EFFECT OF DEGREE OF LOSS AND AGE ON SPEECH IDNTIFICTION WITH MULTICHANNEL HEARING AID

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A Dissertation Submitted in Part Fulfillment of
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ALL INDIA INSTITUTE OF SPEECH AND HEARING
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This work of mine is dedicated to my dearest

Ippa and Imma

CERTIFICATE

This is to certify that this dissertation entitled ***"Effect of degree of loss and age on speech identification with multichannel hearing aids"*** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student (Registration N0.O6AUD010). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that the dissertation entitled *"Effect of degree of loss and age on speech identification with multichannel hearing aids"* has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled *"Effect of degree of loss and age on speech identification with multi channel hearing aid"* is the result of my own study under the guidance of Dr. K. Rajalakshmi, Reader in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted in any other university for the award of any diploma or degree.

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Chapter 1

INTRODUCTION

The last decade has seen numerous and significant improvements in the technology of hearing aids. With advancement of digital technology, digital hearing aids have become increasingly common. Modern digital signal processing technology includes non –linear, adaptive, multi channels / bands, speech enhancement, noise reduction feedback management etc. The issue regarding the ideal number of channels had been a hot topic, and till to date there is conflicting evidence on the benefit of increasing number of channel in digital hearing aid.

Even though multi channel hearing aids are now widely prescribed to the subjects irrespective of their age and hearing loss, due to its frequency dependent compression characteristics, there is conflicting evidence on the benefit from this hearing aid. From theoretical point of view, multi channel compression is considered to be the best remedy for recruitment in sensory neural hearing loss. This is because multi channel compression can 1) improve audibility by better matching the variation of a person's audible range across frequency, and 2) improve the signal to noise ratio (SNR) in situations where the background noise is dominant in a restricted range of frequencies.

Some experiments have shown multichannel compression to be better than single channel compression (Moore, Lynch and Stone, 1992, Souza and Turner 1999) some

have failed to show any advantage for multichannel compression (Crain and Yund, 1995 Hickson and Byrne,1995 , Plomp 1994) and some have found no difference in speech inelligibility using single and multi channel compression hearing aids.

The degree of loss and age of the client are the two of the factors that can also limit the degree of success from the hearing aid (Dillon, 2001). It has long been accepted that listeners with severe loss require different amplification characteristics than listeners with mild to moderate hearing loss (Van tasell 1993). Severe loss is characterized by supra threshold processing deficits, primarily by dramatically reduced frequency selectivity and also in some circumstances by reduced temporal discrimination. When the ability to resolve auditory information is limited, it is critical to select processing techniques that do not further degrade available speech cues. Listeners with severe loss are less able to resolve spectral detail. As a result, they may need to relay to a greater extent on temporal information such as variation in speech amplitude (Rosen et al 1990) , which are altered by multi channel and wide dynamic range compression hearing aids (Moore ,1996). For listeners with mild to moderate hearing loss who presumably depend to a greater extent on spectral cues, does benefit from improved speech recognition with multi channel hearing aids. Barford (1978) also reported that there was a shift towards better performance with the multi channel hearing aids as the severity of impairment decreased.

It also has been demonstrated frequently that older listeners have more difficulty understanding speech than younger listeners (Gordon –Salant and Fitzgibbons

1997).Some studies have found no effect of age on speech recognition when younger and older listeners were matched for hearing sensitivity (Souza and Turner, 1998). In other studies, older listeners demonstrated poorer speech recognition than younger listeners even after accounting for threshold differences (Humes and Christopherson, 1991; Humes and Roberts, 1990). In general ,age deficits occur more often in complex listening situations ,such as speech presented in complex listening situations ,such as speech presented in a noisy or reverberant environment . Studies support that older listeners experience reduced temporal resolution.

Souza and Virginia (2001) showed that mean identification scores decreased significantly with increasing age, the presence of hearing loss, the removal of spectral information, and with increasing distortion of the amplitude envelope (i.e., higher compression ratios). There was a consistent performance gap between young and aged listeners, regardless of the magnitude of change to the amplitude envelope.

Among the reasons for disagreement in the usefulness of multichannel hearing aids, degree of loss and age are important factors. There are limited number of studies directly comparing the effect of age and degree of loss with number of channel. So there is a need to study the effect of number of channel on younger and older listeners and also with varying degree of hearing loss.

Need for the study

Understanding the influence of age and hearing loss on speech identification with multichannel compression hearing aids would be useful in prescribing appropriate amplification. A number of investigators have studied the effect of increase in number of channels in hearing aid on speech identification. Studies have shown conflicting evidence on the performance of multichannel hearing aids. Amplification can alter the natural speech envelope and spectral characteristics which may improve or degrades speech intelligibility. There are also factors like hearing loss and age which can limit the performance with hearing aids. So it is necessary from theoretical and clinical point of view to study whether multichannel hearing aids will be useful or not for different age group and degree of hearing loss.

Aim of the study

To examine the speech identification using multichannel hearing aids across severity of hearing loss and age.

1) To study the effect of severity of hearing loss on speech identification in multi channel hearing aids in quiet and in noise (+5 dBSNR).

2) To study the effect of age on speech identification in multi channel hearing aids in quiet and in noise (+5 dBSNR).

CHAPTER 2

REVIEW OF LITRATURE:

A hearing aid is a device to enable hearing impaired people to make maximum use of their residual hearing area .It should provide maximum intelligibility, minimum interference from unwanted noise and minimum distortion. A common observation with sensory neural hearing loss is the recruitment phenomenon .i.e. the occurrence of a steeper than normal loudness growth function, together with an absolute elevated threshold. The typical means by which a hearing aid compensates for this recruitment is the use of non linear compressor .The general aim of the compressor is to provide higher gain for softer sounds than for louder sounds (Dillon, 2001).

Several different types of compression hearing aids have been developed in recent years. The simplest of these only provides compression at high signal levels so as not to overload the ear. In this form of compression amplification, known as compression limiting, signals below the threshold of compression are amplified without compression while signals above this threshold are compressed substantially. In wide dynamic range compression (WDRC), the threshold of compression is low and signals above this threshold are compressed, but only moderately**.** Multi-channel compression is widely used in order to approximate the frequency-dependent compression characteristics of the normal ear. The input signal is filtered into a set of contiguous frequency bands, each band having a different set of compression characteristics (Kuk, 2000). Eventhough multi

channel compression is beneficial than single channel compression hearing aids, there are also limits with multi channel compression hearing aids. Number of factors can be attributed to the benefits or limits that can be achieved from the hearing aid among which, degree of loss and age are important factors that affect the performance.

Multi channel compression verses single channel compression:

Single channel hearing aids are common alternatives to linear or peak clipping instruments. However, one of the criticisms of single channel amplification is that many speech sounds (and noise) have considerably more acoustic power in the low frequencies, although the weaker high frequency content of the sound contains important information for identification of the sound. In a single channel compressor, amplifier gain is determined by overall signal level and as a result speech sounds of the above type (or speech in noise) are compressed because of the strong low frequency components.

Jenstad, Seewald ,Cornelisse and Shantz (1999) studied the advantage of single channel WDRC hearing aid in twelve subjects with moderate to severe hearing loss. He compared linear hearing aid with that of single channel WDRC hearing aid and found that single channel WDRC hearing aid provides audible and comfortable signal across a wide range of listening conditions in quite compared to linear hearing aid. In fact although single channel instruments may be beneficial for some patients in terms of loudness comfort, much of the early research literature comparing, with linear or peak

clipping hearing aids failed to support compression for speech recognition, showing either no difference or even poor performance for the compression system.

For single channel compression there is disadvantage of too much of compression. When intense components occur in one frequency region compression reduces the gain applied to all frequency regions. So for example, weak high frequency speech components can be made less audiable, if intense low frequency components occur at the same time. This problem may be solved by using multiple channel of compression.

Relative to single channel compression, multi channel compression can increase intelligibility because it increases the audibility of speech. In multi channel compression incoming signal is filtered into two or more frequency bands. Each frequency band is amplified by a separate compression amplifier. The amplification characteristic of each of the separate channels of the hearing aid can be designed to match the spectro-temporal characteristics of the incoming speech signal to that of the impaired auditory system, so that, at the output, the various frequency components of the speech signal are amplified appropriately within the patient's available dynamic range (Dillon 2001).

Unfortunately multi channel compression also decreases some of the essential difference between different phonemes. Because compressors give less amplification to intense signals than to weak signals, multi channel compressors tend to decrease the height of the spectral peaks and to raise the floor of the spectral valleys. That is, they partially flatten spectral shapes. Spectral peaks and valleys give speech sounds much of

their identity. Spectral flattening makes it harder for the aid wearer to identify the place of articulation of consonants (Lindholm et al 1988, Lippmann et al 1981) on the other hand Yund and Buckles (1995), found that this may not have a significant effect on speech discrimination in quite and in noise.

Some experiments have shown multi channel compression to be better than single channel compression (Moore,Lynch and Stone 1992; Souza and Turner, 1999) some have failed to show any advantage for multi channel compression (Crain and Yund,1995 ; Hickson and Byrne, 1995 ; Plomp, 1994) and some have found no difference in speech intelligibility using single and multi channel compression hearing aids.

Multi channel compression and speech recognition:

There is inconclusive result on the number of channels that result in the benefit of the multi channel hearing aid. According to Keidser and Grant (2001), multi channel compression prescribed according to NAL-NL1 to mild to moderately severe hearing loss subjects in up to four channels showed no adverse effect on speech recognition relative to single channel scheme, though most of the subjects preferred single channel hearing aid in quiet and 10 dB SNR condition.

Similarly, Hoffmann and Kollimeier (1995) also recommended the use of fast acting multi channel compression hearing aids in cochlear hearing impaired patients, in

situation with high SNR. Woods, Van Tasell, Rickert & Trine (2006) suggested that for most hearing losses, speech audibility is maximized with the use of five channels. On the other hand, using more than five channels does not seem to degrade speech recognition as long as compression ratios are low (Crain and Yund , 1995) .According to Crain and Yund (1995), negative effects of multi channel compression were found only for extreme multi channel compression condition. Multi channel compression processing with compression ratio adjusted in each channel for the individual subject and having as many as 31 channels (2-31 channels) reveled no negative effects on vowel or voiced stop consonant discrimination.

More number of channels also can help in other issues such as reducing noise and feedback. Yund and Buckles (1995a) studied full-range multichannel compression hearing aids (MCCHA) with 4, 6, 8, 12, and 16 independent frequency channels to determine the effect of the number of channels on the speech discrimination of mild to moderately severe hearing-impaired subjects. He varied Signal-to-noise ratios (S/Ns) from –5 to 15 dB with speech-spectrum noise (70 dB SPL) and used two voices (male and female). He found that average speech discrimination for 16 hearing-impaired subjects increased from 4 to 8 channels but did not change significantly between 8 and 16 channels. The effect of the number of channels did not vary significantly with signal to noise ratio. The results indicate that a MCCHA with at least 8 (and up to 16) channels provides the mild to moderately severe hearing-impaired subject with acoustic information that facilitates speech discrimination in speech-band noise. They (Yund and Buckles(1995b) also conducted the similar study wherein they compared the multi

channel compression hearing aid (MCCHA) with that of linear amplification hearing aid (LAHA) in 16 hearing impaired subjects. Of 16 hearing-impaired subjects, 7 showed significantly better overall speech discrimination with the MCCHA than with the LAHA, 5 showed no difference, and 4 showed significantly better discrimination with the LAHA.

There is a limit, however, to the benefit of increasing the number of compression channels. With a large number of narrow channels, short time constants, and high compression ratios, the risk of removing most spectral information from the speech signal (Plomp, 1988). Studies (De Gennaro, Braida and Durlach ,1986; Plomp 1994) have reported negative effect on speech recognition using multi channel hearing aid.

De Gennaro,Braida and Durlach (1986) , compared linear hearing aid with that of sixteen band compression hearing aid for two listeners with flat hearing loss. System performance was evaluated with non-sense CVC syllables presented at a constant input level and spoken by two talkers. They found that compression consistently provided better performance for one speaker, linear amplification for the other. Averaged over speakers, however, there was no net advantage for the compression systems for any listener. Under some conditions, however, final consonant scores were higher with sixteen band compression than with linear amplification. Compression generally enhanced the distinction between stops and fricatives, but degraded spectral-concentration and relative-intensity cues required to identify place of articulation.

Plomp (1994) also discussed that to reduce the complexity of the hearing aid minimum number of channel should be used and negative effect increases with the number of channels. He recommended the optimum number of frequency channel should be 2-4.

From these studies, it is concluded that there is inconclusive result on the optimum number of channel. The benefit or limitation from the hearing aid cannot solely depend on the number of channel. There are also other factors like degree of loss and age which affect the performance from the multi channel hearing aid

Multichannel compression with different degree of loss:

Most hearing aid wearers are now fit with multi channel wide dynamic range compression (WDRC) that automatically adjusts the intensity range within two or more frequency channels. The intent is to provide a customized amplification system that improves audibility across frequency. However the degree of loss is one of the factor that limit the benefit from the hearing aid .In listeners with mild to moderate hearing loss, comparison of WDRC with linear amplification found that, the greatest benefits for WDRC for low level speech in quite and performance comparable to linear aids for conversational speech in quite and advantage of WDRC over liner amplification for speech in background noise (Moore, Peters, and Stone, 1999).

Similarly, Souza and Bishop (1999), studied subjects with mild to moderate or severe hearing loss on recognition of vowel-consonant-vowel (VCV) syllables digitally processed with linear and two channel WDRC amplification. He found that both the listener groups received the same benefit from the improved audibility provided by WDRC amplification. Eventhough this result cannot be generalized due to the less number of channel in the hearing aids, Yund and Buckles (1995b) in their article have discussed the effect of degree of loss on the performance with eight channel compression hearing aid.

Yund and Buckles(1995) studied the effect of the signal-to-noise ratio (S/N) on speech discrimination with two types of hearing-aid amplification, (1) full-range multi channel compression with eight independent frequency bands and (2) frequency-equalized linear amplification. He varied Signal-to-noise ratios from –5 to 15 dB with speech-spectrum noise (at 70 dB SPL) and used two voices (male and female). They found that hearing-loss severity and multi channel compression hearing aids performance were related. Subjects with less severe impairments showed greater improvement with the multi channel compression hearing aids. These results indicate that a full-range eight-channel multi channel compression hearing aids, for a mild to moderately severe hearing loss, causes little information degradation and can be of great benefit for speech discrimination in noise, particularly at low S/N.

On the other hand, severe loss is characterized by supra threshold processing deficits, primarily by dramatically reduced frequency selectivity and also in some

circumstances by reduced temporal discrimination. When the ability to resolve auditory information is limited, it is critical to select processing techniques that do not further degrade available speech cues. Listeners with severe loss are less able to resolve spectral detail. As a result, they may need to rely to a greater extent on temporal information such as variation in speech amplitude (Rosen et al 1990). De Gennaro, Braida and Durlach (1986), studied speech perception in subjects with severe flat hearing losses. He found that the larger the residual dynamic range of the subjects better performance with multi channel compression than linear hearing aid even though there is no significant difference.

However, Souza, Jenstad and Folino (2005), compared speech recognition with linear peak clipping ,linear with compression limiting and two and three channel multi channel WDRC hearing aids in thirteen listeners with severe sensory neural hearing loss. They used consonant vowel syllable and sentences and found that for listeners with severe hearing loss recognition and preference were lower for a three channel wide dynamic range compression system than for a compression limiting system.

Plomp (1994) also reported that when compression is applied independently in multiple frequency channels the spectro temporal variations of speech can be severely altered, particularly at high compression ratio .This may have a large negative impact on speech recognition. The studies described here shows that increasing number of channel (>3-4) for severe hearing loss does not increase the performance .From these studies it is inconclusive that whether increase in number of channel in multi channel hearing aids

will be useful for the various degree of hearing loss. There is limited number of studies which directly compared the effect of degree of loss on the performance with increase in the number of channel.

Effect of age on speech identification:

It has been demonstrated frequently that older listeners have more difficulty understanding speech than younger listeners (Gordon –Salant and Fitzgibbons 1997). Some studies have found no effect of age on speech recognition when younger and older listeners were matched for hearing sensitivity (Souza and Turner, 1994). In other studies, older listeners demonstrated poorer speech recognition than younger listeners even after accounting for threshold differences (Humes and Christopherson, 1991; Humes and Roberts, 1990). In general, age deficits occur more often in complex listening situations, such as speech presented in complex listening situations, such as speech presented in a noisy or reverberant environment . Studies support that older listeners experience reduced temporal resolution.

Souza (2000) compared the ability of younger and older listeners to use temporal information in speech when that information is altered by compression amplification. He measured recognition of vowel-consonant-vowel syllables for four groups of adult listeners (younger normal hearing, older normal hearing, younger hearing impaired, older hearing impaired) with syllables processed with wide-dynamic range compression (WDRC) amplification and with linear amplification. He found that scores were lower for

WDRC-amplified speech than for linearly amplified speech, and older listeners performed more poorly than younger listeners. He also reported that, age-related deficit in temporal resolution attributed to the poorer scores for compression-amplified speech for older listeners without hearing loss.

According to Souza and Boika (2006), with the additional channels of temporal-envelope information consonant identification increased in both normals and listeners with hearing loss. Over all the older listeners performed more poorly than younger listeners but older listeners could combine temporal information across channels. Similarly, Souza and Virginia (2001) showed that mean identification scores decreased significantly with increasing age, the presence of hearing loss, the removal of spectral information, and with increasing distortion of the amplitude envelope (i.e., higher compression ratios). There was a consistent performance gap between young and aged listeners, regardless of the magnitude of change to the amplitude envelope.

From the literature it is clear that there is an age related deficits that can limit the performance with hearing aids. However, there is limited study which directly had compared the effect of age on performance with increase in the number of channel.

CHAPTER 3

METHOD

Subjects

Sixteen adults in the age range of 20-55 yrs and eighteen geriatric subjects in the age range of 60-80 years, with unilateral or bilateral gradual sloping sensory neural hearing loss served as subjects for the study. Group I consisted of adult subjects (mean age: 38years; age range 20 -55 years) with mild to severe sensory neural hearing loss .Group II consisted of Geriatric subjects (mean age: 70 years; age range: 58-80 years) with mild to severe sensory neural hearing loss. Based on their hearing threshold, these two groups were again subdivided into, mild to moderate hearing loss and moderately severe to severe hearing loss. In group I and group II ,the mean pure tone thresholds for mild to moderate hearing loss was 49dBHL and 45dB HL respectively, and the mean pure tone thresholds for moderately severe to severe hearing loss was 60dBHL and 61 dBHL respectively. Graph 1 depicts the mean audiogram of the groups. Graph 2 and 3 depicts the mean with standard deviation of the pure tone thresholds of the two groups. The Speech identification scores of the all the participants were 50% or greater. They were Naïve hearing aid users. They were native speakers of Kannada language.

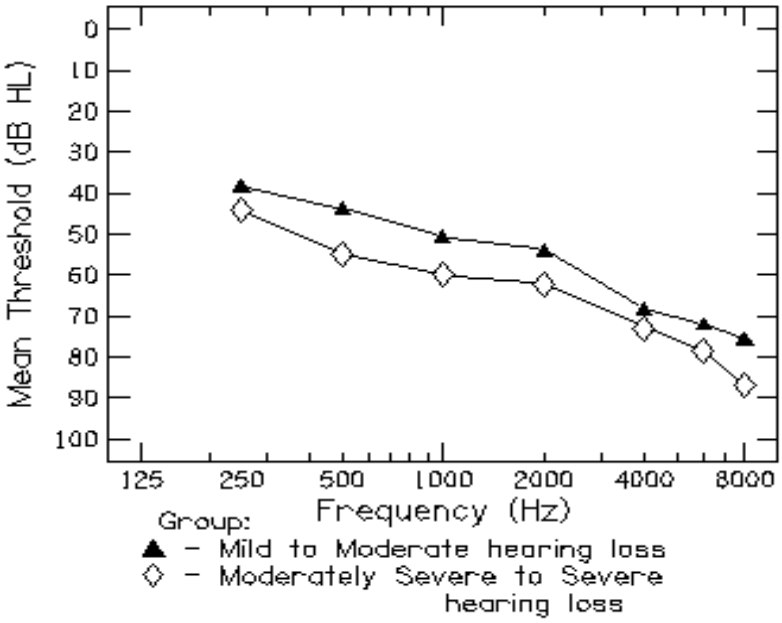
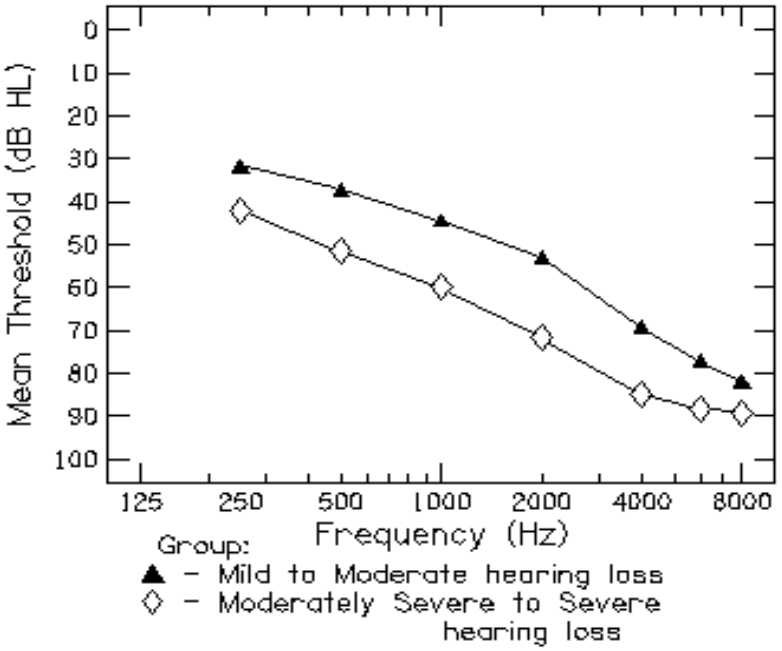


Figure 1: Mean Pure Tone Average threshold for Adult group.



Graph 3: MeanPure Tone Average Threshold for Geriatric Group

Stimuli

The speech stimuli used in the present study was taken from bi syllabic word list in Kannada developed by Vijayalakshmi and Yathiraj (2005). The speech material consists of four word lists each with 25 bi-syllabic words which are phonetically balanced. All the four lists were selected for the present study. As there are six conditions to test, each list was randomized to get two lists out of one list. Total of eight lists were available for testing. The words were spoken in conversational style by a female native speaker of Kannada. Words were digitally recorded in an acoustically treated room, on a data acquisition system, using 44.1 kHz sampling frequency and 16 bit analog to digital converter. All the words in a list were mixed individually with speech babble (Anitha and Manjula, 2005) at +5 dB SNR. The speech babble was mixed with words based on RMS level by the program written in Matlab6.5 software (Narne, 2007).

Hearing aid description

Two non-linear behind the ear digital wide dynamic range compressions hearing aids with 5 channels and 15 channels were taken for the study.

Instumentation

A calibrated dual channel diagnostic audiometer (Madsen orbiter 922) with TDH-39 head phone, B-71 bone vibrator and Martin (C115) speakers were used.

- Calibrated immittance meter (GSI –Tympstar) was used to rule out any middle ear pathology.
- One five channel and fifteen channel hearing aids were used for the comparison of performance.

- Pentium IV computer with NOAH-3 software was used to program the hearing aid. Hi-Pro was used to connect the hearing aid with computer.
- Stimuli were played from Pentium IV computer 44.1 KHz sampling rate and 16 bit software.

Test environment

The testing was done in sound treated double room with the ambient noise level within permissible limits as recommended by ANSI (1999).

Procedure

Pure tone thresholds were obtained using modified Hughson and Westlake procedure (Carhart and Jerger, 1959) across octave frequency from 250 Hz to 8000 Hz for air conduction and 250 Hz to 4000 Hz for bone conduction. Tympanometry and acoustic reflex thresholds were done in GSI -Tympstar using 226 Hz probe tone.

The hearing aids were programmed on the basis of audiometric thresholds using NAL-NL1 fitting formula with the default gain provided by the software in order to avoid any unwanted effect on result. The testing was done in a sound treated double room with ambient noise level within the permissible limits (ASHA 1999). Subjects were seated at a distance of one meter and 45 azimuth from the speaker.

First the testing was done in unaided condition and later in aided condition in quiet and in noise condition. The order of hearing aid tested was randomized for each subject during the aided condition. In case of unilateral hearing loss masking noise was given to the better ear to avoid participation of that ear. The presentation level of the

stimuli was kept at constant at 45 dB and the inter stimulus interval was kept at 2 sec. The subjects were asked to repeat the words presented. The words correctly repeated were scored.

RESULTS

The present study was designed to investigate the effect of severity of hearing loss and age on speech identification with multi channel hearing aids. The statistical analysis includes, mixed ANOVA (two-way repeated measure ANOVA) and independent t test, which was performed using SPSS version 15.0.

1) Effect of degree of loss on speech identification

One of the purposes of the present study was to investigate the effect of severity of hearing loss on speech identification with multi channel hearing aids. The analysis and results are discussed separately for group I consisted of eight mild to moderate hearing loss subjects and seven moderately severe to severe hearing loss subjects and group II consisted of nine mild to moderate hearing loss subjects and seven moderately severe to severe hearing loss subjects.

a) Effect of degree of loss on speech identification in adults:

The mean performance with the 15 channel (A1) and 5 channel (A2) hearing aids in different listening conditions (quiet (Q) and noise(N)) for group-I is shown in the Figure 4.

It can be noted from the Figure 4 that the mean performance with the two hearing aids was different with respect to severity i.e., identification was better for mild to moderate hearing loss subjects than moderately severe to severe hearing loss subjects. In

mild to moderate hearing loss subjects, performance improved with increase in number of channels in quiet as well as in noise. Whereas, the mean performances with the two hearing aids were almost similar with moderately severe to severe hearing loss subjects or in other words the benefit from increase in number of channel was not observed with this group in quiet condition. In background noise, moderately severe to severe hearing loss subjects showed small improvement with increasing numbers of channels. It's also been found that for all the subjects the mean performance in quiet is better than in presence of noise.

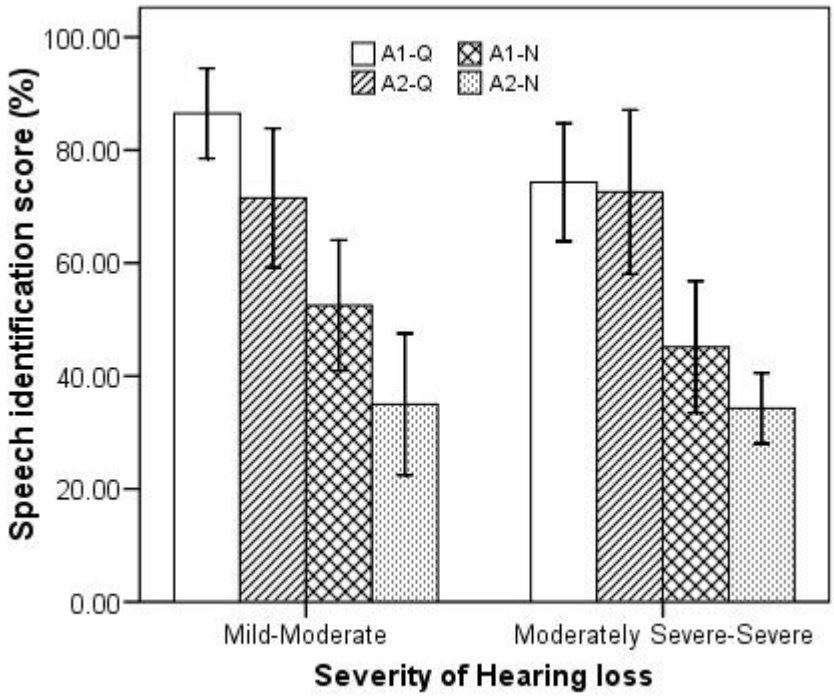


Figure 4: Comparison of effect of severity on mean identification performance with standard error, for bi-syllabic word list presented in quiet (Q) and +5dB SNR (N) for the group I (adult) with A1 (15 channel) and A2 (5 Channel) hearing aids. Bars represent the hearing aids and condition.

Mixed ANOVA (Two way repeated measures ANOVA)was performed to assess the significant difference across channels for different degrees of hearing loss, with number of channels (2 levels: 5 Ch and 15 Ch), listening conditions (2 levels: quiet and noise) as within group factor and severity of hearing loss (2 levels: Mild to moderate and Moderately severe to Severe) as between group factor. Results revealed that there is a significant main effect of numbers of channels ($f_{(1, 26)} = 159.4$, $p<0.001$) and listening conditions ($F_{(1, 13)} = 117.9$, $p<0.001$). Even though the mean scores for severity of hearing loss is different, analysis revealed no significant difference ($F_{(1, 13)} = 0.002$, $p=0.967$) in the performance as a function of severity, which could be due to more variability in the data. Interaction analysis revealed number of channels interact significantly with severity ($F_{(1, 26)} = 3.511$, $p<0.005$) and listening condition ($F_{(1, 26)} = 33.089$, $p<0.001$). Interaction between number of channels and severity of hearing loss indicate, improvement in performance with increasing number of channels was not same between the groups. As it can be noted from the figure 4 that moderately severe to severe group showed minimal improvement with increasing number of channels. Further, it also showed significant interaction between number of channels and listening condition, which indicate that increasing numbers of channels improved the performance in presence of noise. However, there is no interaction for listening condition and severity ($F_{(1, 13)} = 117.964$, $p>0.05$) and number of channel, condition and severity ($F_{(1, 26)} = 0.561$, $p>0.05$). Although there is difference in performance between mild to moderate and moderately sever to severe group in both quiet and noise conditions, as observed from the figure 4, due to the large variability observed in data ,statistics did not show any significant difference.

b) Effect of degree of loss on speech identification in geriatrics:

The data obtained for group II (nine mild to moderate hearing loss subjects and seven moderately severe to severe hearing loss subjects) were analyzed and the mean performance with the 15 channel (A1) and 5 channel (A2) hearing aids in different listening conditions (quiet (Q), and noise(N)) is shown in the figure 5.

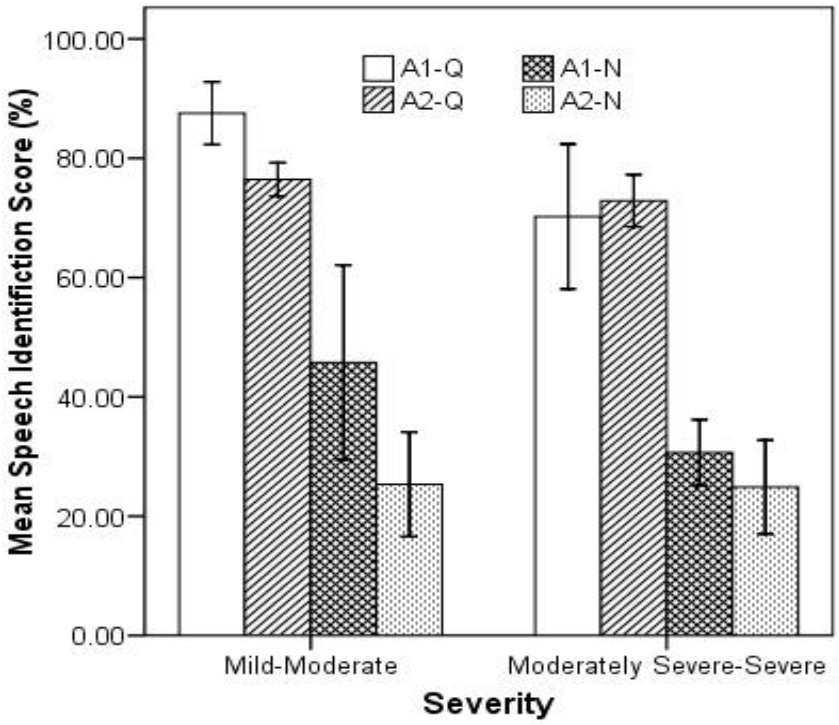


Figure 5: Comparison of effect of severity on mean identification performance with standard error for bi-syllabic word list presented in Quiet (Q) and +5dB SNR (N) for Group II (geriatric) with A1 (15 channel) and A2 (5 Channel) hearing aids. Bars represent the hearing aids and condition

It can be observed from the Figure 5 that, as the severity of hearing loss increases the mean performance decreases in all the listening conditions. Further, the mean

performance was improved with increase in the number of channel for mild to moderate group, whereas moderately severe to severe group showed small deterioration in performance with increasing number of channels in quiet condition. In presence of background noise both the groups showed improved performance but, moderately severe to severe group showed very small improvement when compared to mild to moderate group with increasing number of channels.

Mixed ANOVA (two way repeated measures of ANOVA) was performed to assess the significant difference across channels for different degrees of hearing loss, with number of channels (2 levels: 15 Ch and 5 Ch), listening conditions (2 levels: quiet and noise) as within group factor and degree of hearing loss (2 levels: Mild to moderate and Moderately Severe to Severe) as between group factor. Results revealed that there is a significant main effect of numbers of channels ($f_{(1, 32)} = 194.609$, $p<0.001$) and listening conditions ($f_{(1, 16)} = 111.533$, $p<0.001$). Even though the mean performance scores differ with severity of hearing loss, analysis revealed no significant difference ($F_{(1, 16)} = 3.834$, $p=0.068$) in the performance as a function of severity. Interaction analysis revealed numbers channels interact significantly with severity ($F_{(1, 32)} = 10.614$, $p<0.001$) and listening conditions ($F_{(1, 32)} = 41.586$, $p<0.001$). i.e., the performance with increase in number of channels was not similar with different severity of hearing loss and also in quiet and in noise. As it can be read from the figure 5 that moderately severe to severe group showed decrement in performance with increasing number of channels in quiet and a small improvement in presence of noise, as opposed to better performance seen in mild to moderate hearing loss subjects. Further, it also showed significant interaction between

number of channels and listening condition, which also indicate that increasing number of channels improved the performance in presence of noise. However, there is no interaction for listening condition and severity ($F_{(1, 16)}$ =0.0642, p=0.435) and number of channels, listening condition and severity ($F_{(1, 32)}$ =0.375, p>0.690). Although there is difference in mean performance with increase in severity in both quiet and noise conditions, due to the large variability observed in data, statistics did not show any significant difference.

2) Effect of age on speech identification:

The second purpose of the study was to investigate the effect of age on speech identification with multi channel hearing aid. As there was no significant difference (p>0.01) in the performance between mild to moderate and moderately severe to severe hearing loss subject in both the groups, for further analysis data was combined in each group. The effect of age on speech identification was analyzed by comparing the performance between fifteen adult and eighteen geriatric subjects irrespective of their severity.

Independent t test was carried out for fifteen adult and nineteen geriatric subjects. The analysis revealed that there is mean performance was significantly lower (t = 2.165, p<0.05) for geriatric group when compared to adult group with less number of channel(5 Ch) in noise condition. Even though the mean performance is comparatively better for adult, analysis revealed no significant difference in the performance with increase in

number of channel (15 Ch) in quiet (t =0.361, p = 0.720) and in noise (t = 1.741, p =0.092). There is also no significant difference in the performance (t = 1.283, p = 0.209) with less number of channel in quiet.

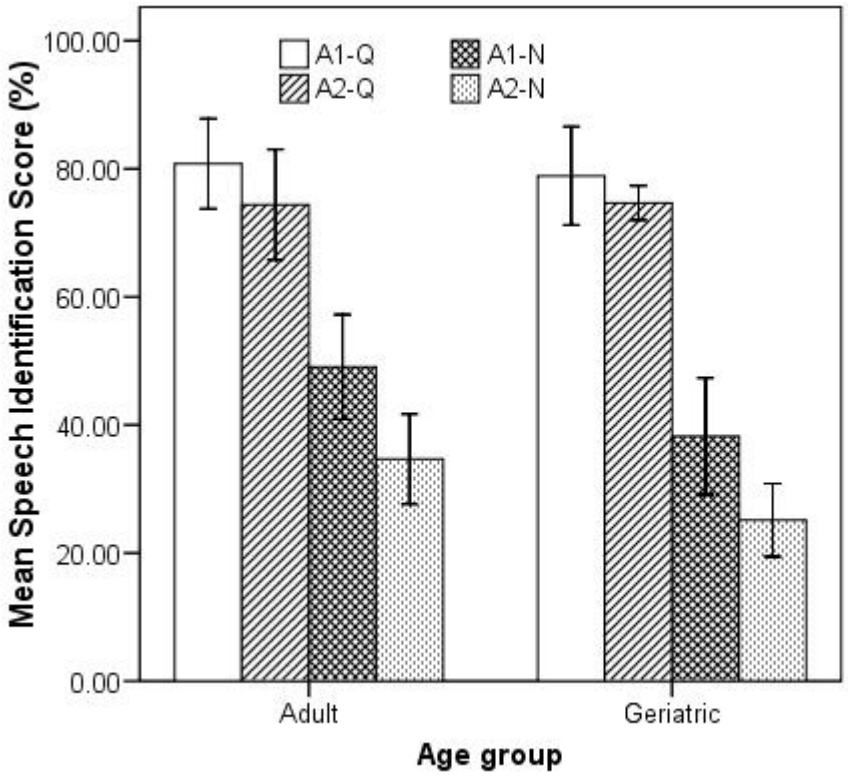


Figure 6: The effect of age on mean speech identification performance with standard error, for bi-syllabic words presented in quiet (Q) and in noise (N) for 15 channel (A1) and 5 channel (A2) hearing aids. Bars represent hearing aids and condition.

Figure 6 shows that the mean performance is slightly better for adult subjects than geriatric subjects in both quiet and noise condition. Even though, adult subjects performed only slightly better in quiet condition than geriatric, they performed better in noise condition. Performance deteriorates with increase in age, which is more evident in noise condition, indicating that geriatric subjects have difficulty hearing in noise.

DISCUSSION

1) Effect of degree of loss on speech identification

Mild to moderate hearing loss subjects showed greater improvement in performance with increasing numbers of channels when compared to moderately severe to severe hearing loss subjects in quiet and in noise. Even though statistics showed no significant effect of severity, the mean performance is different. Similar results reported by number of other investigators (Degannaro, Braida and Durlach 1986; Yund et al 1987). According to Yund and Buckles (1995), at varying signal to noise ratio (-5 to 15), they found that hearing-loss severity and multi channel compression hearing aid (8 channel) performance were related. He found that subjects with less severe impairments showed greater improvement with the multi channel hearing aid. On the other hand, Degannaro, Braida and Durlach (1986) found that there is no significant difference in the performance with 16 band compression non linear hearing aid and linear hearing aid in persons with severe hearing loss.

Exact reason is not known for no improvement or deterioration in performance with increasing numbers of channels for moderately severe to severe hearing loss subjects. One reason could be, these listeners were less able to resolve spectral detail and they may rely to a greater extent on temporal information such as variation in speech amplitude (Rosen et al, 1990). Further, increasing the number of channels alters the spectro-temporal properties of speech (Plomp, 1994) which can have large impact on speech perception in these participants. On the other hand mild to moderate hearing loss

subjects relay on available spectral details to recognize speech, the altered temporal variation due to increase in number of channel would have produced less deleterious effect. In other words fifteen-channel hearing aid, for a mild to moderate hearing loss, causes little information degradation and can be of great benefit for speech discrimination in noise, particularly at low S/N.

One another could be, as severely impaired participants are impaired in combining the temporal information across number of channels (Narne, Manjula and Vanaja, 2007; Souza and Boike, 2006), increasing number of channels would not provide any extra information, further it might deteriorate temporal information (Plomp, 1994) for these participants, as a result they did not show any improvement. Souza and Boika, (2006) reported that ability to combine the temporal information in speech across number of channels, was more significantly impaired because of degree of hearing loss than that of age. This could be one reason that similar pattern of performance observed between adults and geriatrics.

It should also be noted that, the performance in quiet is significantly better than the performance in noise with both the hearing aid. Although in quiet condition both the hearing aid performance is almost similar or with mean performance is little greater for 15 channel hearing aid , in noise condition the performance with 15 channel hearing aid is greater compared to 5 channel hearing aid. Theoretically, the greater the number of channels and narrower the channels the greater the likely hood that important frequency components of the signal will fall into channels which do not include higher intensity components of the noise or of the signal it self. So amplification will increase the signal level greater than the noise, which intern increases the signal to noise ratio in situations

where the back ground noise is dominant in restricted range of frequencies (Dillon 2000). This study is in agreement with the previous studies (Yund and Buckles 1995a, 1995b), that with increase in number of channels (8-16 channels) performance improves in noise condition.

2) Effect of age on speech identification:

The overall mean performance shows that the adult performed better than geriatric listeners did. The mean performance of geriatric group was poorer in noise than adult subjects. However, there is no significant difference in the performance with age except with 5-channel hearing aid in noisy condition. It has been demonstrated that older listeners have more difficulty understanding speech than younger listeners (Gordon-Salant and Fitzgibbons, 1997) and mean identification score decreases with increase in age (Souza and Virginia, 2001). This could because they have reduced temporal resolution (Souza, 2000; Souza and Boika, 2006) when compared to adults.

Although, the performance is lower than adults geriatrics also demonstrated similar pattern of performance with increasing numbers of channels. Geriatrics participants were as good as adult subjects in utilizing and combining the temporal information across channels. In connection, Souza and Boika (2006) reported that the older listeners performed poorly than younger listeners in identifying nonsense syllables, but did not have difficulty combining temporal envelope cues across channel. The poor performance with 5-channel hearing aid in presence of noise in Geriatric subjects can be attributed to the general age deficits, which occur more often in complex listening

situations such as in noise. Whereas, the mean performance with 15 channel hearing aid is slightly better for adult in noise condition, but there is no significant difference in the performance between the age group. With increase in number of channel, signal-to-noise ratio improves (Yund and Buckles 1995a,b) which can be attributed to the improved performance with the 15 channel hearing aid.

To conclude, effect of increasing numbers of channels on speech identification majorly depends upon the degree of hearing loss than the age. That is in other words, benefit from the increase in the number of channel does not improve with severity, in speech identification in quiet and in presence of noise. The multi channel hearing aid at least up to 15-channel will not cause any detrimental effect for mild to moderate hearing loss subjects of younger the age group, in addition they improve the perception in both groups in quiet and in presence of noise.

CHAPTER 5

SUMMARY AND CONCLUSIONS

With advancement of digital technology, digital hearing aids have become increasingly common. Modern digital signal processing technology includes non –linear, adaptive, multi channels / bands, speech enhancement, noise reduction feedback management etc. The issue regarding the ideal number of channels had been a hot topic, and till to date there is conflicting evidence on the benefit of increasing number of channel in digital hearing aid. Degree of loss and age are important factors, which determine the benefit from the hearing aid.

The present study aimed at investigating the effect of degree of loss and age on speech identification in quiet and in noise with multi channel hearing aids. Group I with fifteen adult subjects and Group II with eighteen geriatric subjects with gradual sloping mild to severe sensory neural hearing loss served as a subject. They were again sub grouped into mild to moderate hearing loss and moderately severe to severe hearing loss based on their pure tone average in each group.

The stimulus consisted of recorded version of bi-syllabic wordlist developed by Vijayalakshmi and Yathiraj (2005). All the words in a list were mixed individually with speech babble (Anitha and Manjula, 2005) at +5 dB SNR, based on RMS level by the program written in Matlab6.5 software. Two hearing aids, one with five channels and other with fifteen channels digital hearing aids were programmed on the basis of audiometric thresholds using NAL-NL1 fitting formula with the default gain provided by the software.

The investigation was carried out in a sound treated double room to address the following research goals:

1) To determine effect of degree of loss on speech identification with multi channel hearing aid.

2) To determine the effect of age on speech identification with multi channel hearing aid.

The stimulus was presented at 45 dB HL in the free field condition and the subjects were asked repeat the words heard. The words correctly repeated were scored.

The results obtained are given below:

- The benefit from the increase in number of channel is inversely proportional to the degree of hearing loss. Channels upto fifteen channel would not cause any deleterious effect in performance in mild to moderate hearing loss subjects.
- The overall performance decreases with increasing age, but the geriatric subjects can combine the temporal information across channel with increase in number of channels.
- Effect of increasing numbers of channels on speech identification majorly depends upon the degree of hearing loss than the age.
- With increase in number of channels the performance improved in noise.

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APPENDIX A

Phonemically Balanced Word List Developed by Yathiraj and Vijayalakshmi (2005).

raiṭa	ʧukki	hulu	va:ʧu
anna	hagga	su:dzi	hoṭṭe
moḷa	baṭṭa	rotti	ḍoni
ʧa:ku	mantʃa	gu:be	vadzra
ṭuti	bekku	akka	va:ni
me:ke	lo:ta	e:lu	ṭale
ha:vu	ba:la	vi:ne	kaṭṭe
kaṭṭu	dze:bu	dimbu	me:dzu
bi:ga	mandi	vade	na:ji
o:du	nona	go:li	ba:lu
baḷe	male	ha:lu	ni:li
mu:ru	ṭi:vi	amma	gombe
ra:ni	ḍi:pa:	dzana	ka:ge
ṭapa:	rave	ravi	aḍu
ṭa:ra:	mole	ṭande	dra:kʃi
braʃu	railu	rakta	bægu
hasu	ka:ru	suṭṭu	kaʃta
dzade	divja	ja:va	paisa
nalli	a:ru	ʧandra	mara
kivi	pu:ri	ja:ke	hu:vu
varʃa	haḍḍu	a:le	ṭinnu
ja:ru	suʃma	aiḍu	idli
da:na	ta:ji	nadi	ke:lu
ʃæmpu	ḍana	uppu	sara
ili	a:lu	kriʃna	paḍa