Braida et al., (1982) compared four multiband compression limiters and two linear amplification systems in terms of the intelligibility of consonant-vowel-consonant (CVC) and nonsense syllables for two listeners with hearing-impairment over a 30dB range of input levels. Each system incorporated one two frequency gain characteristics and one of three limiting characteristics (no limiting, moderate limiting, or severe limiting). Result indicated that the spectral degradations introduced by independent compression of 16 frequency bands may have caused the reduced intelligibility at higher input levels. These results point out at large advantage for multi-channel compression which provided improved high- frequency audibility relative to a linear condition in some early studies.

Moore et al. (1999) studied the effect of compression on speech intelligibility in fluctuating noise he used compression parameters [number of frequency channels (NC),compression ratio(CR), attack time release time in ms(T_a/T_r) defined according to ANSI S3.22] (1 + 2 + 4 + 8, 1 + 1-2.9, 7/7), quoted above for single-channel compression, also included multi-channel compression (NC=1 + 2 + 4 + 8). Again, all compression conditions resulted in speech reception thresholds worse than achieved with linear amplification, although none differed significantly. Van Buuren et al. (1999) (1 + 4 + 16, 1 + 2 + 4, 0/0), quoted above, found the same results with multi-channel compression (NC=4 + 16) with CR=2, as with single channel compression. Speech reception thresholds were worse than those achieved with linear amplification, but the differences were not significant.

Walker and Dillon (1982) had compared the results of several studies that used commercially available hearing aids. They also evaluated a set of laboratory studies. They made a distinction between single-channel and multi-channel compression, and slow and fast compression systems. Throughout the review no systematic differentiation between experiments in quiet and in noise was made. The evaluation indicated that compression hearing aids failed to show any consistent advantages in terms of speech intelligibility or wearer acceptance above non-compressive hearing aids. The hearing aids that yielded the highest speech discrimination scores were predominantly the fast systems. Evaluating the laboratory studies they found some minor advantage for fast-acting single-channel compression. With fast-acting multi-channel compression the inter subject variability was large. Some subjects had shown a clear improvement in speech intelligibility with multi-channel amplification as compared to linear amplification. Overall, they concluded that the acquired results provided only minor support for the use of fast-acting compression. They indicated that more work was needed in this area. With respect to slowly-acting compression, Walker and Dillon agreed with Braida et al. although not enough data was available to reach a conclusion. Furthermore, they concluded that there had been very little attention paid to subjective measures like acceptability and pleasantness.

On the contrary, Bustamante and Braida (1987) reported reduction of speech intelligibility with multi-channel compression in individuals with hearing impairment. Hickson (1994) reported no significant difference between the performance with four-channels and single-channel hearing aid.

Barfod (1978) studied the effect of compression on speech intelligibility in stationary noise, he used compression parameters [number of frequency channels(NC),compression ratio(CR), attack time release time in ms(T_a/T_r) defined according to ANSI S3.22](2 + 3 + 4, 1 + 1-3, 6-24/6-24) used fast-acting two-, three- and four channel compression at several positive signal-to-noise ratios (0, +5, +10, +15, and +20 dB). Compression ratios were subject and frequency dependent. The lowest channel always had linear amplification. Result indicated that four-channel compression showed no significant difference in speech intelligibility relative to linear amplification, but three- and two channel compression degraded performance. The four-channel scores were significantly better than those for two or three channels.

Differences in the number of channels could explain differences in results between investigator who demonstrate improved vowel intelligibility using WDRC with a small number of channels (Drescler et al, 1988 and 1989; Stelmachowicz et al,1995) and those who show a detrimental effect (Franck et al,1999) showed vowels were harder to identify via an eight channel compression hearing aid than with a single-channel compression hearing aid.

Crain and Yund, (1995) reported that multi channel compression (MCC) processing could alter the speech spectrum, perhaps reducing spectral contrasts that are important for the discrimination of certain speech sounds. When the MCC processing was adjusted specifically for an individual with hearing-impairment, no negative effect of increasing numbers of channels (2 to 31) was found. In the case of FLAT MCC processing, increasingly degraded discrimination performance was found for both subject groups as the compression ratio increased and as the number of channels increased. There was also a strong interaction between the effects of the number of channels and the compression ratio, with the negative effects of increasing numbers of channels being much greater at the highest compression ratio.

Chapter 3

Method

Present study was designed to compare the speech identification in multi-channel hearing aid in different degrees of sloping hearing loss cases in quiet condition.

Subjects

30 post-lingual individuals with hearing impairment who were satisfying the following criteria were taken as the participants in the study:

- Mild to severe sensori-neural hearing loss in the ear to be tested (either symmetrical or asymmetrical hearing loss).
- Age range 18-55 years.
- Speech identification score greater or equal to 50% in the ear to be aided.
- Kannada speaking.
- Configuration of hearing loss , 10 participants under each of the following categories of audiogram configuration :
  - Flat (difference between the maximum and the minimum thresholds with in 20 dB)
  - Ski sloping(falls from low to high frequency at a rate of approximately 5-10 dB)
  - Steeply or precipitous sloping (threshold increases approximately at the rate of 15 -20 dB per octave)

Stimulus

Recorded version of phonetically balanced word list in Kannada developed by Yathiraj and Vijayalakshmi (2005) was used in this study. The speech material consisted of 4 phonetically balanced word lists and each list had 25 words. Also recorded version of a high frequency Kannada speech identification test (HF KST) word list developed by Mascarenhas and Yathiraj (2002) was used. All the words were presented through a CD.

Instrumentation & Test environment

A calibrated diagnostic audiometer (dual channel) Madsen OB922 version 2 with TDH-39 supra-aural ear phones housed in MX-41 Radio ear cushions B-71 was used for pure tone audiometry and speech audiometry.

Immittance meter (calibrated GSI Tympstar middle ear analyser) was used to rule out middle ear problems. Hardware and software of Pentium computer was used along with NOAH (compass version 4). All the above mentioned tests were performed in a air conditioned, well illuminated room with noise levels within permissible limits (ANSI S3.1-1999).

Hearing aid description

Hearing aids which were used for this study were of 3 types:

- Digital Hearing aid (with 2 channel): MicroTech Vector 4
- Digital Hearing aid (with 4 channel): Micro Tech Vector 8

- Digital Hearing aid (with 8 channel): Micro Tech Vector 16

These hearing aids were used for the purpose of comparison of performance. Hearing aids were connected to programming interface with Hipro box by using appropriate cable.

Prescriptive formula

NAL-NL1 was the formula which was used for programming the above mentioned hearing aids.

Procedure

- The pure tone thresholds were obtained to check that the patient fulfilled the earlier mentioned criteria for inclusion in the study.
- Tympanometric measurements were done using 226 Hz probe tone. This was done to rule out conductive hearing loss. Appropriate probe tips were used to obtain hermetic seal and comfortable pressure for the subject.
- Hearing aids were programmed on the basis of audiometric thresholds with the default gain provided according to NAL NL1 formula. While programming all the additional options were switched off in order to avoid any unwanted effect on result. All the hearing aids were switched to directional microphone mode. Test was done in acoustically treated room with ambient noise levels within permissible limits as per ANSI (1991) specification.

Participants were seated at distance of one meter and at 45° azimuths from the speakers. The stimulus was presented through the audiometer with impedance matched loudspeakers. Hearing aids were used randomly and the intensity level was maintained at 40 dBHL throughout the testing. Written responses were obtained from the subjects, but in case of illiterate participants, the responses were scored by a Kannada speaking clinician.

Chapter 4

Results and discussion

The present study was aimed at finding the usefulness of increasing the number of channels of hearing aids on speech perception in varying degrees of sloping hearing losses. The subjects were divided into three groups based on their loss; Group I (flat), Group II (moderately sloping), and Group III (steeply sloping) consisted of 10 subjects each.

To analyze the data following statistical analysis were done using the SPSS software version 15.0:

1. Descriptive statistics was done to find out the mean and the Standard deviation (S.D) for the following two stimulus conditions:

    a) Percentage score for Phonetically Balanced (PB) word list for flat hearing loss, moderately sloping hearing loss, and steeply sloping hearing loss for 2 - channels, 4- channels and 8 - channels hearing aids.

    b) Percentage score for High Frequency (H.F) word list for flat hearing loss, moderately sloping hearing loss, and steeply sloping hearing loss for 2 - channels, 4 - channels and 8 - channels hearing aids.

2. Mixed Analysis of variance (Mixed ANOVA) was done to find out:

    a) The interaction between the three channels and the three groups of hearing losses for Phonetically Balanced (P.B) word list.

    b) The interaction between the three channels and the three groups of hearing loss for high frequency (H.F) word list.

3. Bonferroni post hoc analysis was done to understand the pair wise differences for the three channels.

4. When mixed ANOVA showed a significant interaction for the channels, repeated measures of ANOVA was done to find out the significant differences for the three channels for flat hearing loss, moderately sloping hearing loss, and steeply sloping hearing loss groups.

5. Bonferroni post hoc analysis was done to see the group wise differences for the three channels whenever repeated measures of ANOVA showed a significant difference.

6. Multiple analysis of variance (MANOVA) was done to check for the existence of significant difference for each channel for the three hearing loss groups.

7. Duncan's post hoc analysis was done to find out the significant differences for each channel of the three hearing loss groups, in case multiple analyses of variance (MANOVA) showed a significant difference.

Speech Identification scores for the PB word list:

Mean and standard deviation (S.D) for the speech identification scores using the P.B wordlist for the three groups across three channels hearing aids was calculated. The mean standard deviation (S.D) for the speech identification scores are given in table 4.1. Table 4.1 revealed a trend towards increase in the speech identification scores with increase in the number of channels within each hearing loss group. It can also be seen that the increase in scores with increase in number of channels was greater for the two sloping hearing losses compared to the flat hearing loss group. The same can be observed in figure 4.1.

Table 4.1.

Mean and standard deviation of speech identification scores of PB list.

Number of Channels of Hearing Aid	**HEARING LOSS**					
	Flat Hearing Loss		**Moderately Sloping Hearing Loss**		**Steeply Sloping Hearing Loss**	
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
2 channel	83.20	13.20	80.00	10.83	83.60	9.32
4 channel	87.50	9.96	91.20	7.49	90.00	6.59
8 channel	93.60	8.044	96.00	5.96	96.40	5.14

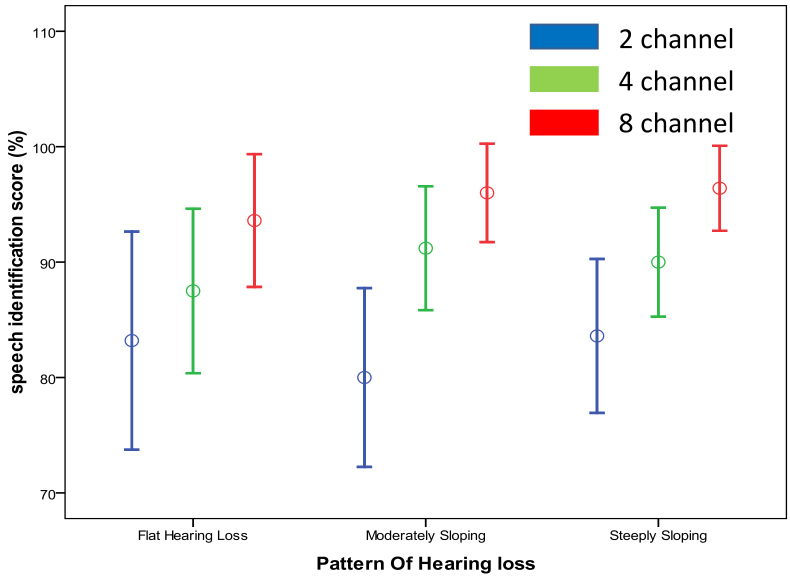

Figure 4.1: Error Bar of aided speech identification scores through 2, 4 & 8-channel hearing aids using PB word list.

Further analysis was done using mixed ANOVA to see the interaction effect for 3 channel and three groups. Mixed ANOVA showed a significant interaction for the three channels of the hearing aid [F (2, 54) = 40.41, $p < 0.05$] but it failed to show any significant interaction between the channel and the three groups [F (4, 54) =1.106, $p > 0.05$]. Further, mixed ANOVA also failed to show any significant interaction of the three groups [F (2, 27) = 0.158, $p > 0.05$]. Since the channel showed a significant interaction, a Bonferroni post hoc analysis was done to see the group wise differences. The details of Bonferroni post hoc analysis are given in table 4.2. The table shows that there was significant channel interaction observed between 2-4, 2-8, and 4-8 channels of the hearing aids.

Table 4.2.

Results of the Bonferroni post hoc analysis for the PB words.

	4 channel	8 channel
2 channel	$p < 0.05$	$p < 0.05$
4 channel		$p < 0.05$

So, an overall trend for increase in the speech perception scores for the PB word list with the increase in the number of channels was found. This was irrespective of degree of the slope of hearing loss. These findings are consistent with reports in literature (Barfod, 1978; Yund & Buckles, 1995, 1995b) which also tend to suggest likewise performance improvement with increase in number of channels up to 8. The present finding could be attributed to maintenance of required audibility in each channel as required by the configuration of hearing loss. Venema (2000) postulated that a multichannel compression hearing aid may be better able to accommodate the variations in hearing threshold at each frequency thereby providing more appropriate and accurate, required audibility for each of the frequencies. Souza and Turner (1998) also reported the improvement in speech identification scores with increase in number of channels to increased audibility. However, there are also reports in literature which suggest that the speech perception scores improved with increase in number of channel only up to 3 or 4 and did not show further improvement (Hickson, 1994; Keidser & Grant., 2001; Van Buuren et al., 1999). Villchur (1978) explained this finding of no improvement to poor post compression frequency equalization for some hearing aids, also the difference between the study and those reported in literature could be attributed to use of different compression ratio in the preview of different channels by the two set of studies.

Speech Identification scores for the HF word list:

Mean and standard deviation (S.D) for the speech identification scores of H.F wordlist for the three groups across three channels hearing aids was calculated. The mean standard deviation (S.D) for the speech identification scores are given in table 4.3.Table 4.3 reveals a trend towards increase in speech identification scores with increase in the number of channels for all the three groups. A comparison of the groups shows better scores for flat configuration compared to the other two whereas the scores for the other two groups (moderately sloping, steeply sloping) were comparable. It can also be seen that the change in performance with increase in number of channels, though noticed for all the three groups, was a lot higher for the moderately sloping and sharply sloping hearing loss groups (nearly 19% and 21%) as opposed to only 14% for the flat configuration group. The same can be seen in figure 4.2.

Table 4.3.

Mean and standard deviation of speech identification scores of HF word list.

Number of Channels of Hearing Aid	HEARING LOSS					
	Flat Hearing Loss		Moderately Sloping Hearing Loss		Steeply Sloping Hearing Loss	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
2 channel	76.50	8.18	48.00	18.73	44.50	9.26
4 channel	80.50	9.84	59.00	17.60	51.50	13.13
8 channel	90.00	6.23	67.50	17.67	65.50	11.89

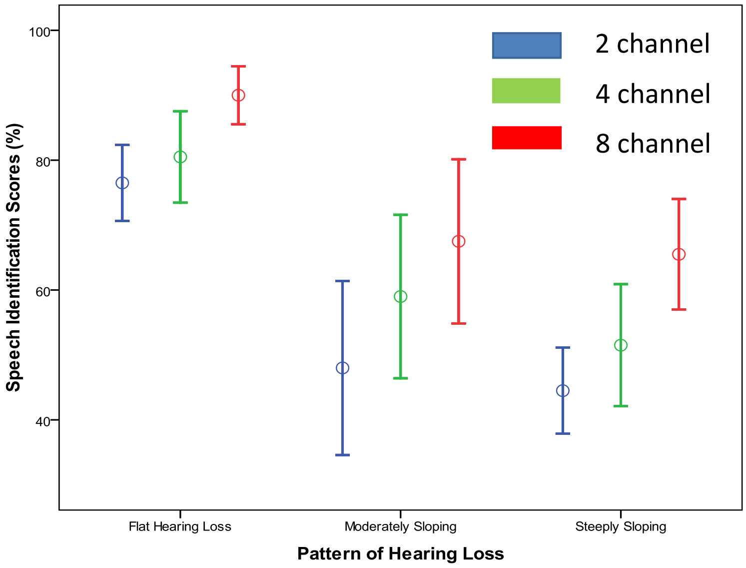

Figure 4.2: Error Bar of SIS in 2, 4 & 8 Channel Hearing Aids for HF word list

Mixed ANOVA was done to see the interaction effect for 3 channels and three groups. Mixed ANOVA showed a significant main effect for the three channels of the hearing aid [F (2, 54) = 105.61, p< 0.05], and it showed an interaction between channel and group [F (4, 54) =2.62, p< 0.05]. Further, mixed ANOVA also showed significant interaction for the three groups [F (2, 27) = 14.77, p< 0.05]. The Bonferroni post hoc analysis was done to see the pair-wise comparison for the channels. The details of the Bonferroni post hoc analysis are given in table 4.4.

Table 4.4.

Results of the Bonferroni post hoc analysis for the HF words.

	4 channel	8 channel
2 channel	$p < 0.05$	$p < 0.05$
4 channel		$p < 0.05$

The Duncan's post hoc test was done to see the group differences. Duncan's post hoc analysis revealed a significant difference between flat hearing loss and moderately sloping hearing loss groups ($p<0.05$), whereas it revealed no significant difference between moderately sloping and sharply sloping hearing loss groups ($p>0.05$). The Duncan's post hoc analysis also revealed a significant difference between flat and sharply sloping hearing loss groups ($p<0.05$).

Since there was an interaction between channel and group, repeated measure ANOVA was done to see which of the groups or channels were significantly different. For the flat configuration group, repeated measures of ANOVA revealed a significant difference for the channels. The Bonferroni pair-wise comparison was done to see the group-wise differences for the channels. The result of the analysis has been portrayed in table 4.5 (a). It is evident from the figure that there was significant difference between 2-

channel and 8-channel hearing aids and also between 4-channel and 8-channel hearing aids (p<0.05). However, there was no evidence of a significant difference for a comparison between 2-channel and 4-channel hearing aids. Likewise, there was also a significant difference for the channels for moderately sloping and sharply sloping hearing loss configurations which necessitated the need of a Bonferroni pair-wise comparison and the results are shown in table 4.5 (b) and 4.5 (c) respectively.

Table 4.5.

Bonferroni pair wise comparison for (a) Flat hearing loss, (b) moderately sloping hearing loss, and (c) steeply sloping hearing loss.

	4 channel	8 channel
2 channel	p>0.05	p< 0.05
4 channel		p< 0.05

a

	4 channel	8 channel
2 channel	P<0.05	p< 0.05
4 channel		p> 0.05

b

	4 channel	8 channel
2 channel	p>0.05	p< 0.05
4 channel		p< 0.05

c

Mixed ANOVA revealed a significant main effect for the groups. To understand the main effect, multiple analysis of variance (MANOVA) was done to see for which of the channels there was a group difference. MANOVA revealed a significant difference for the 2-channel hearing aid [$F(2, 27) = 18.34$, $p<0.01$], 4-channel hearing aid [$F(2, 27) = 11.73$, $p<0.01$] and 8-channel hearing aid [$F(2, 27) = 11.26$, $p<0.01$].

Duncan’s post hoc analysis was done to see for which of the channels the groups were different. The Duncan’s post hoc analysis revealed a significant difference between the flat hearing loss configuration and the moderately sloping hearing loss configuration ($p<0.05$) for 2-channel hearing aid. It also revealed a significant difference between the flat hearing loss configuration and the sharply sloping configuration ($p<0.05$), however, there was no evidence of a significant difference between the sharply sloping and the moderately sloping configurations of hearing loss ($p>0.05$) using a 2-channel hearing aid. Likewise, for 4-channel and 8-channel hearing aids also, there was no significant difference between sharply sloping and moderately sloping configurations ($p>0.05$), however the difference was significant ($p<0.05$) when these two were compared with the flat hearing loss configuration.

So, use of high frequency word list showed slightly different result to the PB word list. Here, there was no significant change in the speech perception scores with increase in number of channels from 2 to 4. However, there was a significant change (increase) in the scores with increase in number of channels to 8. There are no reports in literature that have reported about the effect of number of channels of hearing aids on the speech perception when using the HF wordlist. The present findings could probably be attributed to the frequency configuration of the HF wordlist itself. The wordlist (HF and PB word list) used in the present study was constructed with the use of phonemes that had maximum energy concentration beyond 1000 Hz. The two channel hearing aid in the present study had a cut-off frequency of 1000Hz. So, comparing with the frequency composition of the word list, the hearing aid effectively had only one channel to process the high frequency word list. This would mean that the required accuracy of audibility for the moderately sloping and steeply sloping hearing loss configurations would not be achieved. It is also a known fact that high frequencies are important for speech discrimination (Dubno et al. 1989; Pittman et al 2004)and low frequencies for the audibility of the speech sound (Duffy et al. 1973). So, if the accurate amplification is not achieved in the high frequencies, it would result in poor speech discrimination and thereby in poorer speech identification scores.

A similar scenario would be portrayed by the use of 4-channel hearing aid. In the present study, the four channel hearing aid had less than 500 Hz, 500-1000Hz, 1000-2000Hz and 2000-4000Hz as the different compression channels. Again a similar comparison with the frequency composition of the high frequency word list shows that the hearing aid in question effectively had only two channels to process the speech sound of high frequency word list. This should have, in essence, resulted in slightly better performance compared to two channels, which was exactly the case in the present study. However the present study didn't show the difference between two and four channel hearing aids to produce statistically significant difference for the high frequency word list this could be attributed to the addition of only one extra effective channel in the zone which had the high energy concentration (high frequency zone beyond 1000Hz). This produced slight betterment of scores for four channel hearing aid. However, this could not be appreciated statistically.

The 8-channel hearing aid of the present study had five different frequency channels (1000-1500Hz, 1500-2000Hz, 2000-3000Hz, 3000-4000Hz, and 4000-6000Hz) beyond 1000Hz. This would mean a lot better and more accurate fitting of thresholds in high frequencies and thereby produce better scores than two and four-channel hearing aids. The present study also revealed similar results.

Chapter 5

Summary and Conclusion

A single channel hearing aid optimises the dynamic range across the full range of frequencies. This may be beneficial in cases with flat hearing loss configurations. However, the sloping hearing losses pose different challenges to the amplification system. The use of single channel hearing aids may decrease the overall gain in case of a high level, low frequency input which would effect the audibility of the high frequency sounds, thereby affecting the speech perception. The use of multi channel compression hearing aids would optimise the audibility across different frequencies, especially in case of sloping hearing loss configurations.

There are several reports in literature that have tried to explore the effect of increasing the number of channels of hearing aid on speech perception. The opinions regarding the usefulness are divided with some showing improvement (Barford, 1978; Yund and Buckles, 1995), some showing improvement upto only a small number of channels (Hickson, 1994; Keideser & Grant, 2001; Van Buuren et al. 1999) where as other showing worsening of the scores (Bustamante & Braida, 1987; Drullman & Smoorenberg, 1997). However, all the studies either used severe degrees of hearing losses or specifically did not use participants with high frequency sloping hearing losses. So, the present study aimed at finding the effect of increasing the number of channels of hearing aids on the speech perception in individuals with flat and sloping hearing loses of different degrees of slopes.

To achieve the aims, two different set of wordlists, the regular PB word list developed by Yathiraj and Vijayalakshmi (2005) and the high frequency word list developed by Mascarenhas and Yathiraj (2002) in Kannada language, were used. The groups of participants consisting of flat configuration of hearing loss, moderately sloping configuration of hearing loss, sharply sloping configuration of hearing loss were the participants of the study. Each group was evaluated for performance using a 2–channel, 4-channel and 8-channel hearing aid.

The results revealed increase in the speech perception scores with increase in the number of channels of the hearing aid for the PB word list. These findings are consistent with the reports in literature (Barford, 1978; Yund and Buckles, 1993 & 1995) and could be attributed to improved audibility and better fitment of the thresholds at different frequencies with increase in number of channels. A similar trend was also noticed for the high frequency word list. A comparison of channels for different degrees of slopes revealed no significant increase in number of channels from 2 to 4, however, significant increment was noticed with increase in the number of channels to 8. This could be attributed to the combination of major energy concentration for the high frequency wordlist and the effective number of channels in that area of energy concentration. The high frequency wordlist has major energy concentration beyond 1000Hz. For the 2 and 4-channel hearing aids, the effective number of channels in the major energy concentration zone was 1 and 2 respectively. This would not allow for accurate threshold matching in the high frequency zone and thus, there was no significant difference between the two. However, the 8-channel hearing aid of the present study had 5 effective channels beyond 1000Hz, thus allowing for more accurate fitting of thresholds in the high frequency region and thereby showing significantly high speech perception.

So, it can be concluded that increasing the number of channels produce better speech perception scores at least till 8. The effects are better for the sloping hearing loss configurations, where better results were noticed with 8-channel hearing aid. So, it can be said that individuals with high frequency sloping hearing loss configurations are likely to benefit with multi-channel compression hearing aids, especially with more than 4-channel systems.

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