Effect of Degree of Loss and Age on Speech Identification With Multi Channel Hearing Aids

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Abstract

Digital hearing aids have become common, with numerous modern digital signal processing technology. Multichannel hearing aids are now widely prescribed. There is conflicting evidence on the benefit of multichannel hearing aids. The current study investigated the effect of age and hearing loss on speech identification in multi channel hearing aids. Speech identification is measured using recorded version of bi-syllabic wordlist (Vijayalakshmi and Yathiraj,2005) in quiet and noise, using five and fifteen channel hearing aids ,for two groups, fifteen adult and eighteen geriatric subjects who were again subgrouped into mild to moderate and moderately severe to severe hearing loss subjects. They Analysis of the results revealed that the benefit from the increase in number of channel is inversely proportional to the degree of hearing loss. In mild to moderate hearing loss subjects up to fifteen channel would not cause any deleterious effect in performance. The overall performance decreases with increasing age, but the geriatric subjects can combine the temporal information across channel with increase in number of channels. The degree of loss found to decrease the performance greatly with increase in number of channel rather than age.

Key words: Multichannel hearing aids, Number of channels, Speech identification, Age, and Hearing loss.

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;

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Hickson and Byrne,1995; Plomp, 1994) and some have found no difference in speech ineligibility 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 tassel 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 Kitch (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 on speech identification with multichannel compression hearing aids and understanding the influence of the theses factors would be useful in prescribing appropriate amplification. Therefore the current study was aimed at investigating the effect of number of channel on younger and older listeners and also with varying degree of hearing loss on speech identification.

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).

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 dB HL 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.

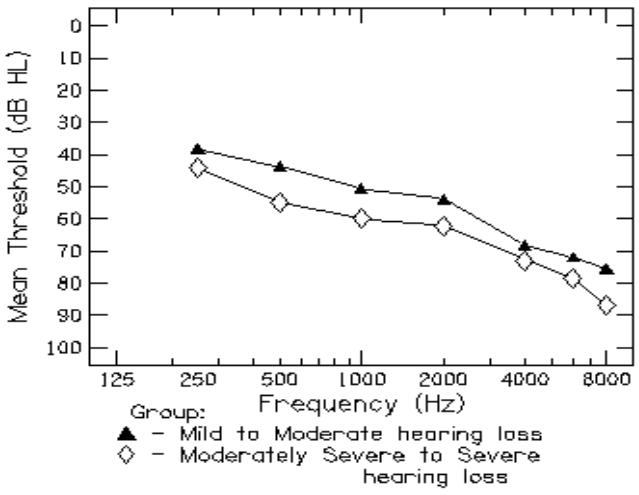

Figure 1: Mean puretone average threshold for adult group.

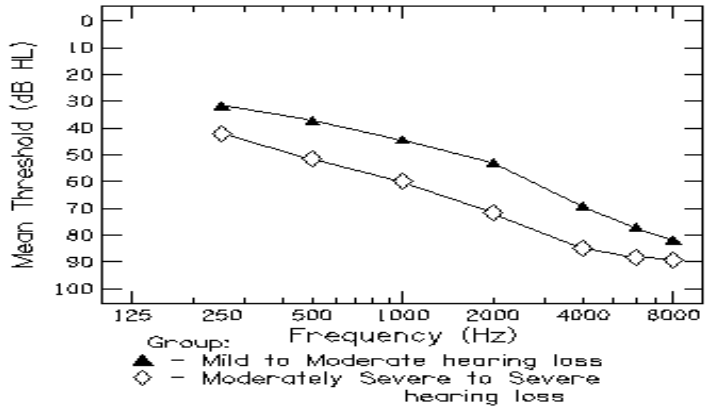

Figure 2: Mean puretone average threshold for geriatric group

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 MATLAB 6.5 software.

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.

Instrumentation:

- 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.

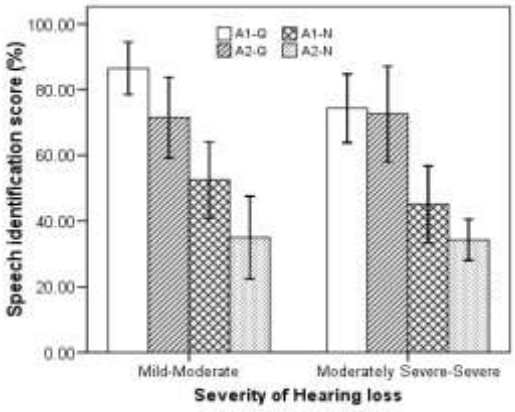

Figure 3: Comparison of effect of severity on mean identification performance with standard error, for bi-syllabic word list presented in quiet (Q) and +5dB SNR (N) for the group I (adult) with A1 (15 channel) and A2 (5 Channel) hearing aids. Bars represent the hearing aids and condition.

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 ,listening conditions as within group factor and severity of hearing loss 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 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.

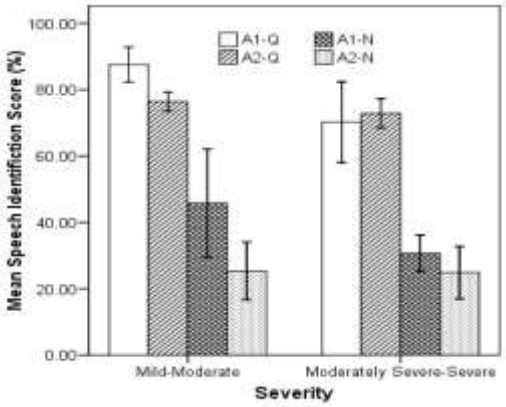

Figure 4: Comparison of effect of severity on mean identification performance with standard error for bi-syllabic word list presented in Quiet (Q) and +5dB SNR (N) for Group II (geriatric) with A1 (15 channel) and A2 (5 Channel) hearing aids. Bars represent the hearing aids and condition

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.

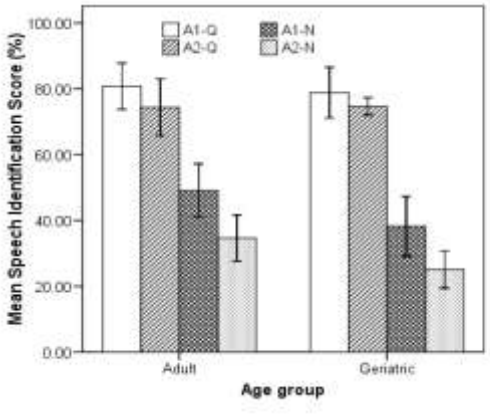

Figure 5: The effect of age on mean speech identification performance with standard error, for bi-syllabic words presented in quiet (Q) and in noise (N) for 15

channel (A1) and 5 channel (A2) hearing aids. Bars represent hearing aids and condition.

Figure 5 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.

Exact reason is not known for lack of 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 2001). This study is in agreement with the previous studies (Yund and Buckles 1995 a, 1995 b), that with 8-16 channels in noise condition the performance with increased number of channel is beneficial.

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 number 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, 1995 a, 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.

Conclusions

The present study investigated 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 MATLAB 6.5 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 determine effect of degree of loss and 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. It can be concluded from the present study that, 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. The degree of loss found to decrease the performance with increase in number of channel rather than age. It's also found that with increase in number of channel the performance improved in noise.

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